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Driver-Vehicle Interfaces for Advanced Crash Warning Systems: Research on Evaluation Methods and Warning Signals

Appendices A-F

Disclaimer

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Crash Warning Interface Metrics (CWIM): Phase 3

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1 Introduction

The evaluation of the Driver-Vehicle Interface (DVI) is essential for assessing the effectiveness of advanced crash warning systems (ACWSs). Currently, there is no standardized approach for this. This project aims to experimentally determine the elements of a standardized evaluation protocol that can be used to inform NHTSA and the public. Several overarching principals bound the evaluation protocol:

- Effectiveness and acceptability of DVIs are not necessarily positively correlated;
- Drivers are most likely to need the support of a crash warning system when they are not attending to the roadway;
- An interface needs to be effective even if the driver is unaware of the presence of the system; and
- The difference between alerting the driver and orienting the driver to the location of the threat is an important distinction in evaluating DVIs: the evaluation needs to consider not only time until the driver returns their attention to the roadway but also the impact of the DVI on outcome measures.

1.1 Background

In 2010 more than 32,500 fatalities and over 2.2 million injuries occurred in automobile accidents (NHTSA, 2012). With an estimated annual cost of $230.6 billion in the year 2000, it also has an immense economic impact on our society (NHTSA, 2002). Two of the four most frequent types of crashes are rear-end and lane change crashes. In 2011, rear-end crashes accounted for approximately 28 percent of crashes, and lane change crashes accounted for approximately 9 percent (NHTSA, 2011). With the mission to save lives, prevent injuries, and reduce economic cost incurred by crashes, a significant effort has been set forth by NHTSA to determine how these systems should be evaluated and what, if any, standardization is needed to protect the driving public. With a number of crash warning systems from several automobile manufacturers in the marketplace, the CWIM project has sought to address these issues.

This protocol completion research builds upon prior CWIM protocol evaluation studies and other published research that examined DVIs for Forward Collision Warning (FCW) systems and Lane Departure Warning (LDW) systems. The CWIM project started under a predecessor project entitled “Development of Driver Performance Metrics for Advanced Collision Prevention Systems.” This project examined the issues around the development of a methodology for evaluating interfaces for crash warning systems (Lerner et al., 2008). It found that ACWSs have the potential to improve driver performance and reduce the frequency and severity of common crash situations. It became clear that the quality of the DVI is essential for such a system to be successful.

The next phase of the CWIM program examined simulation and test track methods for evaluating the DVIs for FCW and LDW systems and transfer of training when switching between vehicles with different DVIs (Lerner et al., 2011; Forkenbrock et al., 2011; Brown et al., 2011).

The CWIM LDW evaluation was conducted using the full motion NADS-1 at The University of Iowa (UI). The CWIM FCW evaluation was conducted in two parts: a test-track evaluation at NHTSA's Vehicle Research Test Center (VRTC) in East Liberty, Ohio, and a simulator evaluation on the NADS-1 that used procedures similar to the LDW evaluation. The transfer of training study was conducted using the motion-based simulator at George Mason University (GMU), and it also focused on FCW systems. The current effort to establish elements of the standardization protocol takes into account the results from all studies in prior CWIM research. Although the transfer of training research is not directly linked to the aims of this project, it does provide useful background information on methods for evaluating the effectiveness of a DVI. A summary of experimental protocol elements that we identified as key can be found in Table 1 for the FCW studies and Table 2 for the LDW study.

Table 1. Forward Collision Warning (FCW)

	VRTC	UI	GMU
Platforms	Test track	NADS-1 high-fidelity full-motion simulator	Medium-fidelity motion-based simulator
Familiarity – Awareness	No	Provided documentation and training	Told there was an FCW system in vehicle
Familiarity – Exposure	No	Prior exposure Repeated measure	Exposure in the simulator to the audio cue when not driving Repeated measure
Incentive	Base pay: $35.00 and $.50 per mile driven from residence to study site $5.00 per pass for headway maintenance $1.50 on the first pass for correct number recall $2.50 on passes 2, 3, and 4 for correct number recall $1.00 was deducted	Base pay: $40.00	Base pay: $15.00 plus parking reimbursement

	per order error Maximum amount possible: $100.00		
Warning Onset	TTC 2.1	TTC 3.5	TTC 1.8
Gender	Balanced	Balanced	Balanced

Table 2. Lane Departure Warning (LDW)

	VRTC	UI	GMU
Platforms	N/A	NADS-1 high-fidelity full-motion simulator	N/A
Familiarity – Awareness	N/A	Provided a PowerPoint presentation	N/A
Familiarity – Exposure	N/A	Experienced the alerts	N/A
Incentive	N/A	Base pay: $40.00	N/A
Warning Onset	N/A	Warned when 6 inches outside lane boundary Warned when 0 inches outside lane boundary When steering torque was used as the warning, it ramped up as the warning boundary was approached and down after crossing it.	N/A
Gender	Balanced	Balanced	Balanced

Focusing on the FCW research, these studies resulted in several divergent results, including some results that differ from prior published research. The FCW study permits comparison of results from the UI, VRTC, and GMU.

According to the ACWS Response Taxonomy (CWIM Phase I), there are three broad evaluative domains for the driver response to ACWS: crash avoidance, general driving performance, and driver/consumer acceptance. The studies at NADS and VRTC both considered response time and thus fall under the heading of crash avoidance. Both efforts found benefits to having a warning for at least one system. Researchers at NADS considered response time with an active warning mode (brake pulse) and a passive warning mode (auditory with head-up display [HUD]). They found that both the brake pulse and the auditory/HUD modes led to similar decreases in driver response time compared to no warning. Researchers at VRTC conducted a study with several levels of alert modality, including a passive (HUD) visual alert, an audio beeping alert, and a seat belt tensioner. They found that only the seat belt tensioner warning resulted in a benefit. Researchers at GMU conducted a negative transfer study. They used auditory alerts, and their participants were exposed to the FCW before the forward collision event. Their findings indicated that familiarity with a system provides a faster response time with each subsequent exposure but a slower response time when presented with an unfamiliar alert.

The lack of benefit associated with auditory alerts reported in the VRTC study conflicts with prior research. A study by Lee et al. (2002) confirmed that warning tones were effective in directing driver attention to the road and the braking lead vehicle. Additionally, Ho and Spence (2009) found that auditory warning signals appear to surpass other types of warning signals and are effective in alerting and orienting a driver's gaze to where attention is urgently required.

Differences in platform and protocol among these studies may explain the difference in sensitivity to the auditory warning. This study was designed to determine the recommended elements for a standardized evaluation protocol by determining the factor(s) that produced better sensitivity.

The CWIM work discussed to this point used secondary tasks such as message reading, bug following, and number reading in order to get the driver's eyes off the road while the crash-imminent situation develops in the scenario. These tasks are artificial, but mimic real-world distracting activities that are not part of a broader vehicle information system. If the Connected Vehicles (CV) program matures as expected, crash warnings will be part of a much broader and more complex informational system. Therefore it will become necessary to adapt CWIM protocols to be more representative of how warnings might occur within a CV context. The Phase 1 Human Factors for Connected Vehicles (HFCV) program work conducted by the University of Iowa used an artificial "warning" consisting of a flashing red light on the dashboard. A re-analysis of these data conducted as part of the current Human Factors CV project suggests that a driver may not be able to interrupt CV tasks without consequences for the primary task of driving. Therefore, Phase 3 examined the effects of modifying the distraction task to resemble connected vehicles tasks on protocol sensitivity. In particular, Phase 3 examined the effects of relocating the distraction task so that its performance did not interfere with assessing a visual FCW presented in the driver's forward view.

Protocol Design Parameters

- *Warning Onset*

In CWIM Phase 2, the test track scenario implemented a FCW time-to-collision (TTC) of 2.1 s, which is considered a late warning alert. GMU implemented a similar late warning onset at 1.8 s TTC, and NADS conducted FCW work with an early warning TTC of 3.5 s.

- *Familiarity (Awareness*)

The VRTC study did not provide familiarization, practice, training, or documentation for the FCW (i.e., subjects had no knowledge that an FCW system was present in the vehicle). The NADS and GMU studies provided training and documentation to the participants about the system. The NADS study included pre-drive familiarization with FCW and LDW. The documentation was consistent with what would be available in an owner's manual, but it was presented in a PowerPoint format during briefing before the simulator drive. Additionally, the auditory and visual FCW alert modes were demonstrated as part of the presentation and the haptic and active FCW alert were described. In the GMU study, participants were told that an FCW system would be installed in the vehicle.

- *Familiarity (Exposure)*

NADS participants had prior exposure to the system during the practice portion of the drive where each participant experienced the warning, and there was a repeated measure of the actual scenario events. The GMU study provided exposure to the warning in the simulator prior to driving; the driver needed to identify the sounds that would be heard in the simulator and had repeated exposure over the drives. VRTC had no prior or repeated exposure.

Representative Warning

- *Platform*

Three different platforms were used: a test track, a high-fidelity simulator, and a medium-fidelity simulator.

- *Incentive*

CWIM Phase 2 incorporated several levels of incentives in the test track study. The NADS-1 experiment in Phase 2 had a base pay and instructed the participants to do their best possible on the distraction tasks. The VRTC study paid participants a base pay of $35 plus $0.50 for each mile driven to the study site, and up to $20 in incentive pay for headway maintenance and up to $45 for secondary task performance. The GMU study paid participants $15.00 per hour plus parking reimbursement.

- *Gender*

In CWIM Phase 2, gender was balanced in the design of the various studies.

- *Connected Vehicle Task*

In a final study, an alternate in-vehicle task was used, located so that it did not interfere with the driver's ability to perceive a visual FCW in the forward view. This task mimicked connected vehicles applications becoming available in vehicles through center console touch screen interfaces.

1.2 Project Objectives

The objective of this research effort was to provide the empirical data necessary to define the elements of a comprehensive protocol to assess the effectiveness and acceptability of the DVIs for ACWS. Additionally, the data collected was used to develop a composite metric of interface performance based on measures of effectiveness and initial driver acceptance obtained from protocol evaluation that can be used as a criterion for evaluating DVI alternatives.

1.3 Research Approach

The overall approach was to divide the effort into a series of studies. There were two preliminary studies to define experimental procedures for the subsequent main studies, and three main studies that focused on remaining aspects of the protocol that needed resolution. A brief description of each study is provided below, followed by an illustration of the flow of independent variables from study to study (see Figure 1).

- Simulator/Test Track Platform & Scenario (Preliminary Study 1) – This study compared results from the VRTC test track study examining FCW interfaces with a replication of that protocol on the NADS-1 simulator. Additionally, this study compared the results with a parallel protocol using a simulated road drive instead of a simulated test track; other elements of the protocol remained the same.

- Distraction/Incentive (Preliminary Study 2) – This study examined different distraction methods across incentive systems to determine the most effective approach to distracting the participant. The distracting secondary task needed to distract the driver long enough to initiate the imminent crash hazard events, permitting a LDW or FCW to be issued while the driver was distracted. The aim was to identify a distraction task that provided a sufficient and consistent secondary task commitment time and an incentive system that balanced the need to distract with sensitivity to LDWs and FCWs displayed in various modalities. This work looked not only at the length of glances but also at the timing of hazard event initiation within the task engagement to minimize situations where the driver delayed starting the secondary task until after the hazard event occurred or removed attention from the secondary task before the warning was given.

- Familiarity (Main 1) – This study examined how familiarity with the system being tested impacted the effectiveness and initial acceptability of the DVI in order to determine what level of familiarity provided the most sensitive evaluation of LDW and FCW DVIs. Both prior exposure to the system and awareness of the presence of the system in the vehicle were examined.

- DVI Modality/Warning Onset (Main 2) – This study examined the effect of warning onset (early or late) on the sensitivity of detecting differences in effectiveness and initial acceptability across DVI modalities. Of particular interest were interactions between the DVI modality and warning onset.

- Simulator Platform (Main 3) – This study will examine the extent to which simulator platform impacts the assessment of DVIs. This study will compare selected results from Main 2 with data collected on the NADS-1 with limited motion and with no motion to determine how motion effects evaluation of the DVIs.

- Connected Vehicles (CWIM-CV) – This study replicated the conditions and protocols from the Main 2 study utilizing an alternate in-vehicle task location.

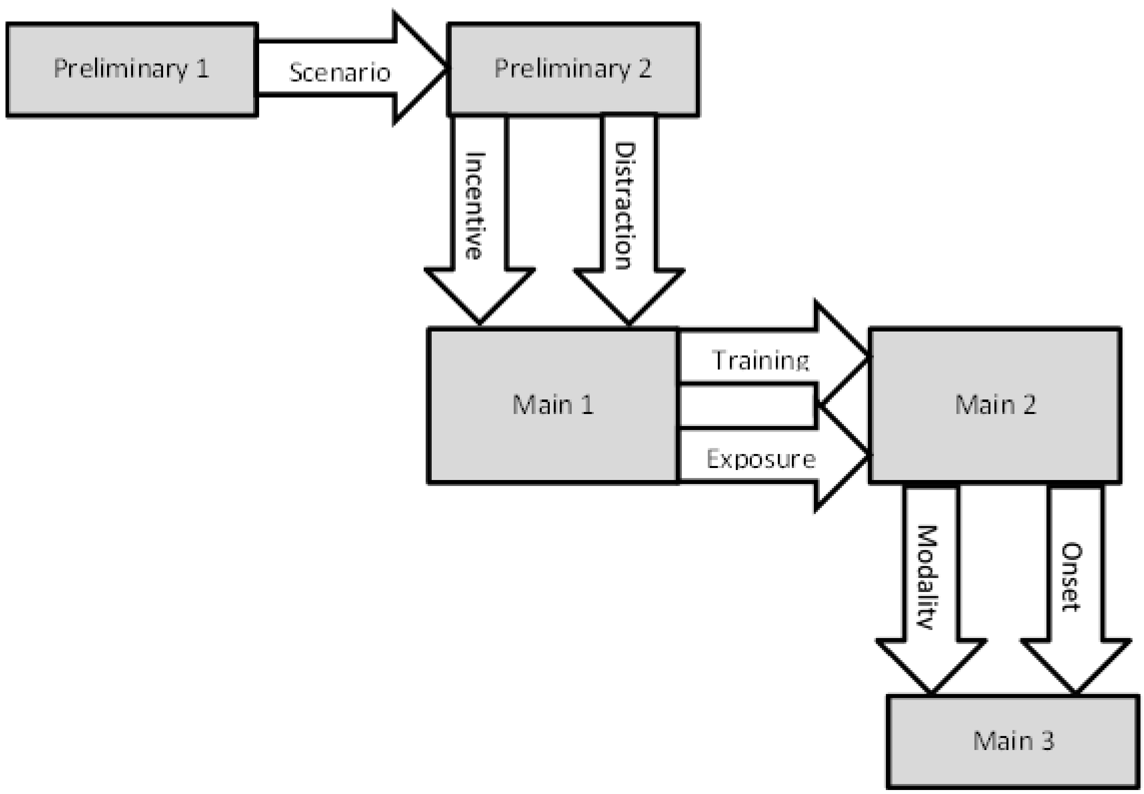

Figure 1. Experimental Flow of Independent Variables

1.4 Selection of Levels for Independent Variables

Prior research in the CWIM program was examined to determine the levels of independent variables to be studied. Additional research was reviewed when insufficient information was available. This section details the rationale for the selection of the levels for each of the independent variables based on prior differences in approach or gaps in the approaches tested. It concludes with Table 6, which describes (1) the selected levels of experimental variables for each study, and (2) which study results determine variable levels in subsequent studies.

1.4.1 System

As the aim of this project was to develop a sensitive protocol for evaluating LDW and FCW DVIs, both systems were used.

1.4.2 Platform

This study used four levels of platforms. The three levels of simulator platform allowed assessment of the impact that motion has on determining the effectiveness and initial acceptability of crash warning DVIs. The platform levels are:

- Test track: Comparison data were collected on the VRTC test track using a multi-lane straightway with turn-arounds at each end and an instrumented vehicle capable of providing FCWs and collecting response data. This platform was selected because the data had been collected in previous VRTC FCW research conducted in support of the CWIM program.
- NADS-1: Data were collected on a high-fidelity full-vehicle simulator with 13 degrees of freedom (DOF). The simulator visual displays provide a 360 degree field of view. This was selected to replicate the environment used in prior FCW and LDW research conducted at NADS in support of the CWIM program.
- NADS-1 with limited motion: Motion on the NADS-1 was limited to hexapod only, reducing the DOF to six.
- NADS-1 with no motion: The NADS-1 dome was used as a static simulator; none of the 13 DOFs were used.

1.4.3 Modality

This study examined the six levels of alert modality for LDW and FCW shown in Table 3. These six levels represent modalities that showed a broad range of effectiveness in previous efforts, enabling the protocol evaluation to compare the sensitivity of the protocol parameter alternatives. For FCW, the seat belt tensioner and brake pulse were the most effective modalities in the VRTC test track and NADS driving simulator studies, respectively, while the HUD lights were the least effective in the test track work. For LDW, the auditory alert was less effective than a steering wheel torque, but more effective than no warning. It was expected that the chosen alert modalities would provide a range of effectiveness across the LDW and FCW systems that would facilitate assessment of the protocol.

Table 3. FCW and LDW Alert Modalities

Alert Modality	**FCW**	**LDW**
Auditory	Repeated Beeps	Acoustic Alert from NADS LDW
Visual	HUD Lights	Side-view Mirror Amber Light
Haptic 1	Seat Belt Tensioner	Steering Wheel Vibration
Haptic 2	Seat Vibration	Seat Vibration
Haptic/Active	Brake Pulse	Steering Wheel Torque
No Warning	None	None

FCW alert modalities:

- Repeated Beeps - audio alert (pulsing tone) based on a 2010 Mercedes E350 that was previously used at VRTC. The audio alert was a beeping tone with a period of 400 ms, a 50% duty cycle, and a total length of four seconds.
- HUD Lights - visual alert (flashing LED strip) based on a 2008 Volvo S80 that was previously used at VRTC. The visual alert was delivered through an HUD LED light strip. The LED flashes with a pulse train of period 200 ms, 50% duty cycle, and total length of four seconds.
- Seat Belt Tensioner - reversible seat belt tensioner based on a 2009 Acura RL that was previously used at VRTC.
- Seat Vibration – seat vibration that provided vibration in the front of the seat similar to a “virtual rumble strip” across the roadway.
- Brake Pulse - brake pulse that decelerated the car momentarily at a level of approximately 0.22 G that was previously used at NADS.

LDW alert modalities:

- Acoustic Alert – auditory tone based on the 2008 Volvo S80 that was previously used in NADS LDW research for CWIM and tested at VRTC.

- Side-View Amber Light- flashing lights located in the side view mirrors that provided directional warning information.
- Steering Wheel Vibration - based on the 2008 BMW 528i that was previously used in NADS LDW research for CWIM and tested at VRTC.
- Seat Vibration – based on research from several studies that produced a "virtual rumble strip" to indicate lane departure. The signal is directional and represents either a center line or edge line rumble strip. This provides an alternate haptic interface to the steering wheel vibration (Sayer, 2005).
- Steering Wheel Torque - based on the 2010 Toyota Prius that was previously used in NADS LDW research for CWIM and tested at VRTC.

Two warning onset timings, early and late, were evaluated. These warning timings were differentiated for the LDW and FCW systems.

1.4.4 Familiarity

Two types of familiarity were considered: awareness and exposure to system functionality. It was important to distinguish between these two types of familiarity, as drivers may have been aware of the presence of a system but might not have previously experienced it in a vehicle.

Familiarity (awareness) has two levels that were evaluated in this work:

- No initial awareness of the system: No details about the warning systems in the vehicle were provided to these drivers. This represented a situation where the driver was unfamiliar with a vehicle, such as when borrowing, renting, or purchasing a car, and provided a worst-case situation for the driver. This was consistent with the FCW work performed as part of the VRTC test track work for CWIM.
- System training: Details consistent with an owner's manual and dealership walkthrough of the vehicle systems were provided to drivers in this condition before the study. This represented a situation where a driver had a working knowledge of systems present in the vehicle. This was consistent with the FCW and LDW work completed at NADS as part of prior CWIM work.

Familiarity (exposure) has two levels that were evaluated in this work:

- No prior exposure to the system: These drivers received no exposure to the warning system in the context of driving. This represented a situation where the driver was not familiar with what the DVI looked, sounded or felt like. This was consistent with the FCW work performed as part of the VRTC test track work for CWIM.
- System exposure: These drivers were presented with a warning in the context of driving so they were able to experience the warning relative to a similar threat (e.g., lane

crossing for LDW, interaction with a lead vehicle for FCW). This represented a situation where the driver had some limited experience with the system triggering, but not in a critical situation. This was consistent with the FCW and LDW work completed at NADS for prior CWIM work.

1.4.5 Incentive for Secondary Task

Three different levels of incentive were evaluated. Two of the levels had been employed in the previous test track and NADS efforts, and the third represented a moderate level between the previous two. Incentives were given for secondary tasks in order to give the tasks importance similar to those drivers perform in their own vehicles. This allowed the tasks to function as needed within the experimental design. The combination of incentive for secondary task was evaluated based on how well each level supported the desired characteristics of the distraction tasks. Participants were provided information about their incentive during the consent process and during the training prior to the drive. They also received feedback on incentive performance in the simulator.

- No incentive – This approach relied on instructing the participant to engage in the tasks and allowed them to self-select the relative priority of the driving and secondary tasks. This was consistent with the incentive used in previous NADS LDW and FCW work for CWIM.

- Low base pay relative to incentive – The potential incentive pay available exceeded the base pay, providing the driver with a monetary incentive to perform tasks well. This approach encouraged the driver to perform well on the tasks that were included in the incentive system. This was consistent with the incentive used in the VRTC FCW work for CWIM, which provided incentive for headway maintenance and secondary task performance.

- High base pay relative to incentive – This approach provided a midlevel incentive system. The participant received an incentive to perform well, but it was less prominent than the base pay. This provided a condition where there was external motivation to perform well, but with less incentive than the other low base condition.

1.4.6 Warning Onset

Two warning onset timings, early and late, were evaluated. These warning onset timings were differentiated for the LDW and FCW systems, as shown in Table 4.

Table 4. Warning Onset Levels

Onset Timing	LDW	FCW
Early	Distance = 12 inches from lane boundary	TTC = 3.5 s
Late	Distance = 3 inches from lane boundary	TTC = 2.1 s

- The early warning FCW alert was consistent with the prior FCW work done for CWIM at NADS based upon input from VRTC.
- The late warning FCW alert was consistent with a late warning that would give the driver the maximum amount of time to respond before receiving a warning.
- The early warning LDW was consistent with early warnings issued by the BMW 528i and Buick Lucerne, tested by VRTC.
- The late warning LDW was consistent with the average warning position of the Infiniti EX35.

An additional level of the LDW onset timing was used for the final study with the distance at the start of the warning being at 6 inches from the lane boundary.

1.4.7 Gender

Both genders were tested throughout the studies. Prior CWIM research showed that there may be differences in the effectiveness of DVI based on gender. To better understand these differences, gender was balanced across studies.

1.4.8 Distraction Task

Four distraction tasks were evaluated in this research to assess the most effective method for keeping the drivers' eyes off the road for the duration of the LDW and FCW events in the Main 1, 2 and 3 studies. Two had been utilized in previous efforts: the number recall task in the VRTC test track effort and the bug task in the NADS simulator effort. The distractions were divided along two axes: direction of gaze and type of interaction. The two gaze directions were (1) toward the back seat, and (2) head-down gaze in the front seat. For the type of interaction, the two configurations were visual with verbal response and visual manual. The distraction tasks were evaluated based on criteria described by Lerner et al. (2011), which included reliably drawing visual attention away from the roadway for a period sufficient to allow the crash scenario to unfold unnoticed by the driver through peripheral vision, and a body turn for LDW scenarios to mask experimenter-induced changes in lane position as driver-initiated. The duration of each task, not including the preliminary instructions and time allocated for orientation to the task, was kept constant at 2.36 seconds based on the work of Forkenbrock et al (2011) to allow sufficient time to be sure that the drivers attention is on the task and away from the forward roadway when the event begins and that the task lasts long enough to be sure that the return of attention to the road can be attributed to the alert rather than the end of the task.

For Preliminary Study 1, the distraction task was based on the distraction task used in the VRTC test track study. The task began 5.5 seconds before collision with the stopped vehicle, while it was still hidden by the lead car, with the playing of the instructions. The presentation of the numbers began at 3.42 seconds TTC. Commitment to the task was required for the 2.36 seconds the numbers were displayed. The timeline is shown in Figure 2.

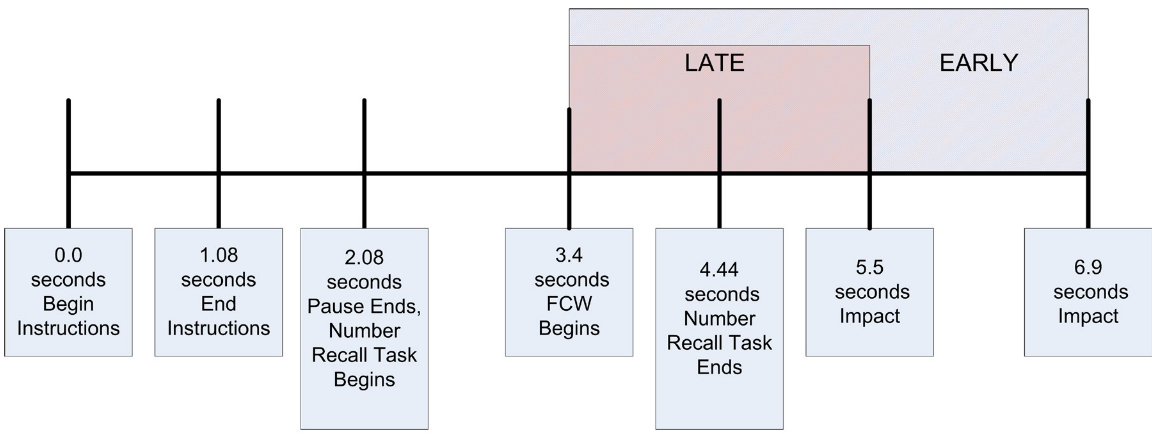

Figure 2. FCW CWIM 3 Timelines

The LDW events began in a similar manner to those in the FCW timeline (see Figure 3). The distraction tasks started at 2.08 seconds. However, the LDW occurred at 12 inches (early) and at 4 inches (late) before lane crossing occurred. Because the initial position of the driver in the lane varied, the exact timing of reaching the warning thresholds could not be specified in the same detail as for the FCW events. However, it was expected that the lane crossing would occur in less than the 2.36 seconds that marked the end of the distraction task.

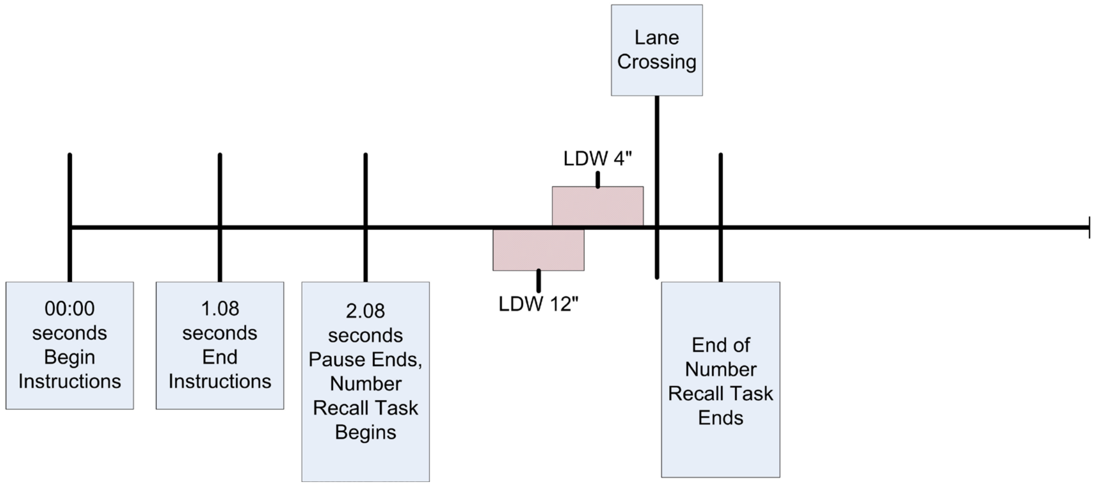

Figure 3. LDW CWIM3 Timelines

For Preliminary Study 2, the duration of the secondary tasks was designed to last at least as long as the duration in Preliminary Study 1. Timing was selected so that the length of engagement required was sufficient to instigate both the early and late FCW and LDW events.

The driver distraction tasks for the Main Studies in CWIM Phase 3 were chosen keeping three criteria in mind. The first criterion was chosen based on the conclusion by the Drivers Focus-Telematics Working Group (June 26, 2006) that the system should allow the driver to leave at least one hand on the steering control. The second criterion was to steer the driver's gaze away from the front view in order to instigate a "surprise" imminent, threatening situation. In order to do this, the driver's gaze needed to be averted continuously or with minimal disruption(s) for the duration of the task. Klauer et al. (2006) defined and classified relative risk of secondary tasks as simple, moderate complex, and complex. The 100-car Naturalistic driving database (Dingus, 2008) used a basic odds ratio equation to determine that a score of 1.0 indicates a crash/near crash risk is equivalent between the primary and secondary task. In this study, glance durations and mean glance duration were determined for activities conducted while driving. Table 5 compares the distraction tasks for CWIM Phase 3 and displays the equivalents of demand, odd ratio category, and mean glance duration levels.

Table 5. Distraction Task Justification

Distraction Task	Gaze Location	Demand	Odd Ratio Category	Mean Glance Duration
Number Recall Task	Backseat	Visual Verbal	Moderate Task	1.04
Message Reading Task	Front Head Down	Visual Verbal	Complex Task	1.45
Bug Task	Backseat	Visual Manual	Complex Task	1.4
Menu Selection Task	Front Head Down	Visual Manual	Moderate Task	1.14

A fifth distraction task was used in the CWIM-CV study. It was modeled after the information search task used in HFCV Phase 1 Task Order 20 and was modified to include additional faux applications and presented search questions visually (See Figure 8). Additionally, the new screens were updated for display on the larger 7" center stack touchscreen display used in HFCV Study 1. These screens are based on the Windows 8 icon design and layout. The font size and contrast were adjusted to be in compliance with ISO 15008: 2009 standards for in-vehicle visual presentations. Both the CV information search task and the message task were used.

- Number Recall Task – This task was located at least 90 degrees to the right of the participant's forward facing position. One second after receiving the instruction to begin, five random single-digit numbers were presented for 472 ms each. The participant was to repeat them aloud in the correct order to the experimenter following the task (Forkenbrock et al., 2011).

- Bug Task – This task required that the participant turn and reach into the back seat to trace the path of the insect on a touch screen display that was located to the rear of the left portion of the passenger seat headrest, at least 90 degrees to the right of the participant's forward facing position. A message indicated when it was time to begin the task. A red X appeared on the screen to orient the participant's finger to the display. 1.5 seconds after the message concluded, the insect began to buzz to start the task and continued to buzz for the duration of the task (2.36 seconds). A trail behind the bug was colored green, yellow, or red to provide visual feedback on performance. This task was an adaptation of the insect used by Lerner et al. (2011) and Brown et al. (2011).

- Message Reading - This task was presented to the driver on a touch-screen located in a head-down position to the right of the center console, ensuring that the driver's gaze would be directed down away from the front window. A message indicated the start of the task and the appearance of the text. The text was similar to that of an email. Timing was consistent with the number recall task. The task for the driver was to read aloud as much of the text as possible in the time available. When the task concluded after 2.36 seconds, the screen was cleared, but the participant could continue to recite any of the text that they had read before the task ended.

- Menu Selection Task - Drivers were presented with a visual distraction task on a touch-screen that mimicked a generic interaction with in-vehicle devices such as mp3 players or navigation systems. The driver was presented a two-word target phrase and asked to locate an appropriate match from the four listed on the screen. This task was located on the same display used for the message reading task such that the driver's gaze was directed down away from the front window. The phrases appeared 1.5 seconds after the prompt concluded. A correct match was when any of the words in the presented phrase appeared in the same location in the selected phrase. During the drive, a message indicated when to begin the task. When the match phrase was located, the driver pressed the screen location for the selection. The phrases were presented on the screen for a total of 2.36 seconds. If the initial selection was incorrect, the participant could try again if there was time remaining (Lees et al., 2007).

- Connected Vehicles Task – Drivers were presented with a visual manual task on a touch screen that mimicked interaction with applications on a touch screen in the center column. The driver was presented with an audio prompt to begin the task. Simultaneously, the home screen of the task appeared displaying a CV-like question and twelve buttons labeled as CV functions that lead to secondary screens that contained information relating to each function. The driver had to choose the appropriate CV function to access the information required to correctly respond to the question on the home screen. Once the correct answer was identified, participants entered their answer using the Yes/ No buttons on the touch screen. New questions were automatically presented until the full 12-second task period was complete. Once 12 seconds of task time elapsed, the secondary task screen went blank until the next task interaction location during the drive.

Figure 4. Information Search Screen Modeled after the Windows 8 Tile Layout.

For all distraction tasks, participants were provided information about the distraction task during the training process before entering the simulator and given time in the simulator to become comfortable with the distraction task.

Table 6. Summary of Independent Variable Levels by Study

			Prelim. 1	Prelim. 2	Main 1	Main 2	Main 3	CWIM-CV
Platform		**Test Track**	Ind. Var. Lv.	--	--	--	--	--
		NADS-1	Ind. Var. Lv.	Control	Control	Control	--	Control
		NADS-1 Limited Motion	--	--	--	--	Ind. Var. Lv.	--
		NADS-1 No Motion	--	--	--	--	Ind. Var. Lv.	--
Incentive		**High-Low**	--	Ind. Var. Lv.	--	--	--	
		Low-High	Control	Ind. Var. Lv.	--	--	--	Control – level match Main 2
		Base Only	--	Ind. Var. Lv.	Control	Control	Control	
Distraction		**Number Recall**	Control	Ind. Var. Lv.	Control	Control	Control	
		Bug Following	--	Ind. Var. Lv.	--	--	--	Control – level match Main 2
		Reading	--	Ind. Var. Lv.	--	--	--	
		Word Match	--	Ind. Var. Lv.	--	--	--	
Familiarity	**Training**	**Yes**	--	--	Ind. Var. Lv.	--	--	Control – level match Main 2
		No	Control	Control	Ind. Var. Lv.	Control	Control	
	Exposure	**Yes**	--	--	Ind. Var. Lv.	Control	Control	Control – level match Main 2
		No	Control	Control	Ind. Var. Lv.	--	--	

Warning Onset		**Late (2.1s, 4")**	Control	Control	Control	Ind. Var. Lv.	Control – level TBD Main 2	Ind. Var. Lv.
		Early (3.5s, 12 ")	--	--	--	Ind. Var. Lv.		--
Alert Modality	**FCW**	**No Alert**	Control	--	--	Ind. Var. Lv.	Ind. Var. Lv.	Ind. Var. Lv.
		Repeated Beeps	Control	Control	Ind. Var. Lv.	Ind. Var. Lv.	Ind. Var. Lv.	--
		HUD Lights	--	--	--	Ind. Var. Lv.	--	Ind. Var. Lv.
		Seat Belt Tensioner	Control	Control	Ind. Var. Lv.	Ind. Var. Lv.	Ind. Var. Lv.	Ind. Var. Lv.
		Seat Vibration	--	--	--	Ind. Var. Lv.	--	--
		Brake Pulse	--	--	Ind. Var. Lv.	Ind. Var. Lv.	--	--
	LDW	**No Alert**	--	--	--	Ind. Var. Lv.	Ind. Var. Lv.	Ind. Var. Lv.
		Acoustic NADS LDW	--	--	Ind. Var. Lv.	Ind. Var. Lv.	Ind. Var. Lv.	--
		Flashing Amber Light	--	--	--	Ind. Var. Lv.	--	Ind. Var. Lv.
		Steering Wheel Vibration	--	--	Ind. Var. Lv.	Ind. Var. Lv.	--	--
		Seat Vibration	--	--	--	Ind. Var. Lv.	Ind. Var. Lv.	Ind. Var. Lv.
		Steering Wheel Torque	--	--	Ind. Var. Lv.	Ind. Var. Lv.	--	--
Gender			Balanced	Balanced	Balanced	Balanced	Balanced	Balanced

2 Methodology

This section describes the general experimental designs and conditions for the preliminary and main studies that determined the characteristics associated with a sensitive protocol. Two preliminary studies examined the effects of platform type, distraction task, and incentive structure for the subsequent main studies. Three successive main studies examined (1) the levels of system familiarity through training to create awareness and exposure to the alert in the vehicle, (2) alert modality and onset, and (3) the effect of simulator platform motion.

2.1 Overall Approach

Three independent variables—platform, distraction task, and incentive—were examined in two preliminary studies in the NADS-1 driving simulator.

The first preliminary study examined the following:

- Three levels of alert modality: no alert, audio, and seat belt tensioner.

The effect of platform: test track vs. simulator (see Table 7). As in the previous VRTC test track study, no training on FCW or exposure to the alert modality was provided in the preliminary studies.

- The extent to which results on a test track replicate in the simulator under similar protocols.

The second preliminary study examined the following:

- Two levels of alert modality: audio and seat belt tensioner.

- Three incentive structures and four distraction tasks. The results determined the incentive structure and distraction task(s) to be used in the main studies.

Table 7. Context of Preliminary Study 1

Platform		Scenario: Test Track	Scenario: Road
	Test Track	Previously Collected	Not Available
	Simulator	Preliminary 1	

Four successive main studies were conducted. The first main study examined familiarity through training on the FCW and LDW systems and exposure to system alerts prior to forward collision and lane departure events during the experimental drives. The second main study examined alert modality and alert onset. These studies used the NADS-1 simulator with full motion. The third main study revisited platform by presenting the final protocol on the NADS-1 with limited motion and no motion. The final study, CWIM-CV, investigated the sensitivity of the protocol by presenting a subset of the Main 2 study conditions using the CV distraction task and the message task.

2.1.1 Driving Scenarios

Four driving scenarios were developed for the six studies conducted as part of this research. Each is described in general here and in greater detail in the sections about the specific method for each study.

For the first preliminary study, which looked at the effects of platform on evaluating DVIs for FCW systems, two driving scenarios were developed. One was designed to replicate the driving environment and scenario from the VRTC FCW experiment (Forkenbrock et al., 2011). The other was designed to replicate the test track experiment on a two-lane rural roadway. In both scenarios, drivers were asked to maintain a headway of 110 feet to a lead vehicle throughout the drive. Participants were provided with a display that contained the current headway to the lead vehicle. The experimental portion of the drive involved the participant driving along a straight segment behind the lead vehicle. At a predefined point along each straightaway, the participant was asked to engage in a menu recall task that took the driver's eyes off the road. On the fourth straightaway, a lead vehicle revealed event was initiated while the driver's eyes were off the road. For participants with an FCW alert, it was triggered with a nominal TTC of 2.1 seconds.

For the second preliminary study, which looked at distraction tasks and driver response to unexpected alerts while distracted, a two-lane rural driving environment was used. This driving environment was the same as the one used in prior CWIM work at NADS (Lerner et al., 2011; Brown et al., 2011), which took participants approximately 25 minutes to complete. During the drive, participants were asked to engage with four different distraction tasks that lasted for several seconds each. Participants engaged with each task four times. Two different orders of tasks were used to control for learning effects. At the end of the drive, the participants engaged in the number recall task a fifth time. During this occurrence of the task, the lead vehicle began to brake rapidly, and an FCW alert was issued.

For the first main study, which looked at training and system exposure, a driving environment built from the database used for the second preliminary study was used. Changes to the driving environment included the introduction of new intersections and changes in speed limits. Over the course of the drive, participants experienced two lane departure events, two revealed lead vehicle events, and two false alarm events. Additionally, participants engaged in short secondary distraction tasks across the drive. The total duration of the drive was approximately 30 minutes.

The driving scenario for the first main study was also used for the second main study, which looked at the effect of warning timing and sensitivity of the protocol across DVI type. It was also used for the third main study, which looked at the effect of motion on sensitivity of the protocol, and for the connected vehicles task study, which looked at the effect of type of task.

2.1.2 Simulator

The NADS-1 is located at The UI's Oakdale Campus. It consists of a 24-foot dome in which an entire car is mounted (see Figure 5). All participants drove the same vehicle—a 1996 Malibu sedan. The motion system, on which the dome is mounted, provides 400 square meters of horizontal and longitudinal travel and ±330 degrees of rotation. Each of the three front projectors has a resolution of 1600 x 1200; the five rear projectors have a resolution of 1024 x 768. The edge blending between projectors is five degrees horizontal. The NADS produces a thorough record of vehicle state (e.g., lane position) and driver inputs (e.g., steering wheel position), sampled at 240 Hz.

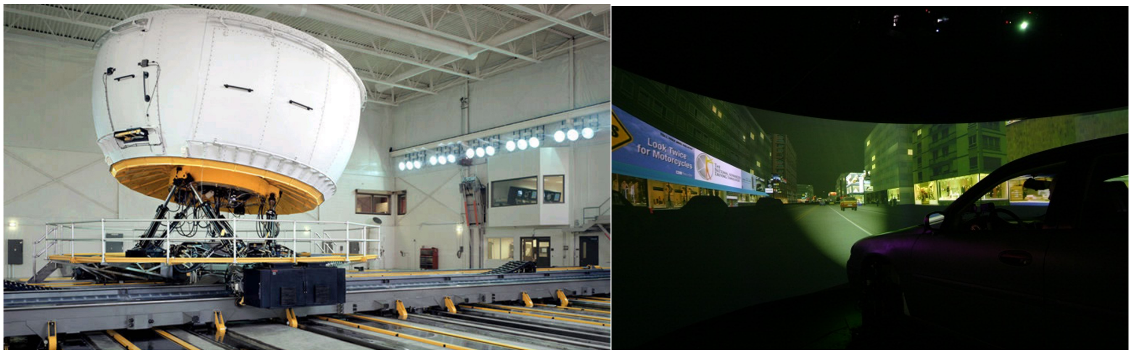

Figure 5. Representation of NADS-1 Driving Simulator (left) with a Driving Scene from Inside the Dome (right).

The cab was equipped with a Face Lab™ 5.0 (Seeing Machines, Canberra, Australia) eye-tracking system that was mounted on the dash above the steering wheel. The worst-case head-pose accuracy was estimated to have RMS error of 5º. In the best case, where the head was motionless and both eyes were visible, a fixated gaze could be measured with an estimated error of 2º. The eye tracker records data at a rate of 60 Hz. The cab was also equipped with a Seeing Machines Driver State Sensor (DSS) V3.4.260101, a single-camera system that was used for head tracking. The installation of the cameras is shown in Figure 6.

Figure 6. Face Lab Cameras Mounted in the Malibu Cab with a Separate Head Tracking System Mounted between Them

The NADS-1 with full motion was used for both preliminary studies and the first two main studies, as well as the CWIM-CV study For the third main study, the NADS-1 was used in a limited motion configuration with only the hexapod to provide motion cueing, and with no motion.

2.1.3 Alert Modalities

The use of the alert modalities identified varied by study. For the first preliminary study, the seat belt tensioner and the auditory FCW alerts were used in addition to the no warning condition. For the second preliminary study, the seat belt tensioner and auditory FCW alerts were used for the final event. For the first main study, the DVIs for the FCW alert included seat belt tensioner, auditory alert, and brake pulse; for the LDW alert, they included steering wheel vibration, auditory alert, and steering wheel torque. For the second main study, all of the DVIs for FCW and LDW were included. For the third main study, auditory and the seat belt tensioner were used for FCW and auditory and seat vibration were used for LDW DVIs. Both the FCW and LDW DVIs also included a no warning condition. For the CWIM-CV study, the DVIs for the FCW alert included seat belt tensioner, visual alert, and no warning condition; for the LDW alert, they included visual alert, steering wheel torque, and no warning condition.

2.1.4 Distraction Task

The distraction tasks identified in the previous chapter were used in different combinations across the studies. For the first preliminary study, the number recall task was used to distract the participants. For the second preliminary study, all four distraction tasks were used to determine which tasks would be best suited for inclusion in the final protocol. For the main studies, the number recall task was used for the LDW and FCW events. For the CWIM-CV study, the connected vehicles task and the message task were used. Additional detail is provided in the specific method section for each study.

2.1.5 Incentive Structure

Either monetary or instructional incentives were provided during the studies to encourage participants to engage in the distraction tasks and to maintain an appropriate headway. For the first preliminary study, the incentive structure was a scaled version of that used for the VRTC study (Forkenbrock et al., 2011). For the second preliminary study, the incentive structure from the first preliminary study was adapted to account for additional instances of distraction tasks and included two additional levels of incentive, high base pay and no monetary incentive. For the main studies and the CWIM-CV study, no financial incentive was used.

2.1.6 General Experimental Procedures

General experimental procedures were the same for all studies, preliminary, main, and CV, and are described in the following sections.

2.1.6.1 Institutional Review Board

Experimental materials were submitted to the UI Institutional Review Board (IRB) for review and approval prior to data collection for each of the studies. Modifications and continuing reviews were submitted as required.

2.1.6.2 Participant Recruitment

The NADS volunteer database, which contains over 5,000 individuals, was queried for participants who were 35 to 55 years old, and an email was sent to those who had provided an email address. Potential participants in the volunteer database were also contacted by telephone. A telephone screening procedure was used to ensure participants met all inclusion requirements. The phone screenings for all studies are included in the Appendix in Section 11. Participants who met all requirements and could meet the study schedule were scheduled for study participation. A total of 312 participants completed all study procedures and were included in the final analyses. A breakdown per study is provided in Table 8.

Table 8. Participants per Study

Study	Number of Participants
Preliminary 1	36
Preliminary 2	24
Main 1	96
Main 2	96
Main 3	48
CWIM-CV	24
Total	324

2.1.6.3 Briefing

The same overall briefing procedures were followed for all studies. Upon arrival at the NADS facility, participants were escorted to a participant room where the informed consent document was reviewed with participants. Copies of the informed consent documents for each study can be found in the Appendix in Section12. They were encouraged to ask questions and allowed as much time as they needed to read the informed consent document. Once informed consent was obtained, their licenses were confirmed as valid, and a video release form and a payment form were completed. A generic video release form is provided in the Appendix in Section 13, and a generic payment form in the Appendix in Section 14. Driving history and demographic data were collected (see the Appendix in Section 15). Participants then watched a self-paced PowerPoint presentation describing the driving simulator, the incentive structure, and the task they would be expected to perform while driving. The training presentation for each study is in the Appendix in Section 17. The distraction task was then practiced, if applicable to condition within a specific study.

2.1.6.4 Simulator Drive

Once participants were situated in the simulator, eye-tracking calibration procedures were completed. The participants then completed a single experimental drive. The experimental drive was followed by an assessment for signs of simulator sickness (see the Appendix in Section 18).

2.1.6.5 Debriefing

Following the study drive, participants returned to a participant room where simulator realism was assessed (see the Appendix in Section 19). Situational awareness was evaluated using the Situational Awareness Rating Technique (Taylor, 1990) (see the Appendix in Section 20). System acceptance was also evaluated (see the Appendix in Section 21). Their compensation was reviewed, and any questions were answered prior to the conclusion of their study visit. Each participant was also provided a debriefing statement that explained the true purpose of the study and asked not to discuss the details of the study until after all data collections for this project were concluded (see the Appendix in Section 22).

2.1.7 Dependent Measures

Several types of dependent measures will be used across the studies. These types of measures include measures that document how well the event choreography (timing) occurred, driving performance measures from the subject during the tasks, measures related to the outcome of the forward crash events, and measures related to the outcome of the lane departure events. These measures[1], including definitions and the studies in which they were used are summarized in Table 10. Additionally, for each study, a list of the measures used in that study is provided in the appropriate chapter.

[1] Accelerator release time was not included ass a measure of analysis due to potential confounds associated with normal fluctions in throttle position associated with normal speed maintenance and throttle release by the driverwhile engaging in the secondary tasks.

Table 9. Summary of Dependent Measures Across Studies

Measure	**Type of Measure**	**Description**	**Test Track Comparison**	**Secondary Task and Incentive Considerations**	**System Training and Exposure**	**Alert Timing and Protocol Sensitivity to Systems**	**Motion Feedback Considerations**	**Crash Warning Evaluation in a Connected Vehicle Environment**
Speed	Choreography	Velocity of the subject vehicle measured at a particular point in time.	✓					
Distance		The gap from the front bumper of the subject’s vehicle to the back bumper of the specified vehicle	✓					
Time-to-Collision		Range to the lead vehicle divided by the range rate between the two vehicles.	✓					
Time to visual commitment	Visual Commitment	The time from the end of the instruction to the first instant the participant’s vision departs forward	✓	✓				
Time to end of visual commitment		The start of the task until the first instant that the participant's vision returns forward		✓				
Time to end of visual commitment from warning		The time the alert began or would have begun until the first instant that the participant's vision returns forward	✓	✓	✓	✓	✓	✓

Measure	Type of Measure	Description	Test Track Comparison	Secondary Task and Incentive Considerations	System Training and Exposure	Alert Timing and Protocol Sensitivity to Systems	Motion Feedback Considerations	Crash Warning Evaluation in a Connected Vehicle Environment
Duration of first visual commitment		The time from the beginning of visual commitment to the first interruption, or end of visual commitment		✓	✓	✓	✓	✓
Engagement duration		Total time of visual commitment to distraction task after subtracting glances to front scene		✓	✓	✓	✓	✓
Visual commitment duration		Time from beginning of first visual commitment to the distraction task to end of last visual comment including any glances back to the roadway	✓	✓	✓	✓	✓	✓
Glances back to roadway		Count of full glances back to roadway during distraction task		✓	✓	✓	✓	✓
Change in velocity during visual commitment	Performance	The change in speed from the beginning of the distraction task until its completion with positive numbers indicating an increase and negative numbers indicating a decrease.		✓				
Average lane position during visual commitment		The average position of the driver's vehicle in the lane during the distraction task.		✓				

Measure	Type of Measure	Description	Test Track Comparison	Secondary Task and Incentive Considerations	System Training and Exposure	Alert Timing and Protocol Sensitivity to Systems	Motion Feedback Considerations	Crash Warning Evaluation in a Connected Vehicle Environment
Standard deviation of lane position		Standard deviation of subject vehicle lane position over the duration of event		✓				
Maximum change in lane position		The maximum of the absolute value of the change in lane position relative to the driver's position in the lane when the distraction task began		✓				
Time-to-collision at the end of visual commitment	Forward Crash	The time to collision when the participant's vision returns forward	✓	✓	✓	✓	✓	✓
Collision	Forward Crash	Contact between the participant's vehicle and the stopped vehicle	✓	✓	✓	✓	✓	✓
Minimum time to collision	Forward Crash	The minimum time to collision (TTC) with the stopped vehicle after the alert	✓		✓	✓	✓	✓

Measure	Type of Measure	Description	Test Track Comparison	Secondary Task and Incentive Considerations	System Training and Exposure	Alert Timing and Protocol Sensitivity to Systems	Motion Feedback Considerations	Crash Warning Evaluation in a Connected Vehicle Environment
Adjusted minimum TTC		The adjusted minimum TTC with the stopped vehicle after the alert with positive values indicating minimum TTC and negative values indicating how much sooner the driver would have needed to respond based on collision velocity and deceleration profile			✓	✓	✓	✓
Brake reaction time		Time from alert to brake pedal depress	✓		✓	✓	✓	✓
Maximum lane exceedance	Lane Departure	The maximum lateral distance that the leading edge of the vehicle is out of the lane			✓	✓	✓	
Area of lane exceedance		A composite measure that takes into account both the lateral and longitudinal distances that the vehicle is out of the lane			✓	✓	✓	
Duration of lane exceedance		Amount of time subject vehicle was outside lane boundary			✓	✓	✓	

Measure	Type of Measure	Description	Test Track Comparison	Secondary Task and Incentive Considerations	System Training and Exposure	Alert Timing and Protocol Sensitivity to Systems	Motion Feedback Considerations	Crash Warning Evaluation in a Connected Vehicle Environment
Steering reaction time		Time from alert to steering response			✓	✓	✓	

2.1.8 Data Handling

2.1.8.1 Video Coding

For each study, visual commitment of the participants to the distraction tasks was video coded. Each event for each participant was dual coded, and discrepancies were resolved by a third reviewer. Criteria for the beginning and end of visual commitment were based upon those given by Forkenbrock et al. (2011). Specifically, Forkenbrock et al. (2011) defined the start of visual commitment as the instant when a driver begins to turn his or her head toward the display and the end of visual commitment as “the instant the driver returns their vision to a forward-looking position.”

To accomplish this, the quad split video from the drive was loaded on the computer, and the researcher found the appropriate location on the video through the log streams documented on the video overlay. The start and end of visual commitment were documented based on the simulator frame number on the video overlay. Additional details can be found in the Appendix in Section 23. The video data coding was integrated with the simulator data to provide the timing of the visual commitments.

2.1.8.2 Data Reduction

Data from each simulation study was reduced to provide an Excel workbook that contained all the data for analysis. Separate worksheets were generated for each event in the experimental drive.

The raw binary data from the simulator was reduced using Matlab scripts to provide the data needed to assess the effectiveness of the protocol and determine the ability of the protocol to assess differences in the effectiveness of the DVIs being evaluated in the protocol.

2.1.8.3 Data Verification & Cleaning

Data verification occurred at multiple levels: verification of validity of the event and verification of the data accuracy. The former verified that the event was executed accurately, and the latter verified that the data accurately reflected what happened in the event.

Verification of the validity of the event was assessed at several levels. For each drive, the critical events where LDW or FCW events occurred were reviewed. The review included verification of the following:

- speed and headway (for FCW events) was within the required range;
- the driver engaged in the secondary task;
- the driver was engaged in the secondary task when the alert was given or would have been given; and
- the appropriate DVI warning was provided.

Participants who did not meet these requirements for the preliminary studies were replaced. In the main studies, participants were replaced if they failed to meet the criteria for the first critical event.

Verification of the accuracy of the data was accomplished through a series of procedures designed to identify potential problems. The first step was an automatic check of the data after it was collected but before it was reduced that examined the raw data collected. This process looked to determine if any of the data exceeded specified minimums and maximums for the individual data streams and if the data varied as expected (i.e., there were no unrealistic discontinuities in the data and the data did not remain at a fixed value for an unrealistic period). The next step was to verify that reduced data was consistent, including verification that dependent measures were within the bounds of data expected. The final piece of the verification was to look for extreme outliers during a univariate analysis prior to the formal data analysis. Issues identified at any point in this verification process were researched to determine the appropriate corrective action.

2.1.9 Data Analysis

Each of the studies had its own specific analysis plan. Unless noted otherwise, the SAS General Linear Models (GLM) procedure was used to perform an Analysis of Variance (ANOVA) on the parametric dependent measures. Post-hoc tests were used where appropriate for significant main effects and utilized the post-hoc t-test with the Bonferoni adjustment. For significant interactive effects, a simple effects test was performed.

3 Test Track Comparison

3.1 Specific Method

The aim of this study was to compare results from the VRTC test track study examining FCW interfaces with a replication of that protocol on the NADS-1 simulator. Preliminary Study 1 replicated the test track drive from the VRTC effort in a simulator driving scenario on NADS-1. It used a road course that provided a parallel driving environment on two-lane rural roadways and left curves with a single lead vehicle revealed event in the latter portion of the drive. The number recall distraction task and the incentive structure from the VRTC test track protocol were replicated for these studies. The VRTC incentive structure was used in a scaled form to meet institutional needs. The late warning onset was used for all FCW alerts. No LDW system was present. No training on FCW or the alert was provided to participants prior to their drives. Participants were not exposed to the FCW alert during their drive prior to the single FCW event at the end of their drive.

3.1.1 Hypotheses

There were two main hypotheses for this preliminary study:

- There will be no differences in visual commitment or response/outcome between the test track course conducted on <u>test track</u> and the <u>NADS-1</u> simulator.
- There will be no differences in visual commitment or response /outcome for the <u>test track course</u> and <u>road course</u> for the NADS-1 simulator.

3.1.2 Experimental Design

This study utilized a 2x3 factorial with between-subject variables: platform and alert modality. Platform was at two levels: test track and simulator. Alert modality had the levels of no warning, audio, and seat belt tensioner. These alert modalities represented a subset of the data that was previously collected on the test track as part of prior CWIM research (Forkenbrock et al., 2011)

Table 10 shows the relationship of the data collected for this preliminary study to the overall approach laid out in Table 7. The two levels of platform were a driving simulator scenario replicating the test track drive on NADS-1 and the road drive version on the NADS-1.

Table 10. Preliminary Study 1 Experimental Design

Platform	Scenario: Test Course	Scenario: Road
Test Track	Previously Collected	Not Available
Simulator	Preliminary 1	

	Alert Mode: None	Alert Mode: Audio	Alert Mode: Seat belt Tensioner
Simulator w/ test course scenario	6 participants	6 participants	6 participants
Simulator w/ road scenario	6 participants	6 participants	6 participants

3.1.3 Dependent Measures

As the aim of this effort is to compare data to previously collected data from the test track, common dependent measures will be used. Data from the simulator were reduced to provide the same measures used on the test track. The dependent measures considered were:

- Speed
- Distance
- Time-to-Collision
- Time to visual commitment
- Time to end of visual commitment from warning
- Visual commitment duration
- Time-to-collision at the end of visual commitment
- Collision
- Minimum time to collision
- Brake reaction time

3.1.4 Participants

Thirty-six participants completed all study procedures successfully. Fifty-six participants were enrolled in the study, and twenty were dropped for the reasons documented in Table 11.

Table 11. Participants Enrolled by Condition

	Test Track						Road						Total
	Baseline		Auditory		Seat Belt Tensioner		Baseline		Auditory		Seat Belt Tensioner		
	F	M	F	M	F	M	F	M	F	M	F	M	
Enrolled	3	4	5	4	9	4	3	4	4	5	8	3	56
Out of Range for Speed or Headway			1		2						1		4
Didn’t Look Away					3						1		4
Looked Back			1	1	1			1		1	1		6
Invalid Event						1			1		1		3
Simulator Sick											1		1
Simulator Issues		1								1			2
Completed	3	3	3	3	3	3	3	3	3	3	3	3	36

3.1.5 Apparatus

Two displays were mounted in the simulator cab for this study: the number recall display located to the participant’s right, and the headway display located near the participant’s line of vision.

3.1.5.1 Number Recall

The number recall task, described in Section 1, was mounted on the front of the passenger seat headrest and adjusted for each participant so that the display was located at an angle of at least 90 degrees to the right of the forward-looking position (see Figure 7).

Figure 7. Number Recall Display

3.1.5.2 Headway

The headway display was mounted on the dashboard centered 4.5 inches to the right of the forward line of sight of the participant (see Figure 8). The display provided the headway to the lead vehicle in feet.

Figure 8. Headway Display

3.1.6 Experimental Procedures

The general experimental procedures were described in Section 2. Study-specific procedures for this experiment are documented in the following sections.

3.1.6.1 Experimental Ruse and Deception

Participants were told that the goal of the research was to examine headway maintenance, when in fact their response to a warning system was being evaluated.

3.1.6.2 Headway

Participants were instructed to maintain a headway of 110 feet ± 15 feet.

3.1.6.3 Training

The training presentation included descriptions of the number recall task and headway maintenance task as well as a description of the incentive pay.

3.1.6.4 Compensation

Compensation was based on that provided in the VRTC study (Forkenbrock et al., 2011), except that it was scaled to meet the needs of local participant recruitment and institutional review considerations concerning coercive compensation. Base compensation was set at $17.50, which represents 50% of the amount used in the VRTC study. Maximum incentive compensation was set at $27.50, which is 42% of the amount used in the VRTC study. This provided a maximum compensation of $45. The base pay was pro-rated. If participation lasted less than 1 hour, participants earned $10. If participation last for over 1 hour, participants earned the full base pay.

The incentive was based on the participant's ability to correctly complete the number recall tasks and maintain a safe headway. The ratio of incentive for the headway maintenance and number recall was consistent with the VRTC study: the maximum incentive for headway maintenance was $8.48, the maximum incentive for the number recall task was $19.05, and both are 42% of the amount used by VRTC.

3.1.6.5 Incentive

For headway maintenance, participants received incentive pay based on how well they maintained a headway of 110 feet. Incentive compensation was available based on successfully staying within 15 feet of this target (95 to 125 feet) and the percentage of time in this range. Participants could earn up to $2.12 for each of the four segments, for a total of $8.48. If participants kept within the range for at least 80% of the segment, they received the full incentive compensation for that segment. If participants were not able to stay within the range, their incentive compensation was scaled based on the percentage of time that the headway was in the correct range.

For the number recall task, participants received incentive pay based on how many numbers they got correct. On the first instance, participants earned $0.63 per number successfully recalled in the order presented. After the first instance, participants earned $1.06 per number successfully recalled in the order presented. If the number sequence indicated was incorrect, participants lost $0.40. Each instance of the number recall was separate and did not influence the amount of money that the participant could earn on the other recall tasks. Minimum incentive compensation was $0.00.

Incentive feedback was provided to participants at the end of each segment and combined feedback for both tasks. Additional details can be found in the Appendix in Section 24.

3.1.7 Scenarios

Two driving scenarios were used for this study: test track and road course (see Figure 9 and Figure 10 , respectively). Each scenario had a practice segment followed by four segments in which participants maintained headway, engaged in the number recall task, and received feedback. Throughout the four segments, participants followed a lead vehicle at a nominal headway of 110 feet with a nominal speed of 35 mph. During the fourth segment, a lead vehicle revealed event was triggered. The choreography of the lead vehicle revealed event followed the timeline that was laid out in Figure 2 for the late warning.

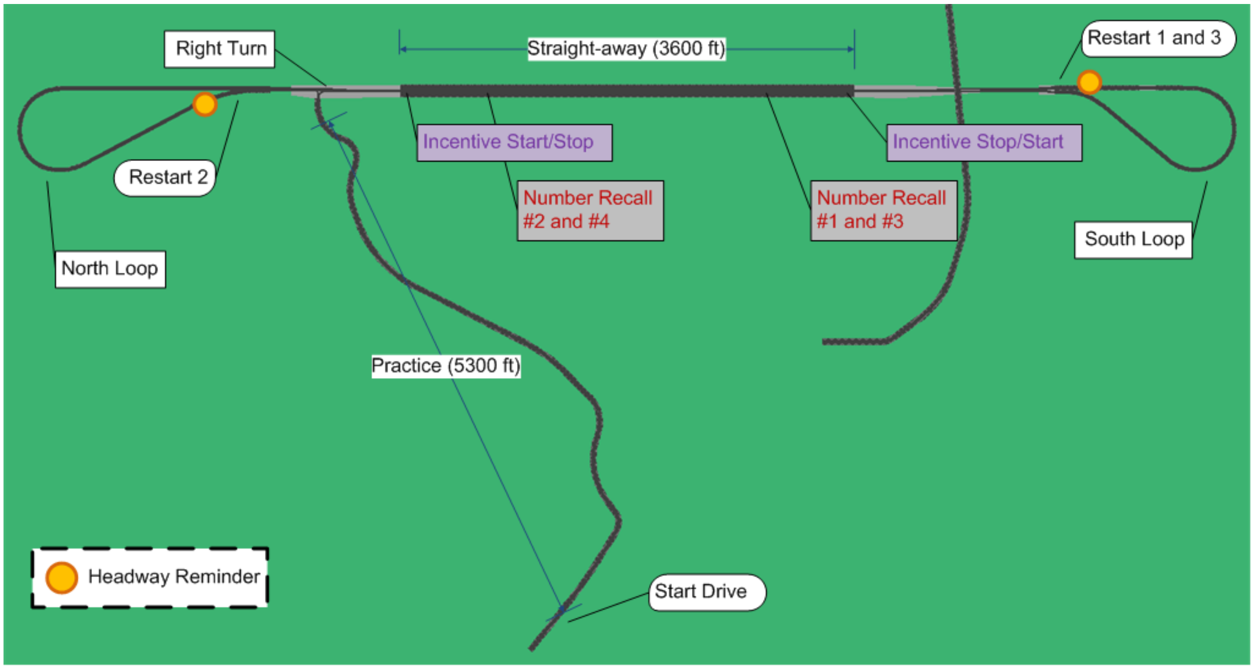

Figure 9. Replica Test Track Road Network

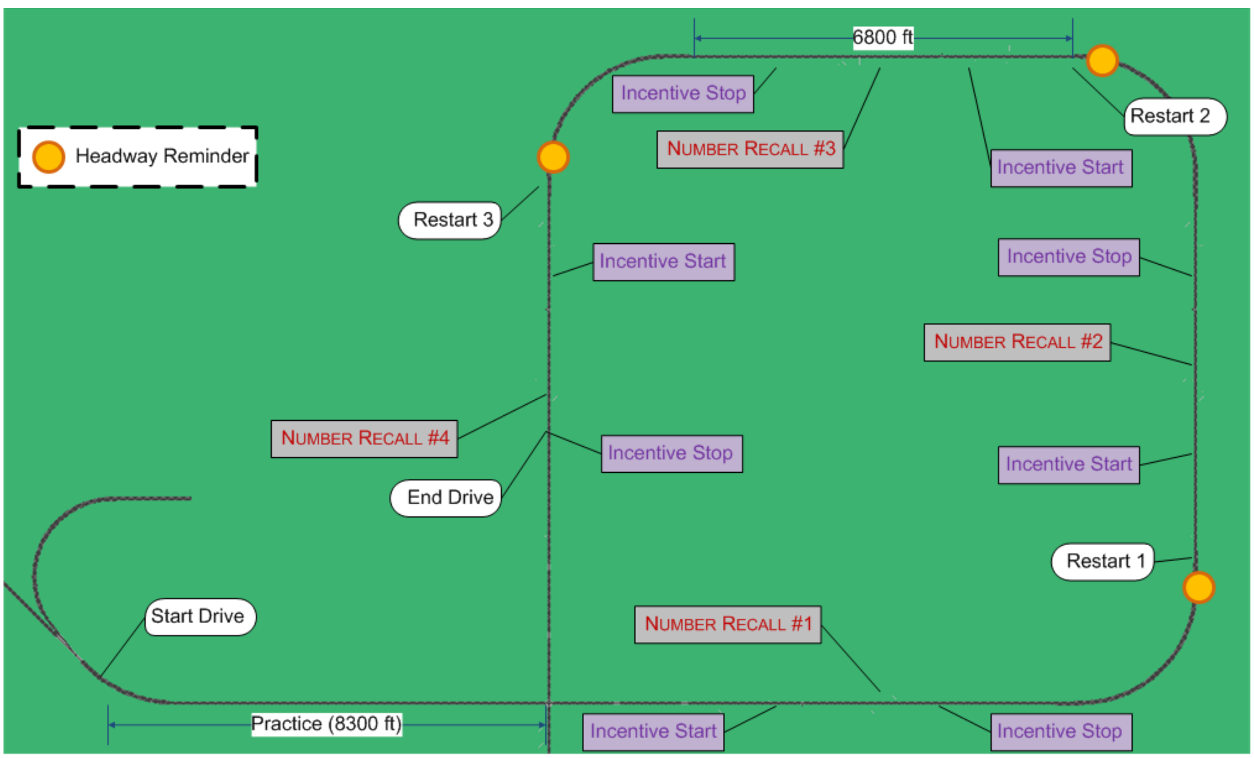

Figure 10. Equivalent Road Course Network

3.1.8 Analysis Plan

After data were verified, three primary analyses were conducted to address the hypotheses. The first analysis focused on how well the event choreography aligned with the events from the VRTC test track study. Data from the VRTC experiment was derived from the summary report completed by Forkenbrock et al (2011). The second analysis compared the simulated test track to the real-world test track at VRTC. This analysis included addressing the first hypothesis looking at time to end of visual commitment and TTC at the end of visual commitment as well as secondary endpoints that provide context. The third analysis compared the simulated test track to the simulated road course. This analysis included addressing the second hypothesis looking at time to end of visual commitment and TTC at the end of visual commitment as well as secondary endpoints that provide context.

For the first analysis, the event choreography data from the simulator was compared against the event choreography from the test track. Separate analyses were used for the simulated test track and the simulated road course.

For the second analysis, the standard parametric procedures were used to compare the simulated test track and the test track. For the third analysis, the same procedure was used to compare the simulated road course and the simulated test track.

3.2 Results

3.2.1 Choreography Comparison

The initial evaluation of the results is to verify that the test course could be replicated successfully in the simulator environment. To that end we examine how closely the data on the simulator matches the data published from the VRTC study. In looking at the subject vehicle speed over the course of the interaction with the task and the lead vehicle revealed event, the corresponding values for subject vehicle speed at four critical points in the process are presented in Table 12. As can be seen the observed speeds in the NADS on the virtual test track closely resemble the values from VRTC. The mean values differ by less than 0.5 mph across the four points in time. One important item to note is the speed at the conclusion of visual commitment on the NADS. The initial plan was to utilize eye-tracking to identify the beginning and end of visual commitment automatically; however, after reviewing the data, it is clear that the placement of the display was causing difficulties for the eye tracker. As a result, we switched to video coding which was completed by dual coding each event.

Table 12. Speed Across Critical Points during Lead Vehicle Revealed Event

Description	SV Speed (mph)								
	Task Instruction		Random Numbers Presented		FCW Alert		VC Concludes		
	VRTC	NADS	VRTC	NADS	VRTC	NADS	VRTC	NADS Eye Tracking	NADS Video Coding
Min	33.0	31.0	31.1	32.3	30.8	31.3	30.8	0.1	30.6
Max	37.5	38.4	38.1	37.6	38.3	38.0	38.2	34.3	39.4
Mean	35.2	35.0	35.2	34.8	35.1	34.6	34.9	24.6	34.5
Std Dev	1.1	1.6	1.3	1.2	1.4	1.4	1.5	8.5	1.7
Median	35.2	35.0	35.2	34.8	35.2	34.4	35.1	27.0	34.1
Nominal	35	35	35	35	35	35	35	35	35

For distances between the subject vehicle and stopped lead vehicle, the values for the simulator are typically larger than at VRTC (see Table 13). However, although the NADS values are systematically larger for many of the items, they do correspond well to the nominal values. This is likely the result of the greater precision available within the simulation environment to guarantee that events will fire at the correct time. When looking at the conclusion of visual commitment which is dependent upon the subject, it should be noted that on the NADS there were cases where the subject did not end their visual commitment before striking the lead vehicle.

Table 13. Distance to Stopped Vehicle Across Critical Points during Lead Vehicle Revealed Event

Description	SV-to-SLV Distance (feet)								
	Task Instruction		Random Numbers Presented		FCW Alert		VC Concludes		
	VRTC	NADS	VRTC	NADS	VRTC	NADS	VRTC	NADS Eye Tracking	NADS Video Coding
Min	278.5	280.4	150.7	158.1	103.3	105.8	16.4	-10.1	-3.2
Max	279.3	284.8	170.5	179.5	108.7	110.0	94.5	64.3	83.6
Mean	278.9	282.5	160.5	169.7	106.1	107.8	52.7	23.5	58.7
Std Dev	0.2	1.0	4.0	4.5	1.5	0.9	23.9	20.2	16.5
Median	278.9	282.5	160.2	170.1	106.1	107.6	50.0	28.2	62.1
Nominal	282.3	282	172.2	172	107.8	108			

For TTC to the stopped lead vehicle, the values for the simulator are typically similar to those at VRTC (see Table 14). This general good correspondence is consistent with what would be expected from the distance data presented above.

Table 14. TTC with Stopped Vehicle Across Critical Points during Lead Vehicle Revealed Event

	SV-to-SLV TTC (seconds)								
Description	Task Instruction		Random Numbers Presented		FCW Alert		VC Concludes		
	VRTC	NADS	VRTC	NADS	VRTC	NADS	VRTC	NADS Eye Tracking	NADS Video Coding
Min	5.070	5.000	2.758	2.880	1.879	1.940	0.319	-1.450	-0.070
Max	5.765	6.210	3.743	3.790	2.325	2.350	1.872	1.330	1.860
Mean	5.412	5.520	3.117	3.330	2.064	2.120	1.030	0.440	1.160
Std Dev	0.165	0.250	0.186	0.190	0.094	0.090	0.466	0.570	0.340
Median	5.410	5.510	3.112	3.330	2.055	2.130	0.927	0.560	1.180
Nominal	5.5	5.5	3.4	3.4	2.1	2.1			

3.2.2 Test Track – Simulator Comparison

3.2.2.1 Visual Commitment

To assess the correspondence visual commitment times between the test track data and the simulator data for the virtual test track course, several measures were examined. These include time to visual commitment, visual commitment duration, and time to visual commitment end from alert. When comparing the time to the start of visual commitment, ideally all of the values across conditions would be the same, indicating roughly comparable groups. The times in the NADS are shorter than those from VRTC, as can be seen in Figure 11. This may indicate a greater willingness to engage in the tasks in the simulated environment compared to the test track. When comparing the visual commitment duration, the data from NADS is similar to data observed on the test track (see Figure 12). The means from the NADS study are consistent with the range of means from the test track, although with a somewhat narrower range. When comparing the end of visual commitment relative to the warning or time the warning would have gone off, the data from NADS shows faster response times and less variance than the VRTC data (see Figure 13). This may reflect the fact that drivers in the NADS study have been looking away longer at the time the warning is triggered due to the faster start of the task.

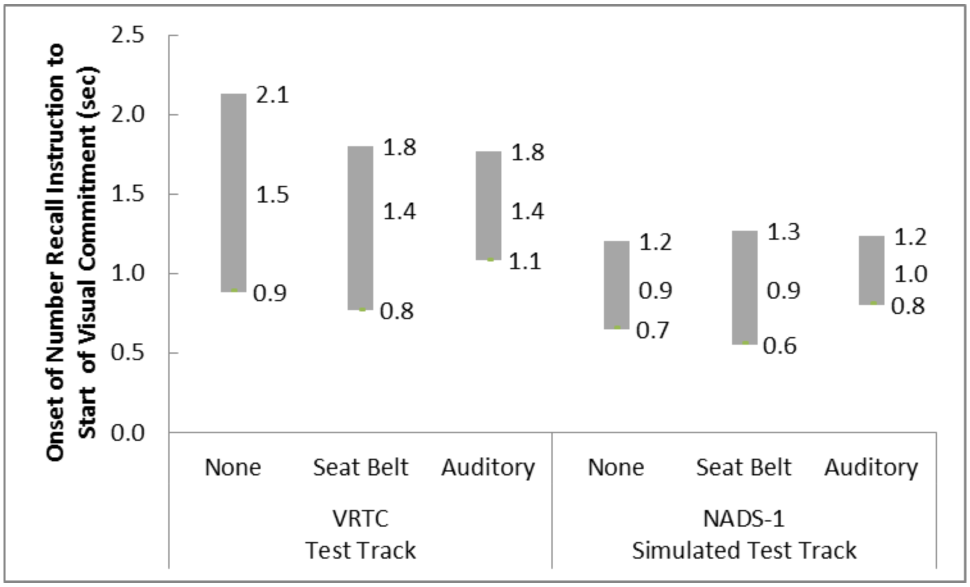

Figure 11. Range and Mean Time to Visual Commitment from Onset of Numbers Task

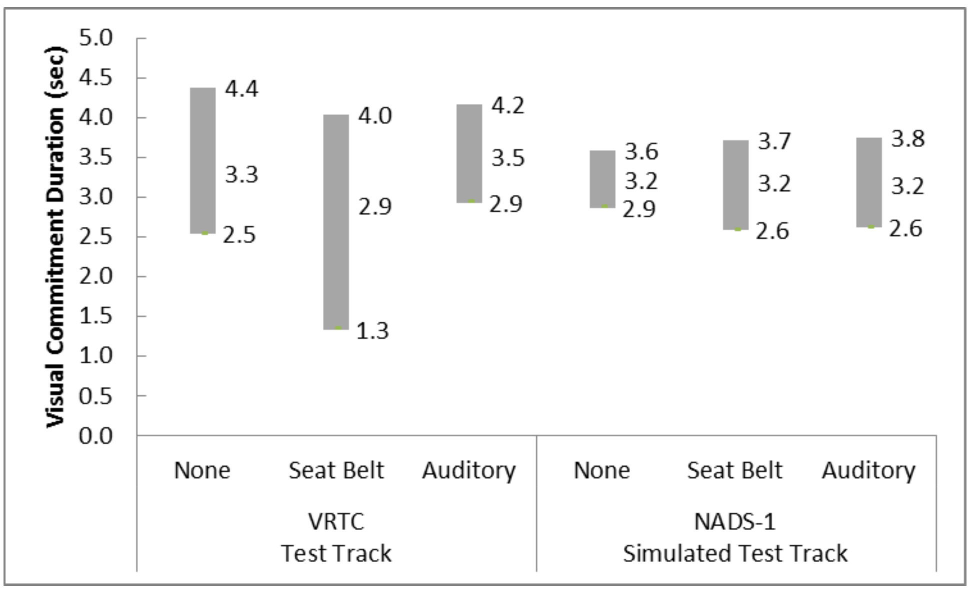

Figure 12. Range and Mean Visual Commitment Duration

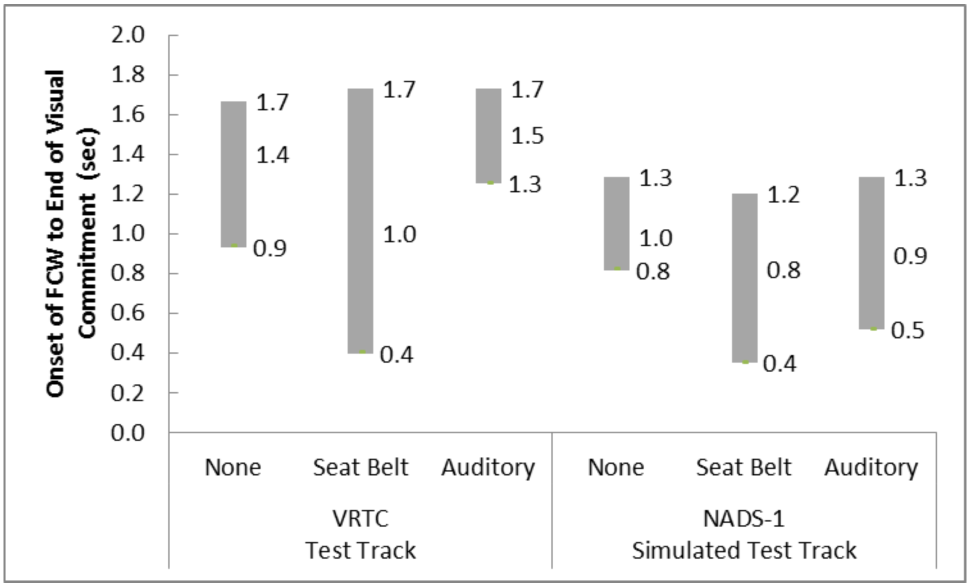

Figure 13. Range and Mean Time to Visual Commitment End from Alert

3.2.2.2 Response

To assess the correspondence response between the test track data and the simulator data for the virtual test track course, several measures were examined. These include time-to-collision at the end of visual commitment, and brake reaction time. When examining TTC at end of visual commitment, the means from the NADS-1 study were greater for all conditions, although the ranges of data fit within the range of data from the VRTC study for the no warning and seat belt condition (see Figure 14). When examining brake reaction time, brake reaction times were shorter on average for the auditory and no warning conditions, but about the same for the seat belt condition (see Figure 15).

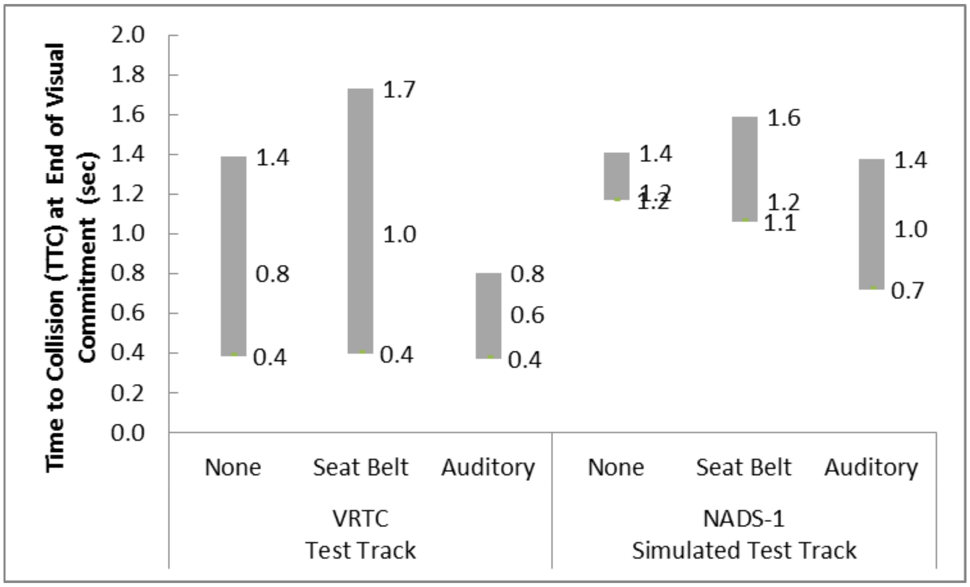

Figure 14. Range and Mean Time-to-Collision at Visual Commitment End

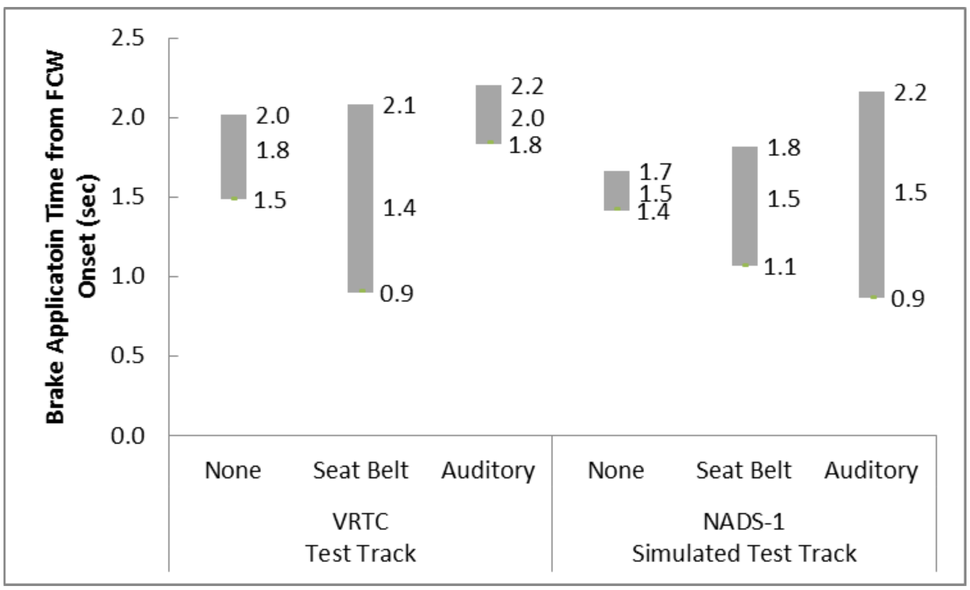

Figure 15. Range and Mean Brake reaction Time

3.2.3 Simulated Test Track – Simulated Road Course Comparison

3.2.3.1 Visual Commitment

To assess the correspondence visual commitment times between the simulated test track and simulated road course, the same visual commitment measures were again examined: time to visual commitment, visual commitment duration, and time to visual commitment end. For time to visual commitment, there was no significant difference between the road course and the test track (p=0.2669) nor any interaction with warning type (p=0.5659). Figure 16 shows the distribution of the data for each warning type on each course. For visual commitment duration, there was no significant difference between the road course and the test track (p=0.8177) nor any interaction with warning type (p=0.1941). Figure 17 shows the distribution of the data for each warning type on each course. For time to visual commitment end from alert, there was no significant difference between the road course and the test track (p=0.7972) nor any interaction with warning type (p=0.3419). Figure 18 shows the distribution of the data for each warning type on each course.

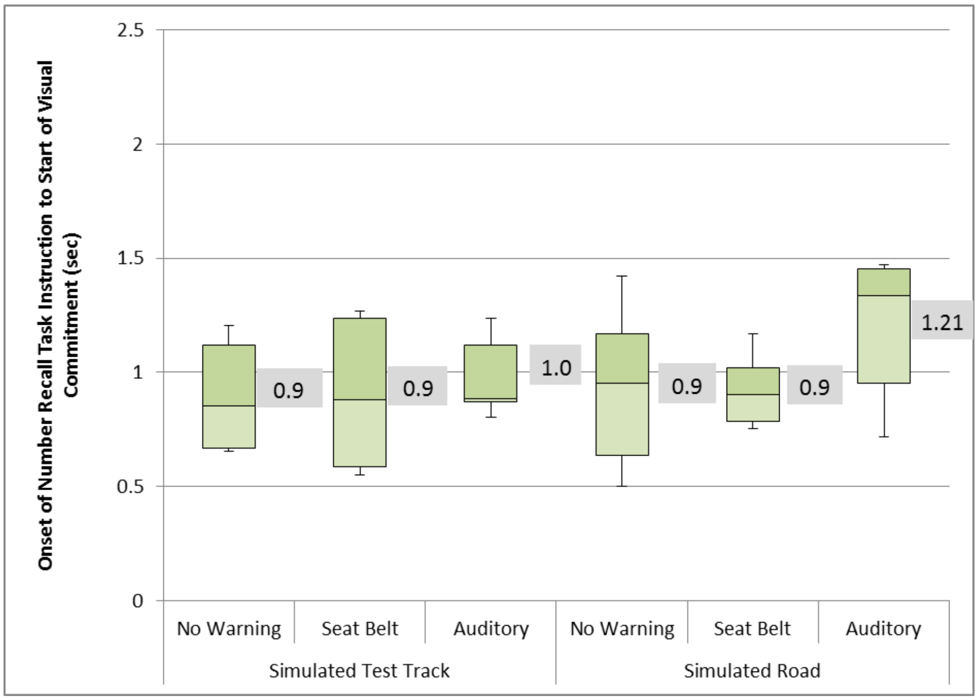

Figure 16. Comparison of Time to Visual Commitment on Simulated Test Track and Road Courses

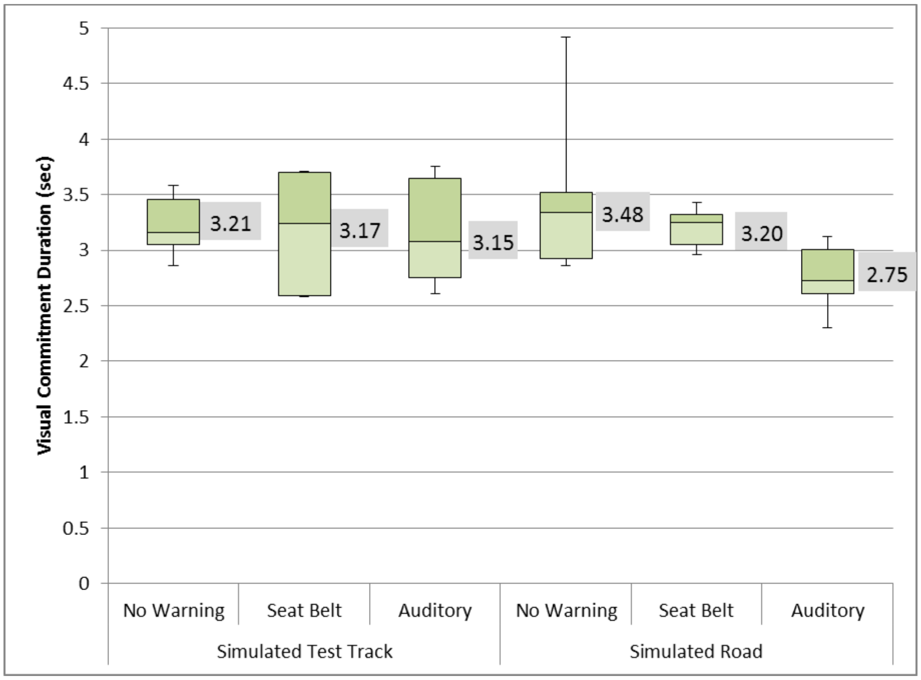

Figure 17. Comparison of Visual Commitment Duration on Simulated Test Track and Road Courses

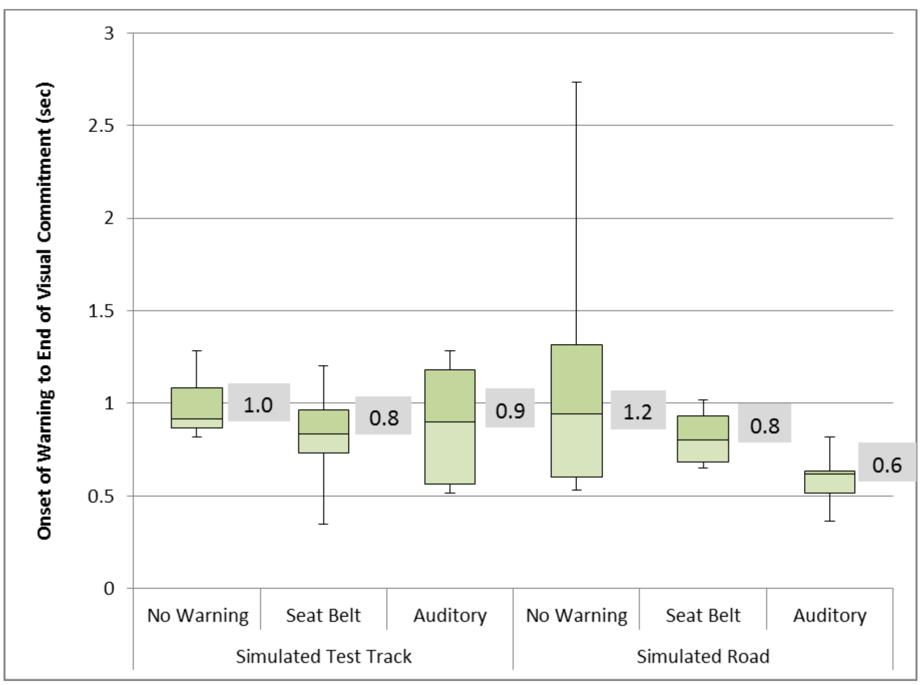

Figure 18. Comparison of Time to End of Visual Commitment from Alert on Simulated Test Track and Road Courses

3.2.3.2 Response

To assess the correspondence response between the simulated test track and the simulated road course, time-to-collision at the end of visual commitment and brake release time were examined. There were no significant effects on time-to-collision at end of visual commitment between the road course and the test track (p=0.6465) nor any interaction with warning type (p=0.3816). Figure 19 shows the distribution of the data for each warning type on each course. There were no significant effects on brake reaction time between the road course and the test track (p=0.8330) nor any interaction with warning type (p=0.9972). Figure 20 shows the distribution of the data for each warning type on each course.

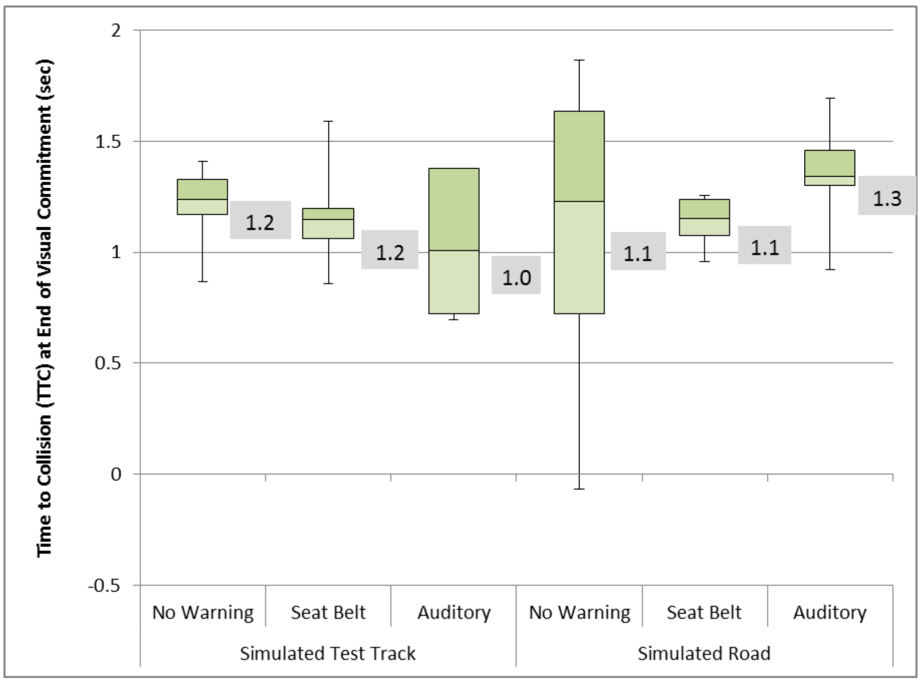

Figure 19. Comparison of Time-to-Collision at End of Visual Commitment on Simulated Test Track and Road Courses

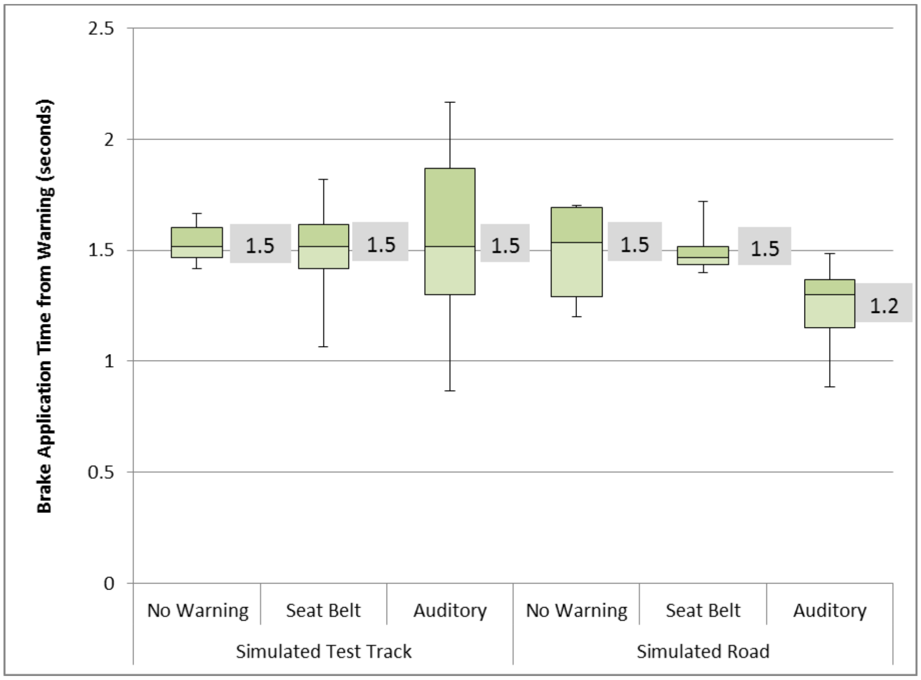

Figure 20. Comparison Brake reaction Time on Simulated Test Track and Road Courses

3.3 **Discussion**

Overall, the performance of subjects on the simulated test track was quite comparable to the performance on the VRTC test track. From a choreography standpoint, the advantages of the simulator actually resulted in a more precise execution of the interaction between the subject and other vehicles. Subjects in the simulator were faster to engage in the numbers task and faster to stop it in response to the alerts, but overall visual commitment duration remained the same between the two environments. Response measures showed similarities between the test track and the simulator, particularly for the no warning and seat belt tensioner conditions. The results suggest that protocols developed on the test track should be able to be translated into the simulator. It also provides hope that the reverse would also be true with simulator scenarios translated to the test track.

When comparing the simulated test track and simulated road environments, results were generally comparable. This was particularly true for the no warning and seat belt tensioner conditions. Although there was no statistical difference, there appeared to be a trend across several measures for a more cautious response from subjects with the auditory alert on the road course compared to the test track environment. Overall, these results point to an opportunity to translate events between road courses and test track in some circumstances if care is taken.

3.4 Protocol Implications

The main aim of this study was to examine how test track and road protocols compare. For FCW events, both test track and road routes seem to be useable for the evaluation of the DVIs for these systems. In light of the desire to examine these system DVIs in a more natural driving environment and the desire to include lane departure events for subsequent studies, a simulated road course may be the best option for comprehensive evaluation of crash warning interfaces.

4 Secondary Task and Incentive Considerations

4.1 Specific Method

The aim of this study was to examine different distraction methods across incentive systems to determine the most effective approach to distracting the participant sufficiently to initiate imminent crash events and for LDW or FCW alerts while also allowing the final protocol to be sensitive to visual alerts. Additionally, this study aimed to determine the role of financial incentive on driver willingness to disengage with secondary tasks when presented with a surprise alert. The protocol included four distraction tasks, three incentive structures, and two alert modalities. Alert onset was held constant at relative to engagement with the number recall task. No LDW system was present. No training on FCW or the alert was provided to participants prior to their drive. Participants were not exposed to the FCW alert during their drive prior to the single FCW event at the end of the drive.

4.1.1 Hypotheses

There were three primary hypotheses for this preliminary study:

- There will be significant differences between distraction tasks in terms of engagement and degree of visual commitment.
- There will be significant differences in engagement with the distraction task across the levels of incentive.
- For the FCW event, drivers reach the end of visual commitment more quickly when no financial incentive is provided compared to the two conditions with financial incentives.

4.1.2 Experimental Design

This preliminary study combined two experimental designs into a single simulator experiment as illustrated in Table 15. The first experimental design was a 3x4 mixed factorial with three levels of incentive structure as the between-subject variable and four levels of distraction task as the within-subject variable. The second experimental design was a 3x2 between-subject design presenting two levels of alert modality, audio and seat belt, at each of the three levels of incentive structure. The final distraction task in the drive was paired with a decelerating lead vehicle event and an FCW alert

Three incentive structures were used, although total potential compensation was the same for all groups: high base pay ($27.50) with low additional financial incentives (up to $17.50), low base pay ($17.50) with high additional financial incentives (up to $27.50)[2], and a fixed sum compensation ($45.00) with no incentive component[3].

Four distraction tasks were presented as within-subject variables: number recall, bug, message reading, and menu search. These tasks were described in Chapter 2 on page 13.

Table 15. Preliminary Study 2 Experimental Conditions

		Experimental Design 1				Experimental Design 2	
		Distraction Task				Final Event Alert Modality	
		Number Recall	Bug	Message Reading	Menu Search Selection	Audio	Seat Belt Tensioner
Incentive Structure	High base	8 participants				4 participants	4 participants
	Low base (VRTC)	8 participants				4 participants	4 participants
	No incentive (NADS)	8 participants				4 participants	4 participants

4.1.3 Dependent Measures

The following dependent measures were examined for the distraction task/incentive comparison:

- Time to visual commitment
- Time to end of visual commitment
- Duration of first visual commitment
- Engagement duration

[2] Based on the approach used in VRTC study (Forkenbrock et al., 2011).

[3] Based on the approach used in prior CWIM work completed at NADS (Lerner et al., 2011; Brown et al., 20XX)

- Visual commitment duration
- Glances back to roadway
- Change in velocity during visual commitment
- Average lane position during visual commitment
- Standard deviation of lane position
- Maximum change in lane position

Additionally, the following measures were examined for the final event:

- Time to end of visual commitment (from warning)
- Time-to-collision at the end of visual commitment
- Collision

4.1.4 Participants

Twenty-four participants completed all study procedures successfully. Thirty-two participants were enrolled, and nine participants were dropped for the reasons documented in Table 16.

Table 16. Participants Enrolled by Condition

	Auditory						Seat Belt Tensioner						Total
	Fixed Sum		High Base		Low Base		Fixed Sum		High Base		Low Base		
	F	M	F	M	F	M	F	M	F	M	F	M	
Enrolled	2	4	3	3	2	3	3	4	2	3	2	2	32
Looked Back								2		1			3
Seat Belt Didn’t fit							1						1
Simulator Sick													0
Simulator Issues		2	1	1		1							5
Completed	2	2	2	2	2	2	2	2	2	2	2	2	24

4.1.5 Apparatus

Three displays were mounted in the simulator cab for this study: a monitor to display the number recall and bug tasks located to the participant's right, a display for the message reading and menu search task located down and to the right of the participant, and a headway display located near the participant's line of vision.

4.1.5.1 Distraction Tasks

The four distraction tasks described in Section 1 were used in this experiment.

The number recall task and the bug task were combined on a single display for this study. Timing for the number task remained consistent with the task used in the first preliminary study. The display for these tasks was mounted on the rear of the passenger seat headrest and adjusted for each participant so that the display was located at an angle of at least 90 degrees to the right of the forward looking position and required the participant to extend his/her arm to reach the display to engage in the bug task. The display was positioned so that it was outside the SAE specification for an in-vehicle display by ensuring that the viewing angle exceeded 30 degrees down from the forward view. The appendix in Section 25 provides additional detail on how the display was positioned. The number recall task implemented for this study is shown in Figure 21, and the bug task is shown in Figure 22.

Figure 21. Number Recall Task

Figure 22. Bug Task

The message reading task as implemented for this study is shown in Figure 23, and the menu selection task is shown in Figure 24.

Figure 23. Message Reading Task

Figure 24. Menu Selection Task

4.1.5.2 Headway Display

This display was the same as the one used in the first preliminary study and documented in Chapter 3.

4.1.6 Experimental Procedures

The general experimental procedures were described in Section 2. Study-specific procedures for this experiment are documented in the following sections.

4.1.6.1 Experimental Ruse and Deception

Participants were told that the goal of the research was to evaluate several new in-vehicle equipment designs and technologies, when in fact their interaction with the distraction tasks and response to a surprise FCW warning was being evaluated.

4.1.6.2 Headway

Participants were instructed to maintain a headway of 185 feet ± 15 feet.

4.1.6.3 Training

Three different training presentations were used for this study – one for each of the incentive conditions. Each provided detail on the distraction tasks to be performed. They differed in the description of the incentive pay, which was based on the experimental conditions for each participant.

Additionally, participants practiced with the distraction tasks before going into the simulator to become comfortable performing each task (see the Appendix in Section 26). Participants were prompted to engage with each of the tasks consistent with the method used in the simulator. They were asked to practice until they could perform each task successfully. The criterion for each task is documented in Table 17 .

Table 17. Criterion for Distraction Task Training

Task	Criterion
Bug	No time in the red zone
Number Recall	All five numbers correct with no sequence errors
Menu Search	Correct selection without an error
Message Reading	Read at least 80% of sentence without an error

4.1.6.4 Compensation

Three compensation schedules were used for this study based on the incentive condition. For the fixed compensation condition, the total compensation was $45 with no incentive pay. For the high base condition, the base compensation was $27.50 with a total compensation of up to $45. For the low base condition, the base compensation was $17.50 with a total compensation of up to $45.

The base pay was pro-rated. If participation lasted less than 1 hour, participants earned $10. If participation lasted for over 1 hour, participants earned the full base pay. The incentive was based on the participants' ability to correctly complete the distraction tasks and maintain a safe headway.

4.1.6.5 Incentive

For headway maintenance, participants received incentive pay based on how well they were able to maintain a headway of 185 feet. Incentive compensation was available based on successfully staying within 15 feet of this target (170 to 200 feet) based upon the percentage of time in this range. Maximum incentive pay for each of the four segments of the drive is documented in Table 18 for each condition. Maximum headway incentive pay for the whole drive was $5.38 for the high base condition and $8.46 for the low base condition. If participants kept within the range for at least 80% of the segment, the participant received the full incentive compensation for that segment. If participants were not able to keep within the range, their incentive compensation was scaled based on the percentage of time that the headway was in the correct range.

For distraction tasks, participants received incentive pay based on their performance on each task. The amounts available for each occurrence of each task by incentive condition are included in Table 18. Minimum incentive compensation for any given task was $0.00.

Table 18. Preliminary Study 2 Incentive Structure

	Fixed	High Base	Low Base
Headway (4)	N/A	\$1.35	\$2.12
Number Recall (5)	N/A	\$0.61	\$0.95
Bug (4)	N/A	\$0.76	\$1.19
Message Reading (4)	N/A	\$0.76	\$1.19
Menu Selection (4)	N/A	\$0.76	\$1.19

To determine the incentive compensation for each task, the following equations were used:

$$\begin{Bmatrix} \$0.122, if\ High\ Base \\ \$0.19, if\ Low\ Base \end{Bmatrix} \times \#\ Correct - \$0.07 \times Sequence\ Error \qquad \text{(Number Recall)}$$

$$\begin{Bmatrix} \$0.76, if\ High\ Base \\ \$1.19, if\ Low\ Base \end{Bmatrix} \times Green\ Zone\ \% - \$0.40 \times (4\ \times Red\ Zone\ \%) \qquad \text{(Bug)}$$

$$\begin{Bmatrix} \$0.76, if\ High\ Base \\ \$1.19, if\ Low\ Base \end{Bmatrix} \times \%\ of\ Words\ Read - \$0.25 \times \#\ of\ Incorrect\ Words \qquad \text{(Message Reading)}$$

$$\begin{Bmatrix} \$0.76, if\ High\ Base \\ \$1.19, if\ Low\ Base \end{Bmatrix} \times \begin{Bmatrix} 1, if\ Correct \\ 0, if\ Incoreec \end{Bmatrix} - \$0.25 \times \#\ of\ Incorrect\ Selections \qquad \text{(Menu Selection)}$$

Incentive feedback was provided to participants at the end of each segment and combined feedback for both tasks. Additional details can be found in the Appendix in Section 24.

4.1.7 Scenarios

One driving scenario with two orders of distraction tasks was used for this study. A map showing the locations of the distraction tasks is provided in Figure 25. The scenario had a practice segment followed by four segments in which participants maintained headway and engaged in the distraction tasks. The order of the distraction tasks was blocked using a Latin Squares approach to balance the presentation of the distraction tasks across the drive (see Table 19). Throughout the drive segments, participants followed a lead vehicle at a nominal headway of 185 feet with a nominal speed of 55 mph. For the final event, which was always the number recall task, a lead vehicle began to rapidly decelerate while the driver was engaged in the task, resulting in an FCW alert. The alert was timed to occur one second after the first number appeared.

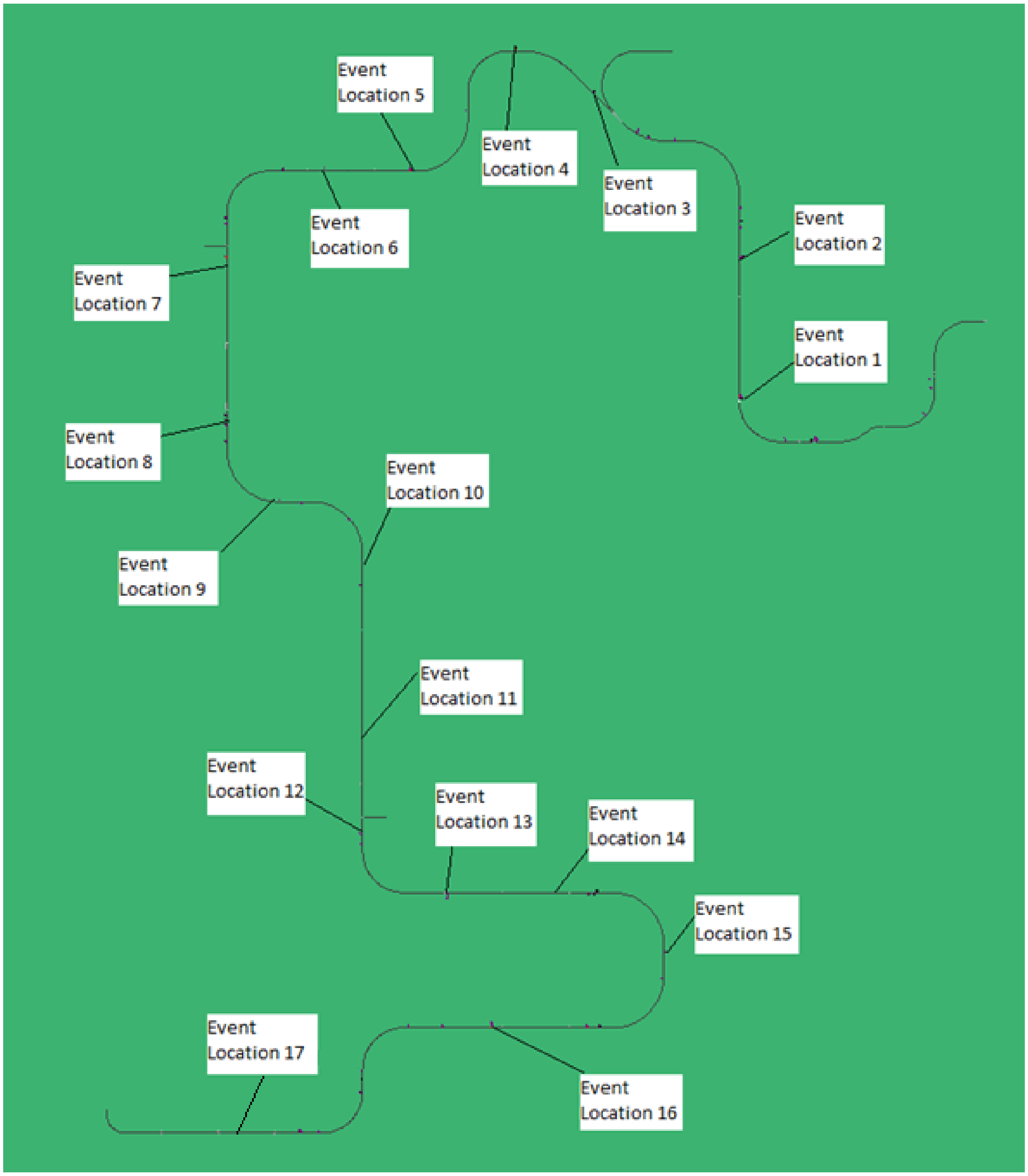

Figure 25. Map of the Driving Database for Preliminary Study 2

Table 19. Scenario Order of Events

Event Number	Event Order 1	Event Order 2
1	Bug Task 1	Menu Selection 1
2	Number Recall 1	Number Recall 1
3	Message Reading 1	Bug Task 1
4	Menu Selection 1	Message Reading 1
5	Message Reading 2	Bug Task 2
6	Menu Selection 2	Message Reading 2
7	Bug Task 2	Menu Selection 2
8	Number Recall 2	Number Recall 2
9	Menu Selection 3	Number Recall 3
10	Message Reading 3	Menu Selection 3
11	Number Recall 3	Message Reading 3
12	Bug Task 3	Bug Task 3
13	Number Recall 4	Message Reading 4
14	Bug Task 4	Bug Task 4
15	Menu Selection 4	Number Recall 4
16	Message Reading 4	Menu Selection
17	Number Recall 5	Number Recall 5

4.1.8 Analysis Plan

Data from this study were reviewed in order to determine what incentive should be used, if any, and what distraction tasks best meet the aims of the project in developing a sensitive protocol. Thirty-two participants were enrolled in the study and data collected from 31 of those participants. For the initial analysis looking at the four instances of the four distraction tasks (bug, number recall, menu selection, and message reading) under the three incentive conditions (no incentive, high base pay, and low base pay), data from all 31 participants were included. For the next analysis looking at willingness to disengage from the distraction task in response to an alert, only the twenty-four that had valid data for the final event were included.

The initial analysis focused on initial engagement with the task (time to begin visual commitment, duration of visual commitment, time from start of task to end of first visual commitment, and looks back to the road), total engagement with the task (total duration, whether they looked back to the road way), and effect on driving performance (initial headway, change in speed, standard deviation of lane position, change in lane position, and lane departures).

The second analysis focused on duration of initial visual commitment, time to end of visual commitment from alert and whether there was a collision.

The recommendations based on this analysis and supporting information are provided below.

4.2 Results

Our recommendation for incentive structure was for no financial incentive for performance to be provided. Our rationale was that there were no significant effects of incentive across the two analyses. What trends were present indicated a potential dis-benefit associated with increasing incentive pay. We recommended use of Number Recall Task for both FCW and LDW events. Our rationale was that the number recall task was used successfully in the VRTC study for FCW events. Supporting evidence for these recommendations is provided in the following sections on engagement and driving performance. Included in the section are results that directly informed our recommendations.

4.2.1 Task and Incentive Effects on Engagement

Engagement is a key consideration in the selection of a distraction task. Drivers must quickly engage in the task and stay engaged until an alert is presented to allow the orchestration of scenario events. There were no significant effects of incentive on engagement. Engagement did differ across the four tasks.

How quickly engagement began following the end of the task prompt is revealed by time to visual commitment, Figure 26. The short blue lines indicate the beginning of the task. The number recall and menu tasks both showed consistent engagement prior to the beginning of the task by the third trial. Once engagement has begun, drivers must stay engaged while scenario events unfold.

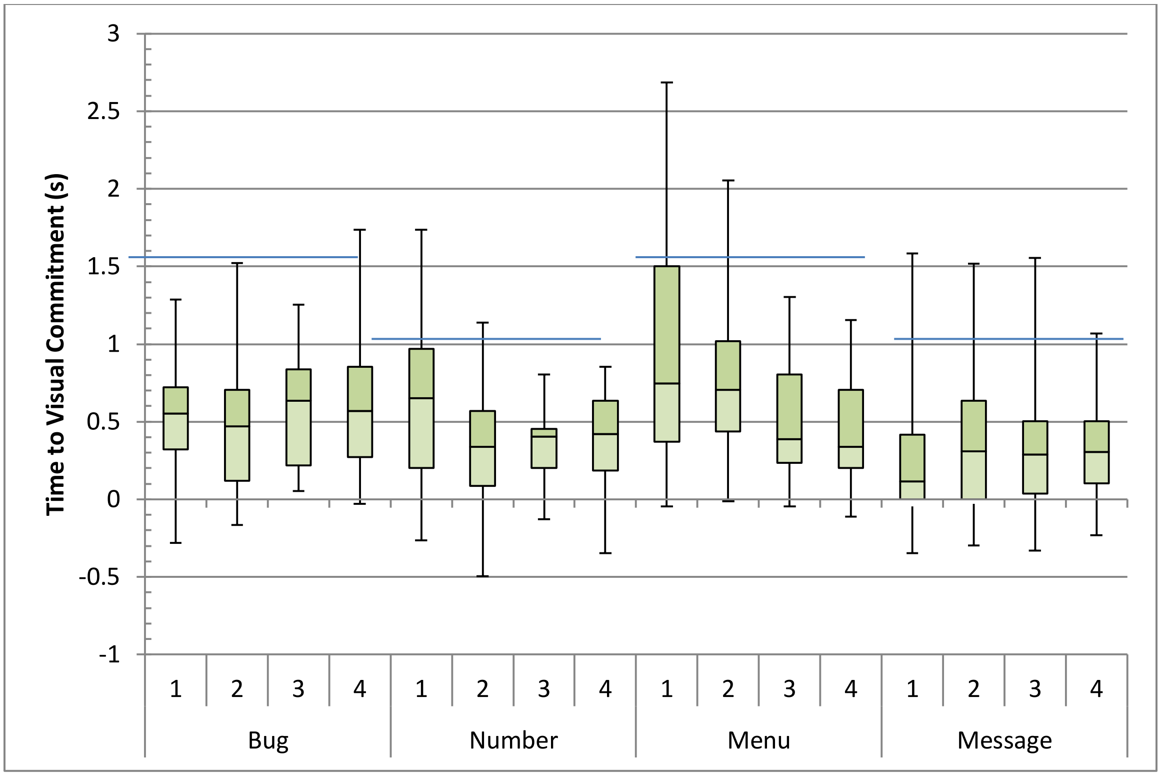

Figure 26. Time to Visual Commitment

The start of the task to the end of the first visual commitment for all four tasks is shown in Figure 27. The red horizontal line represents the time at which the tasks ends. For the number recall task, the median value for all four trials is greater than the end of task time, and for the second, third and fourth trials the 1st quartile value is greater than 2 seconds which is after the final number has been displayed. It can also be observed the at 1st to 3rd quartile range for the number recall task is much smaller on the last three trials than it is for any of the other tasks.

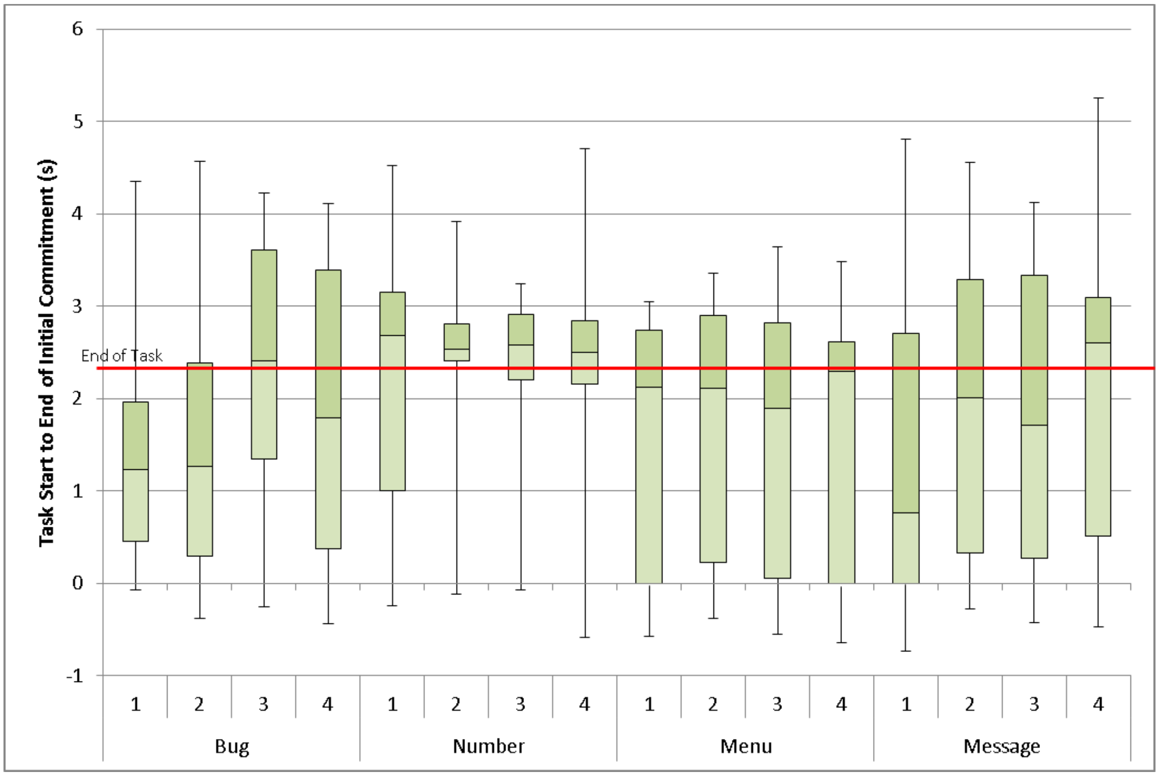

Figure 27. Time from Start of Distraction Tasks to End of First Visual Commitments by Task and Trial

Some drivers looked back to the forward roadway prior to the end of the tasks as indicated by the end of initial visual commitment. The number recall task had the fewest number of full glances back to the roadway. Figure 28 shows the number of times during the first visual commitment to the distraction tasks that the driver moved their visual attention toward the road without ending their visual commitment, “attempted glances”. It should be noted that drivers were more likely to engage in this behavior when performing the number recall task than with the other tasks. Although this is concerning, the frequency is reduced by the third trial and is only 10% greater than the other three tasks (25% versus 15%) when the values stabilize for the third and fourth trials. It should be noted that these do not constitute an end to the visual commitment and are of very short durations such that the driver does not get much, if any, visual information from the forward roadway.

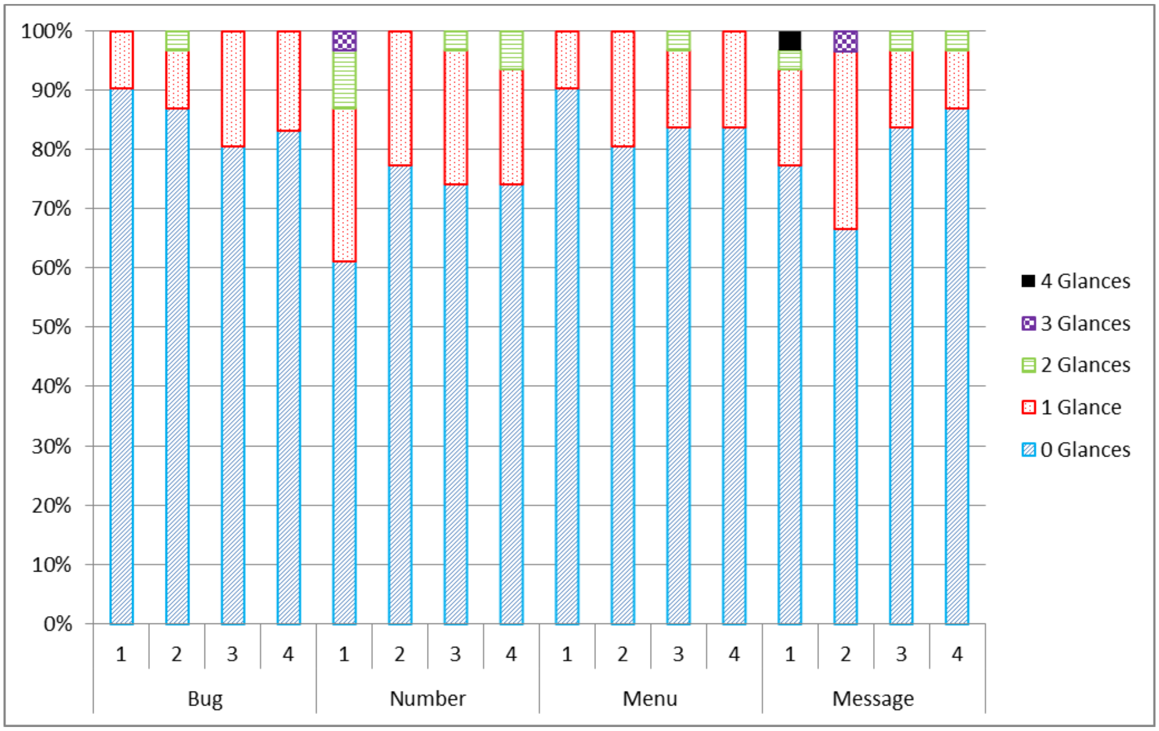

Figure 28. Proportion of Drivers Who Attempt Zero to Four Glances Forward during the First Visual Commitment

4.2.2 Task and Incentive Effects on Driving Performance

The effects on driving performance inform whether the same or different distraction tasks should be used in FCW and LDW scenarios. The impact on lane position variability and percent of drivers who depart the lane during the task are shown in Figure 29 and Figure 30. Although a significant proportion of drivers departed the lane regardless of the task, the number recall task resulted in the fewest lane departures and smallest standard deviations of lane position. Lane stability is useful in orchestrating both the FCW and LDW events.

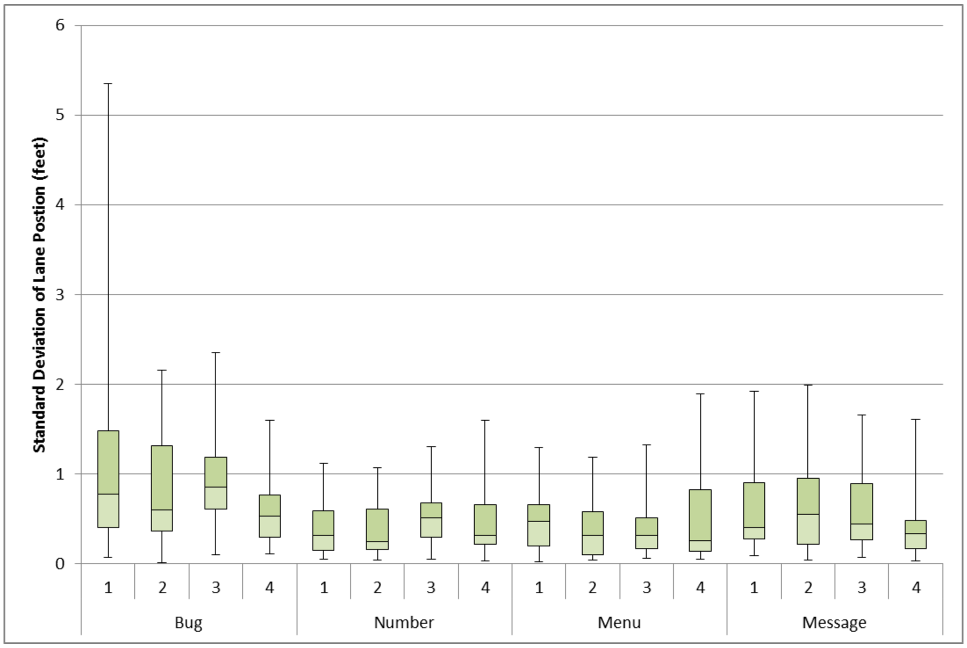

Figure 29. Standard Deviation of Lane Position by Task and Trial

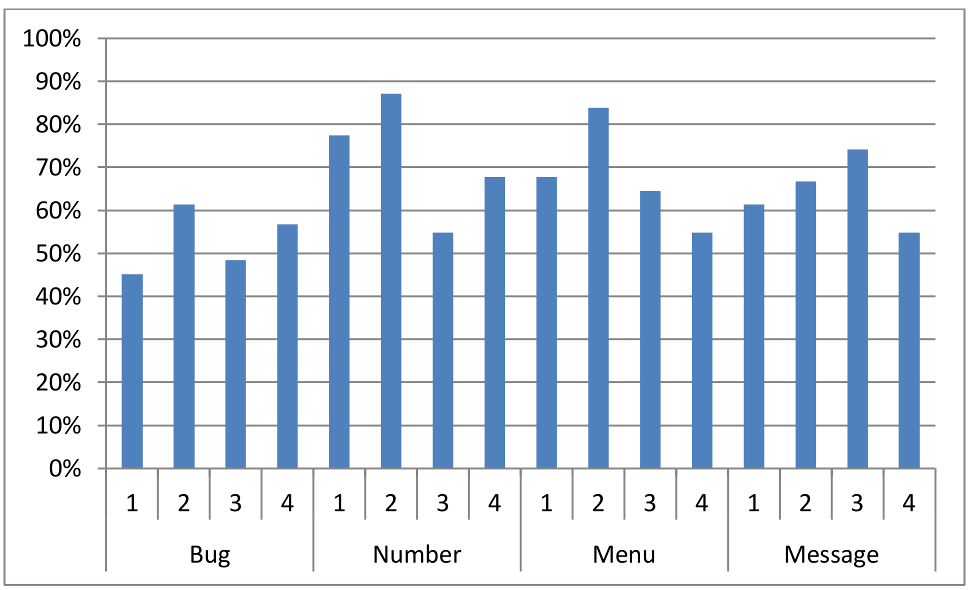

Figure 30. Proportion of Drivers Who Did Not Depart their Lane

4.2.3 Disengagement from Task in Response to Alert

Across the incentive structures, the trend was for initial visual commitment time to increase with increasing performance incentive (see Figure 31 in which the means are shown within the box plots). Given there was no effect on time to initial visual commitment associated with the different incentive structures, the trend for longer initial commitment duration with higher incentive suggests a difference in the end of visual commitment.

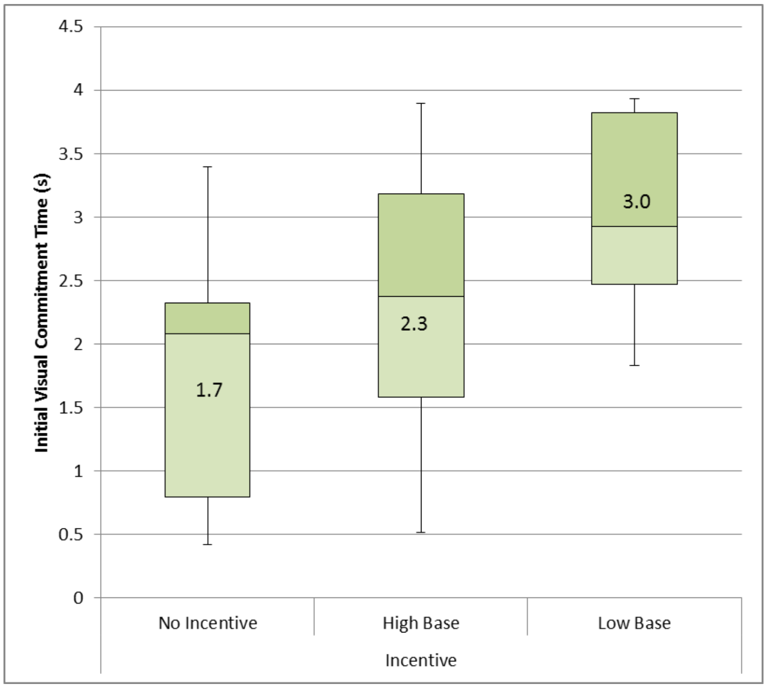

Figure 31. Initial Visual Commitment Duration by Incentive for Surprise Braking Event

The mean time to visual commitment end from the alert is presented in Figure 32 within the box plots for each incentive structure. The higher mean (1.7s) for the low base condition indicates the higher incentive pay may result in drivers' have less willingness to disengage in the task when they have received an alert. The other two conditions, no incentive and high base, had the same mean.

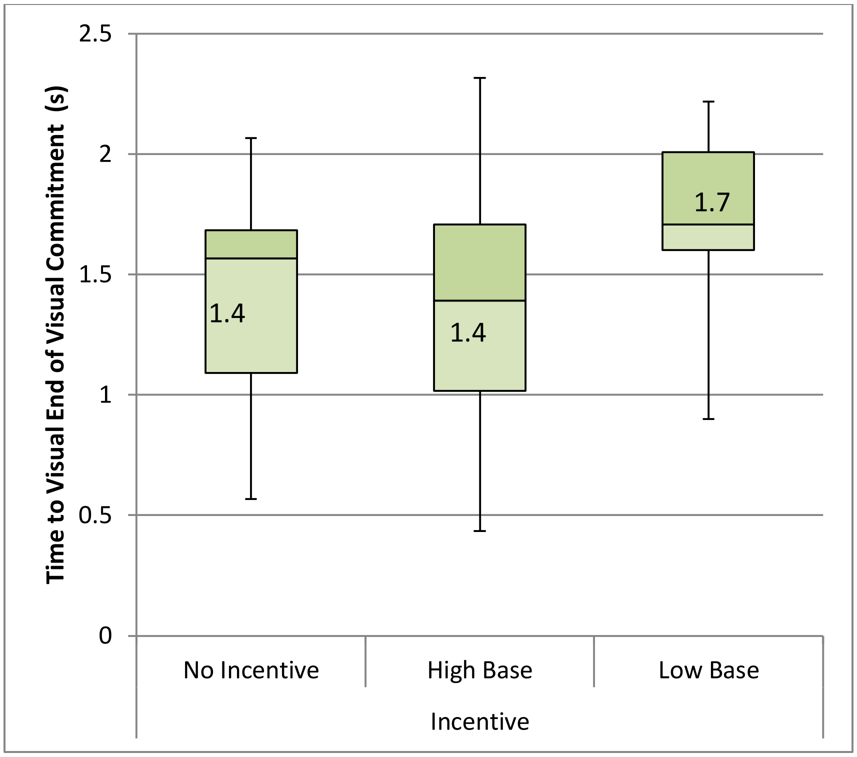

Figure 32. Time to Visual Commitment End from Alert

4.3 Discussion

When comparing the number recall task with the other tasks studied, there are benefits and drawbacks to each. The number recall tasks performed best when considering the frequency with which driver's visual commitment ended after the task was complete. Although drivers engaged in the number recall task had more "attempted glances" to the forward roadway without ending their initial visual commitment to the task, this is by far outweighed by the longer start of task to end of visual commitment time. Additionally, the number task leads to the greatest stability in lane keeping and fewest lane departures, which will make it easier to initiate our forced lane departures.

When considering incentive structure, longer initial glances reflect a shift in driver willingness to stay engaged with secondary tasks, which by itself is not a significant problem. However, when combined with longer times to end visual commitment in response to the warning, it indicates that the incentive may be causing the driver to ignore the warning which could result in a bias in the evaluation of the warning DVI. Additionally, there was also no significant effect of incentive on headway maintenance. Given there was no significant effect of incentive structure on initial visual commitment, the no incentive structure offers the best condition for evaluating various warning DVIs.

4.4 **Protocol Implications**

4.4.1 Distraction Tasks

It is important to remember when considering the distraction tasks that the aim of these tasks is to have the subject engage in an activity that is relatively rare in the real world so that we can assess the utility of DVIs for crash warning systems in situations where they are most likely to be needed. To that end, the protocol will require the driver to disengage from the driving task long enough for the lateral and longitudinal events to be fired; however, the timing requirement is generally longer and more consistent for the longitudinal event. When identifying the best task, we must consider not only the mean duration of the task but also the variance and the relationship of the distribution to the time required to initiate events. When considering these four tasks, all tasks resulted in drivers beginning the task within the expected window. When comparing engagement with the task, the numbers task better meets the need of getting and keeping the drivers' eyes off the road due to the smaller variance and the greater portion of the distribution that keeps their eyes off the road until the task ends. The findings of this task suggest that the numbers task is the best fit of those tested and should be used in the protocol.

4.4.2 Incentive

The use of incentives in driving research has the potential to encourage greater engagement with the incentivized task(s) and to attempt to match some of the inherent motivation that drivers experience in the real world. The risk is that the monetary incentive will instead incentivize drivers to behave in ways that are not consistent with what would be expected in the real world, such as ignoring safety warning alerts to finish a secondary task. The evidence from this study does not support the idea that incentive improves engagement with the task in such a manner that would improve reliability of collecting data while drivers are distracted without causing drivers to delay response to the alerts.

5 System Training and Exposure

5.1 Specific Method

The aim of the first main study was to examine familiarity with the FCW and LDW systems through different levels of training on the system and associated alert modality and whether or not participants were exposed to the alert in the vehicle prior to receiving it during an FCW or LDW event. Late alert onset was held constant for FCW and LDW alerts. Three alert modalities were presented to different groups of participants.

5.1.1 Hypotheses

There were two main hypotheses for this study:

- There will be greater protocol sensitivity between warning system DVI for drivers with no prior knowledge and no prior exposure.
- The protocol will show more sensitivity for DVI differences during Event 1 than during Event 2.

5.1.2 Experimental Design

The experimental design for this study was a 2x2x3x2 mixed between/within-subject design with two between-subject levels of awareness, two between-subject levels of exposure, three between-subject levels of alert modality (see Table 20) and two within-subjects levels of event. Two levels of awareness of the systems were provided to participants during the briefing portion of the experimental procedures. The first level was no awareness and the second was training on material similar to that included in the owner's manual of a vehicle that is equipped with an FCW system.

The two levels of exposure were no exposure prior to the warnings and exposure at the beginning of the drive. The choreographed exposure was implemented during the first few minutes of the drive by instructing participants to approach a lead vehicle until they experienced the FCW alert and asking the participants to drive toward the lane lines until they experienced the LDW alert.

The three levels of alert modality were haptic, auditory, and haptic/active. For the FCW system, these were seat belt tensioner, repeated beeps, and brake pulse. For the LDW system, these were steering wheel vibration, acoustic alert from the NADS LDW, and steering wheel torque.

The two levels of event were first presentation and second presentation for the FCW and LDW events.

Table 20. Main 1 Experimental Design

		Prior Exposure					
		Yes			No		
		Haptic	Auditory	Haptic Active	Haptic	Auditory	Haptic Active
Awareness	Training	8 participants	8 participants	8 participants	8 participants	8 participants	8 participants
	No Training	8 participants	8 participants	8 participants	8 participants	8 participants	8 participants

5.1.3 Dependent Measures

The following measures were analyzed for the FCW and LDW events:

- Time to end of visual commitment from warning
- Duration of first visual commitment
- Engagement duration
- Visual commitment duration
- Glances back to roadway
- Time-to-collision at the end of visual commitment
- Collision
- Minimum time to collision
- Adjusted minimum TTC
- Brake reaction time
- Maximum lane exceedance
- Area of lane exceedance
- Duration of lane exceedance
- Steering reaction time

5.1.4 Participants

Ninety-six participants completed all study procedures successfully. One hundred thirty-eight participants were enrolled, and forty-two withdrew or were dropped for the reasons documented in Table 21.

Table 21. Participants Enrolled by Condition

	No Training												Training												
	No Exposure						Exposure						No Exposure						Exposure						
	Haptic		Auditory		Haptic Active		Haptic		Auditory		Haptic Active		Haptic		Auditory		Haptic Active		Haptic		Auditory		Haptic Active		
	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	Total
Enrolled	6	4	10	5	6	4	8	8	4	4	7	5	5	8	5	7	5	8	6	4	4	5	6	4	138
Withdrew			1				1				1					2									5
Simulator Sick			2		1						1			1				1	1						7
Short Visual Commit(s)	2		1				1					1	1		1			1					1		9
No FCW Event			2	1	1		1										1	1							7
Didn't Engage with Tasks							1																		1
Medical Concerns														1					1						2
Scheduling Issues											1											1			2
Simulator Issues								4						2		1		1					1		9
Completed	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	96

5.1.5 Apparatus

Two displays were mounted in the simulator cab for this study: a monitor to display the numbers task located to the participant's right, and the headway display located near the participant's line of vision.

5.1.5.1 Distraction Tasks

The number recall task was the same task used in Preliminary Study 2. The description of this task is provided in Section 4.1.5.1.

5.1.5.2 Headway Display

The headway display was mounted on the dashboard centered 4 ½ inches to the right of the forward line of sight of the participant (see Figure 33).

Figure 33. Revised Headway Display Location

The headway display used in the prior two studies was updated based on the results of the first two studies. The display provided an analog representation of the accuracy of the headway maintenance. The revised display is illustrated in Figure 34. A close-up photo of the display is provided in Figure 35

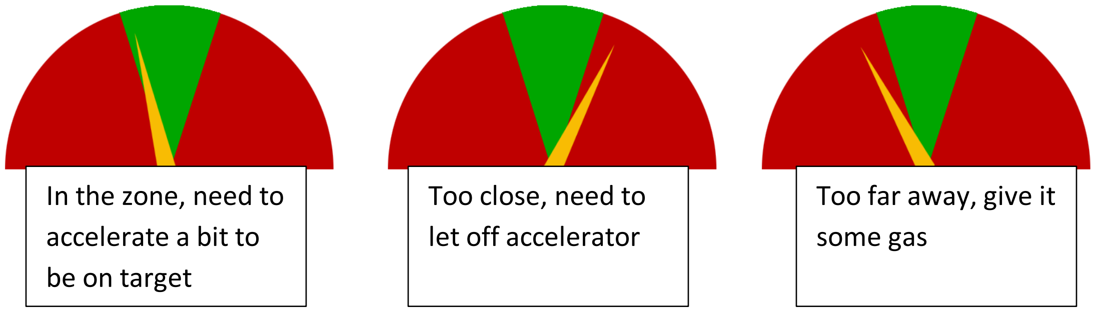

Figure 34. Illustration of Revised Headway Display

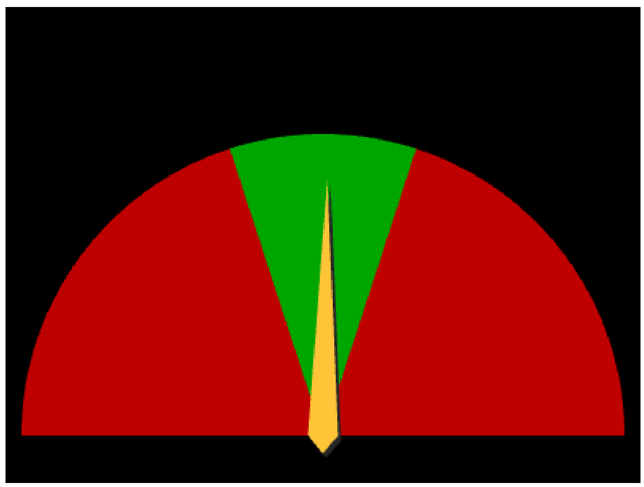

Figure 35. Representation of Headway Display as Implemented

5.1.6 Experimental Procedures

The general experimental procedures were described in Section 2. Study-specific procedures for this experiment are documented below.

5.1.6.1 Experimental Ruse and Deception

Participants were told that the goal of the research was to evaluate several new in-vehicle technologies, when in fact their response to surprise LDW and FCW events was being evaluated.

5.1.6.2 Headway

Participants were instructed to maintain position in the green zone of the headway display provided.

5.1.6.3 Training

Two different training presentations were used for this study based upon the experimental conditions. Each provided detail on the distraction tasks to be performed. They differed in the description of systems present in the car based on the experimental conditions for each participant.

Additionally, participants practiced the number recall task before going into the simulator to become comfortable with performing the task. Participants were prompted to engage with the task consistent with the method used in the simulator. They were asked to practice until they could perform the task successfully. The criterion for the number recall task is documented in Table 22.

Table 22. Criterion for Distraction Task Training

Task	**Criterion**
Number Recall	All five numbers correct with no sequence errors

5.1.6.4 Compensation

Compensation for this study was selected based on the results of the prior study. Base compensation was set at $45. The base pay was pro-rated. If participation lasted less than 1 hour, participants earned $10. If participation lasted for over 1 hour, participants earned the full base pay.

5.1.7 Scenarios

The driving database used for this study was the same as used for Preliminary 2; however additional task locations were added, as shown in Figure 36, and all tasks were the number recall task.

5.1.8 Analysis Plan

After verification of the data, one primary analysis was conducted to address the hypotheses for both the FCW and LDW events. The analysis focused on the main effects of awareness and exposure across the three levels of system. The analysis also focused on which experimental configuration allows for the greatest sensitivity in identifying differences between system DVIs. The primary measures of interest were driver’s initial response, including time to end of visual commitment, and reaction time. The aim was to identify which levels of awareness and exposure should be used in the protocol.

The outcome of this study was an understanding of how different levels of familiarity affect the evaluation of crash warning DVIs, and the selection of levels of familiarity that will be used for subsequent studies and in the final protocol.

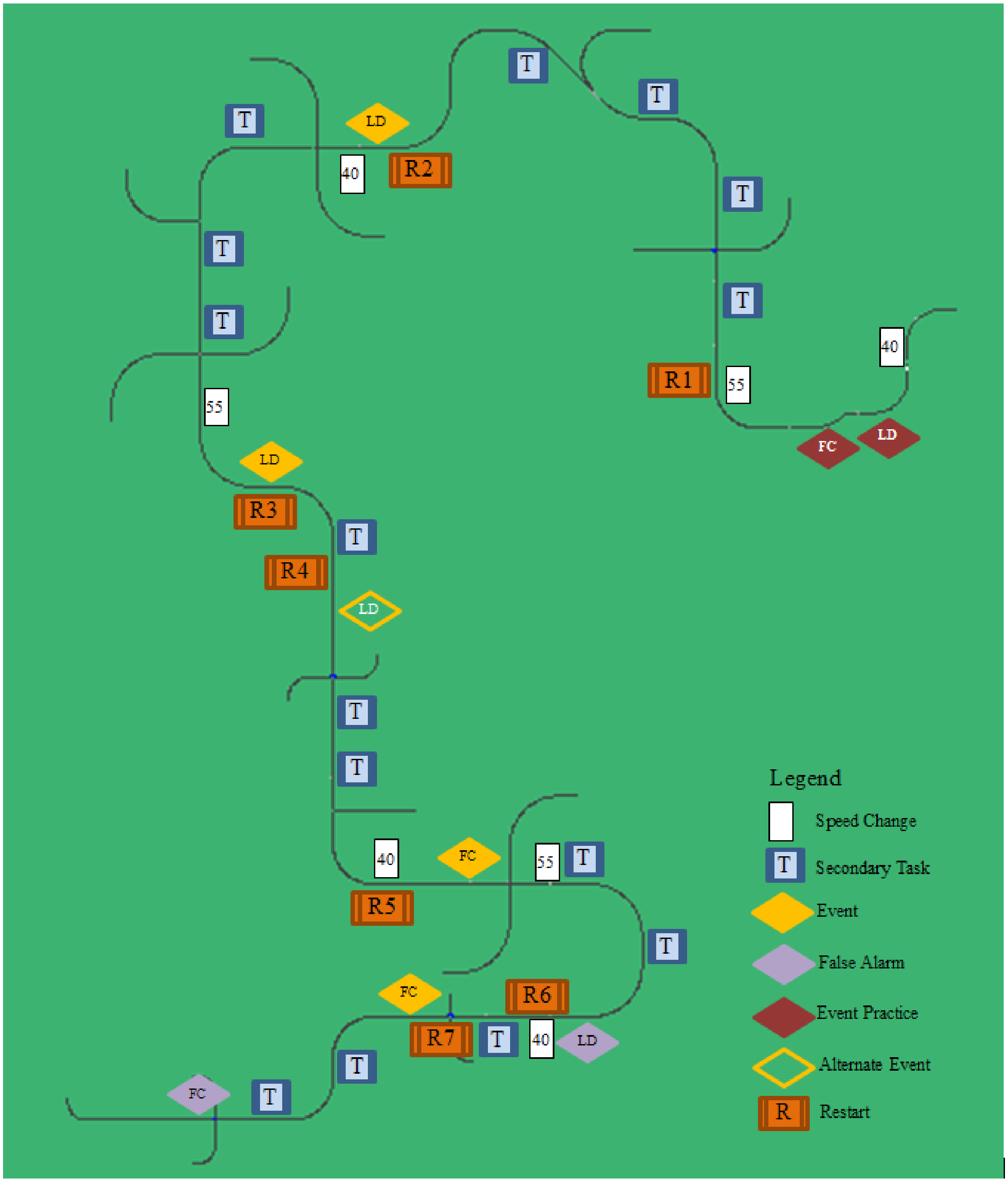

Figure 36. Main 2 Road Network with Task and Event Positions

5.2 Results

Our recommendation for whether to make subjects aware of the presence of the system before they experience it or to provide them with prior exposure to the system before the first critical event were for no training but with prior exposure. The following results form the basis of that recommendation.

5.2.1 Lane Departure Events

When looking at the two key endpoints for response to the alert for lane departure events, there were no effects associated with awareness of the system or prior exposure to the system. Time to the end of visual commitment was not significantly different for either awareness (p = 0.5697) or for exposure (p=0.0985); however there was a significant three-way interaction between exposure, gender and warning type (p=0.0413). There were no interactive effects for awareness with warning type for time to end of visual commitment. As can be seen in Figure 37, on average, prior exposure leads to a longer response time than with no exposure. Males take longer to respond to the auditory alert and active steering inputs compared to the female subjects, but responded faster for the seat belt tensioning. When looking at the warnings, prior exposure results in greater differentiation between conditions for the males, but little difference for females. Without prior exposure, there is greater differentiation for females but less for males. The pattern of differences for males is similar with and without prior exposure, but for females, the pattern differs between conditions. Steering reaction time to the alert was not significantly different for either awareness (p=0.1716) or for exposure (p = 0.9545). Additionally there were no interactions for either awareness or exposure with warning type for steering reaction time.

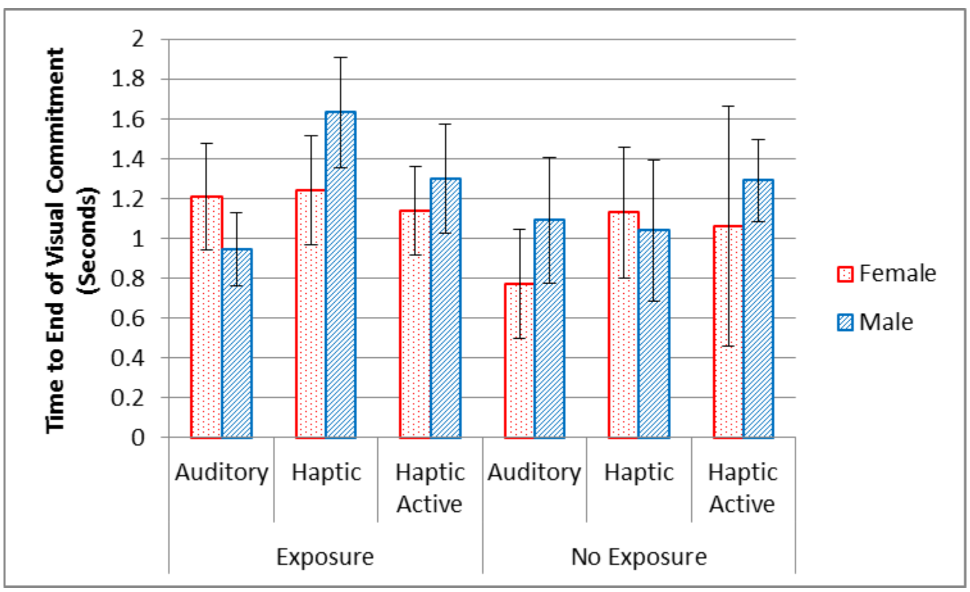

Figure 37. Interaction of Exposure, Gender and Warning Type on Time to the End of Visual Commitment

When looking at the other measures that might be influenced by awareness and exposure, there were no significant differences based on awareness of the system for any of the measures of visual commitment or response. However, there were significant differences for exposure. Significant differences were observed for visual commitment duration (p=0.0077), initial visual commitment duration (p=0.0162), and engagement duration (p=0.0171). As can be seen in Figure 38, commitment durations were longer by 250-300 ms with prior exposure to the alert.

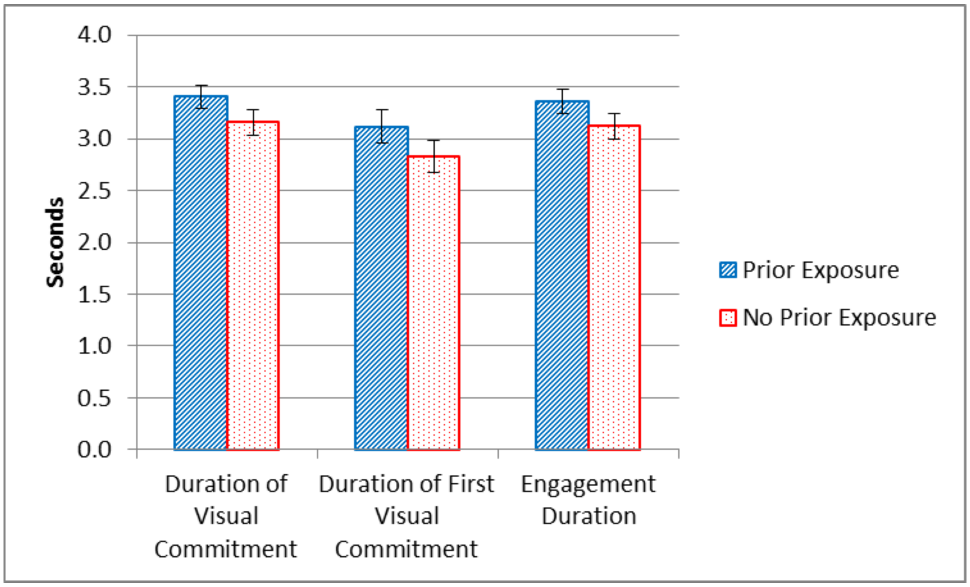

Figure 38. Visual Commitment Times for Lane Departure Events

When looking at the differences between the warning types, there were no significant differences for the two primary measures, but there were differences in the overall visual commitment duration (p=.0142), initial visual commitment duration (p =0.0020), and engagement duration (p=0.0245). As can be seen in Figure 39, Visual commitment durations were shorter for the auditory alert condition than for the haptic or active haptic alerts.

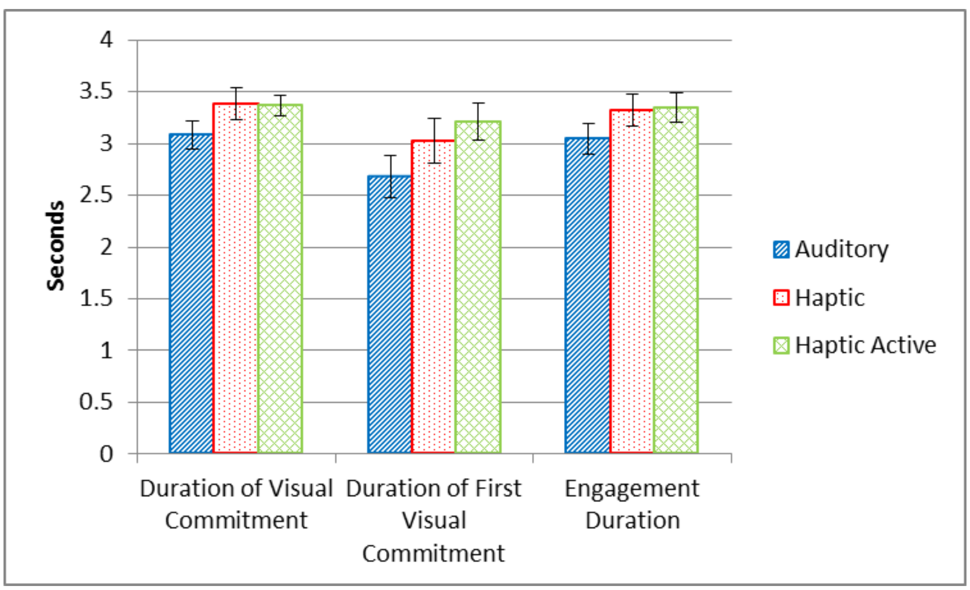

Figure 39. Main effect of Warning Type on Visual Commitment for Lane Departure Events

When looking at differences associated with gender, there were significant differences associated with visual commitment duration (p=0.0439) and engagement duration (p=0.0343). As can be seen in Figure 40, males were willing to commit to the tasks longer than females by 160 and 180 ms, respectively.

When looking at differences associated with event, there were significant differences associated with outcome. Differences were found for area of lane exceedance (p=0.0049) and maximum lateral extent of the exceedance (p=0.0011). As is seen in Figure 41, the second lane departure events resulted in less severe outcomes as indicated.

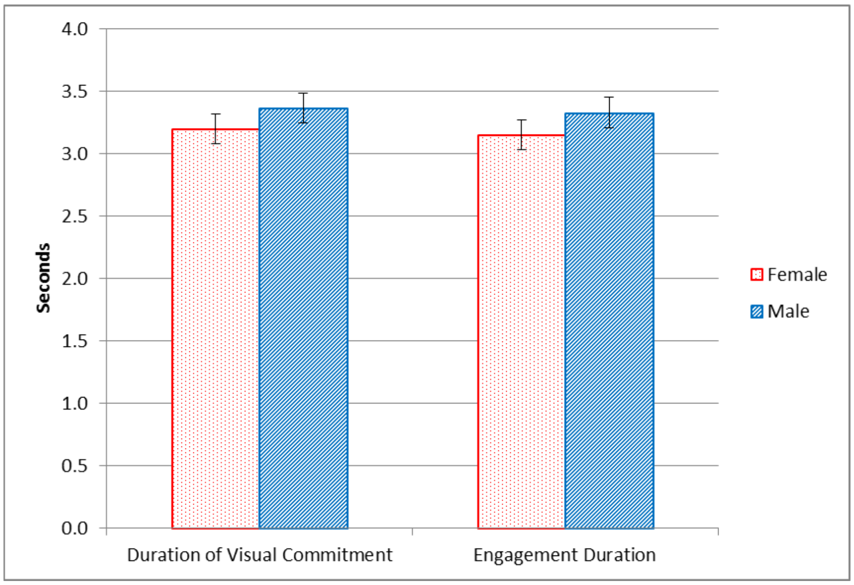

Figure 40. Commitment Times for Lane Departure Events by Gender

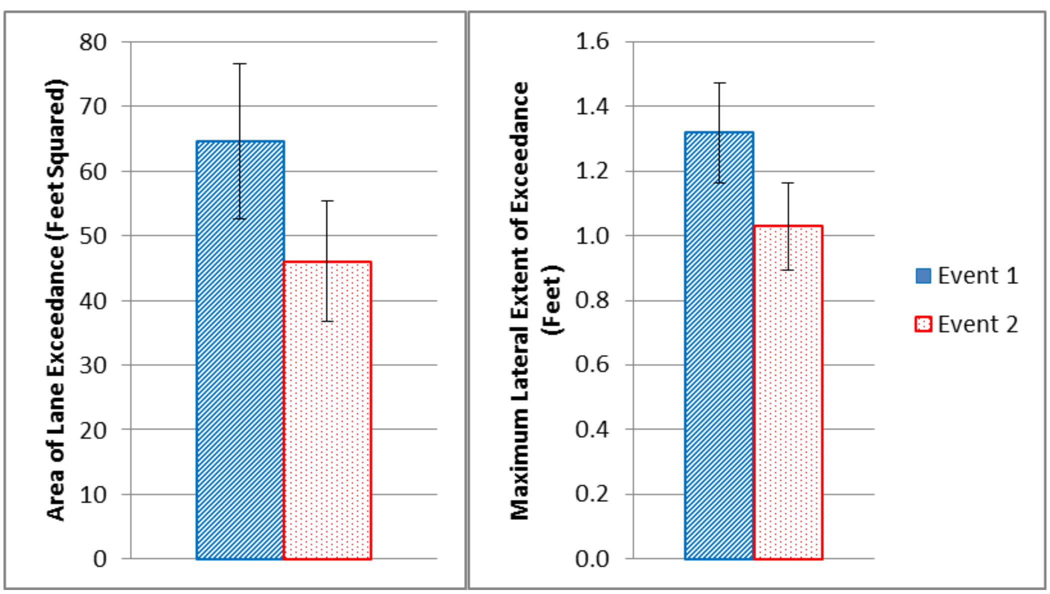

Figure 41. Outcome for Lane Departure Events by Event

5.2.2 Forward Crash Events

When looking at the two key endpoints for response to the alert for forward crash events, there were two significant effects associated with awareness of the system and none associated with prior exposure to the system. Time to the end of visual commitment was not significantly different for either awareness (p = 0.1067) or for exposure (p=0.2069); however there was a significant two-way interaction between exposure, and event (p=0.00366). There were no interactive effects for awareness with warning type for time to end of visual commitment. As can be seen in Figure 42, with prior exposure, subjects maintained visual commitment longer for the first forward crash event than for the second event. Brake reaction time to the alert was significantly different for awareness (p=0.0.0082) but not for exposure (p = 0.7419). As can be seen in Figure 43, subjects who were aware of the system responded approximately 171 ms faster than subjects who were not aware of the system. There were no interactive effects for awareness or exposure with warning type for brake reaction time.

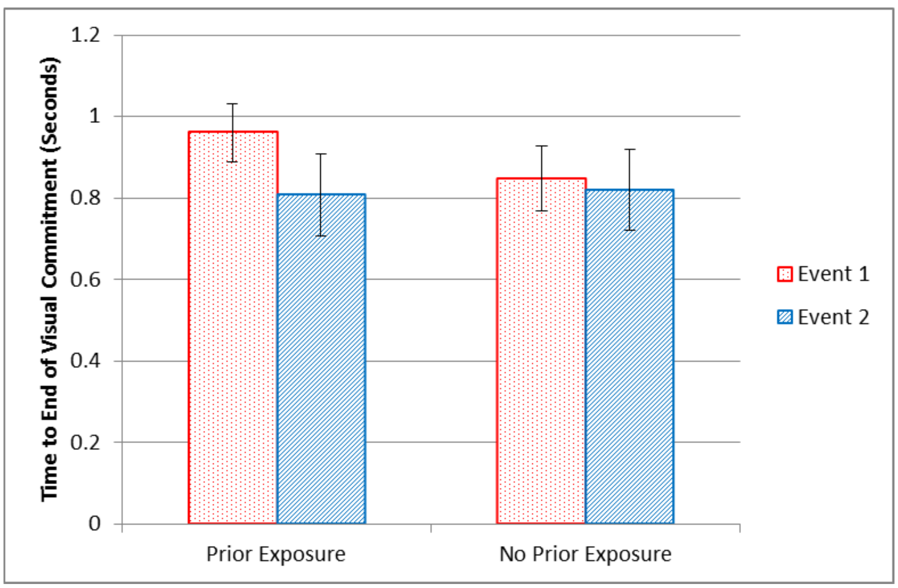

Figure 42. Effect of Prior Exposure and Event on End of Visual Commitment

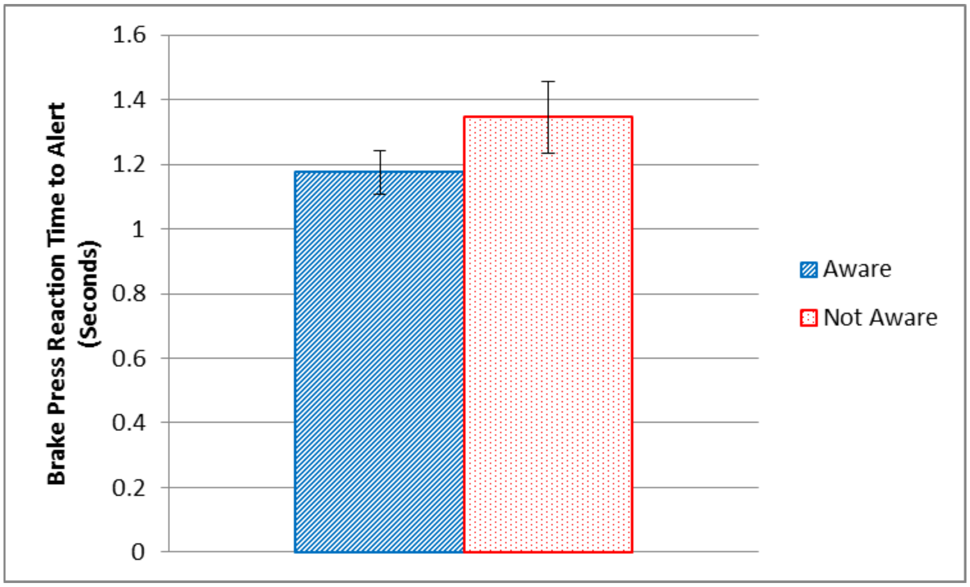

Figure 43. Main effect of System Awareness on Brake Reaction Time

When looking at the other measures that might be influenced by awareness and exposure, there was a significant difference relative to awareness for minimum time-to-collision, but no significant differences for exposure. There were however two interactions between exposure and event. For minimum TTC, subjects with prior exposure to the alert had significantly greater minimum TTCs (p= 0.0238)

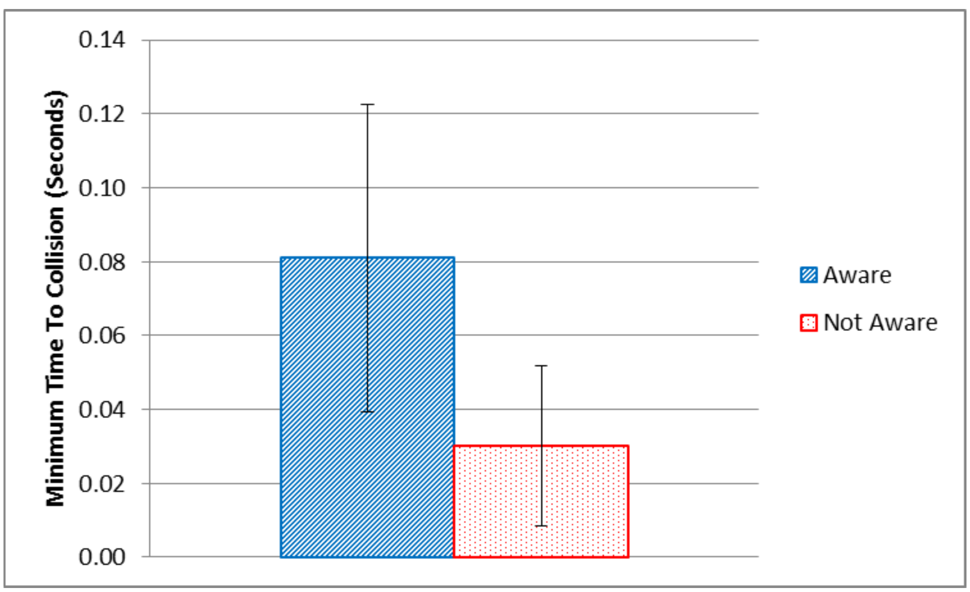

Figure 44. Main effect of Exposure on Minimum TTC

When looking at the differences between the warning types, there was a significant difference for the primary measure of time to end of visual commitment (p=0.0366) but not for brake reaction time (p=0.1275). There were also significant effects for visual commitment duration (p=0.0480), initial visual commitment duration (p=0.0461), and engagement duration (p=0.0432). As can be seen in Figure 45, visual commitment durations were shorter for the haptic alert condition than for the active haptic alerts.

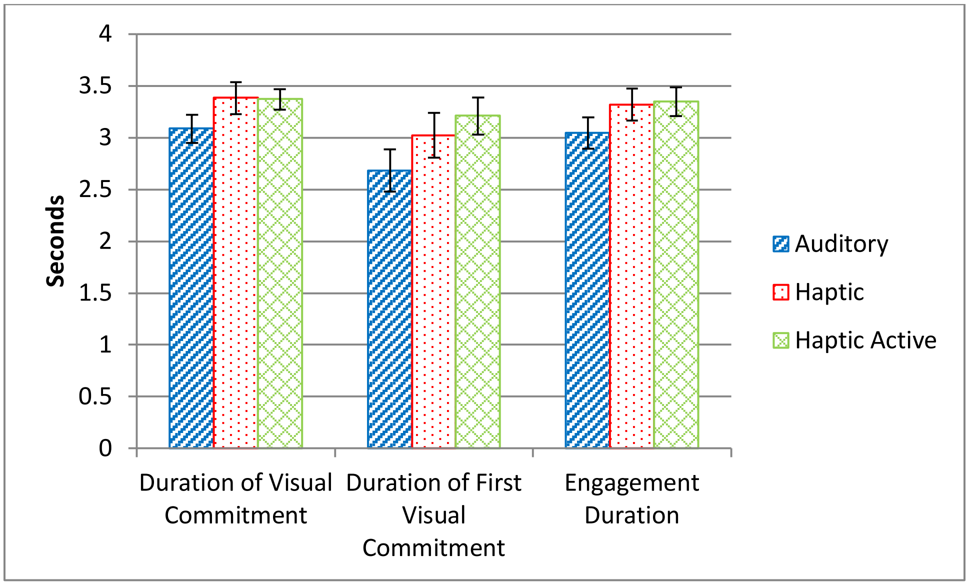

Figure 45. Main effect of Warning Type on Visual Commitment for Forward Crash Events

When looking at differences associated with gender, there were no significant main effects; however there was a significant interaction between awareness of the system and time to visual commitment (p= 0.0072). As can be seen in Figure 46, females who were aware of the presence of the warning system took significantly longer to engage in the numbers task compare to females who were not aware and both groups of males.

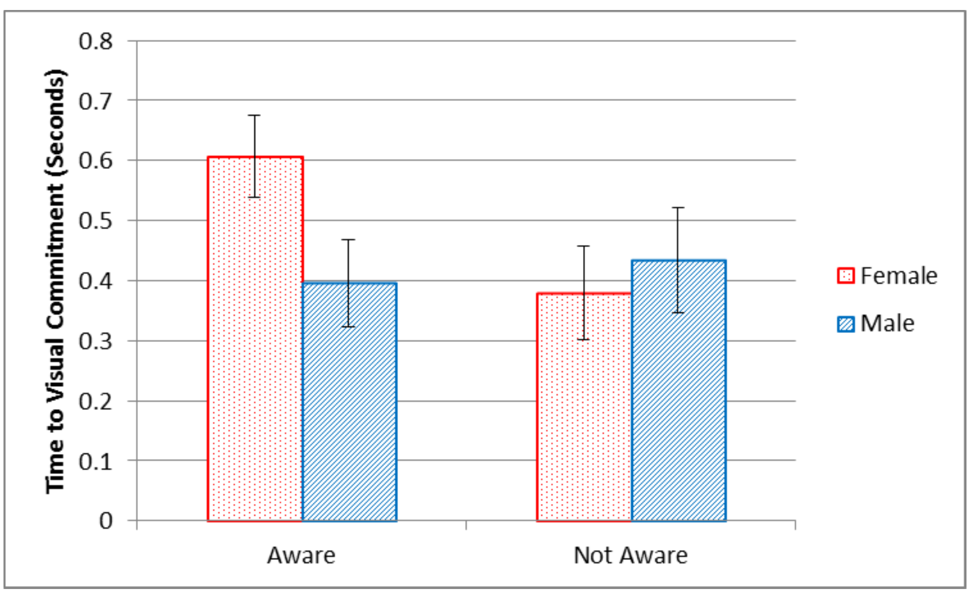

Figure 46. Effect of System Awareness and Gender on Time to Visual Commitment

When looking at differences associated with event, there were significant differences associated with visual commitment, response and outcome. Differences were found for initial visual commitment duration (p=0.0242), time to visual commitment end (p < 0.0001), TTC at visual commitment end (p<0.0001), and brake reaction time (p=0.0058). As is seen in Figure 47, subjects had shorter initial visual commitments and returned their attention to the road quicker for the second forward crash event. As can be seen in Figure 48a, there was a resultant greater TTC at visual commitment end. As can be seen in Figure 48b, subjects were faster to apply the brakes in response to the alert on the second event.

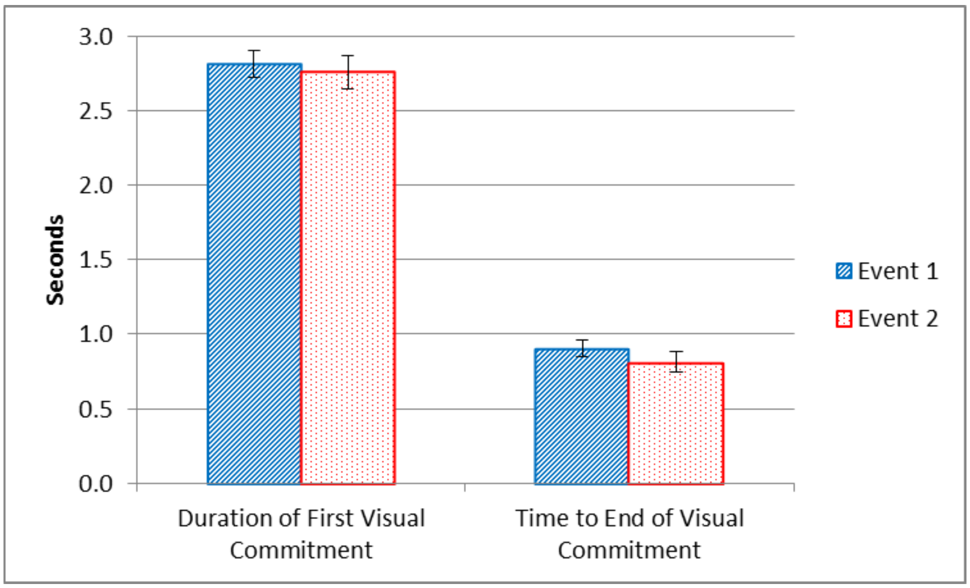

Figure 47. Effect of Repeated Event on Visual Commitment

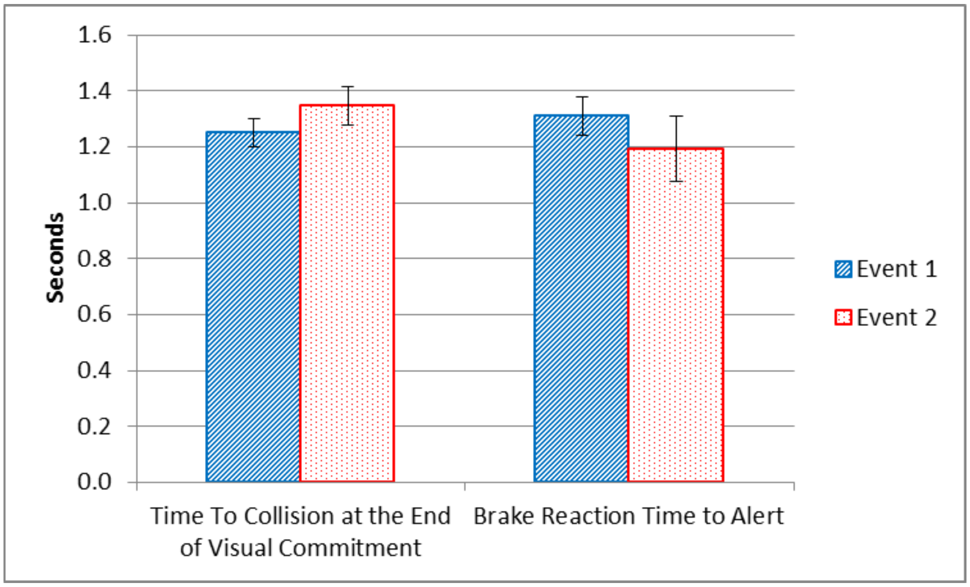

Figure 48. Effect of Repeated Event on Response in terms of TTC at the End of Visual Commitment, and Brake Reaction Time

5.2.3 Incomplete Data

Another consideration is the amount of incomplete data that required replacement which can lead to a less efficient protocol. The number of subject needing replacement due to lost data is provided in Table 23. No statistics were computed for this; however, the condition where there is awareness of the presence of the system but no prior exposure has the greatest number of lost data needing replacement.

Table 23. Subjects Requiring Replacement Due to Missed Events

<table>
<tr><td colspan="2" rowspan="2">Dropped</td><td colspan="2">Exposure</td></tr>
<tr><td>No</td><td>Yes</td></tr>
<tr><td rowspan="2">Awareness</td><td>No</td><td>7</td><td>6</td></tr>
<tr><td>Yes</td><td>13</td><td>2</td></tr>
</table>

5.3 Discussion

When considering how much familiarity subjects should have with the system in order to best assess the effectiveness of the warning system DVI, there are the practical consideration of what occurs in the real world and how different types of familiarity affect the ability to differentiate between DVIs of different effectiveness. The first consideration is largely philosophical as different drivers will have different familiarities with the systems in their vehicle, and cannot be assessed by the data.

Providing subjects with awareness that the crash warning systems were present in the car through a pre-drive training presentation resulted in no differences in engagement with the secondary task or driver response for the lane departure events. When considering the forward crash events, the presence of the pre-drive training resulted in greater minimum TTCs and faster brake applications. For neither type of event was there an interaction with type of DVI used for the warning system.

Providing subjects with prior exposure to the warning system during the drive resulted in differences in visual commitment for the lane departure events. These differences were that with prior exposure, subjects had longer engagement times with the secondary task, but that there was no resultant difference in end of visual commitment in response to the alert. When considering the forward crash events, there were no differences based solely on exposure, but when considering whether it was the first or second event, subjects with prior exposure waited longer to end their visual commitment.

When considering the use of more than one crash warning event in a drive, there is little indication that additional lane departure events have any impact on driver engagement or disengagement from the secondary task for the lane departure events, but that there are differences in response which may reflect greater familiarity with what the alert means. For the forward crash events, there are differences in secondary task engagement and response. Subjects have shorter initial visual commitment duration and disengage faster from the task in response to the alert. Additionally subjects respond with a brake application quicker. This may indicate a greater sense of caution after experiencing the forward crash event.

When considering data needing replacement, providing exposure to the alert appears to reduce the amount of data needing replacement, but there is a mixed effect of providing prior awareness of the system.

5.4 Protocol Implications

5.4.1 System Awareness

Based on the findings, an argument could be made for either providing the subject with this information or not prior to the study drive. Knowing about the warning in greater detail seems to allow drivers to respond more quickly. No overall guidance can be provided for whether to provide training based on this data. When looking at trends in the data for engagement, the strongest argument would be to not provide training based on the trend toward towards shorter engagements with the secondary task by approximately 120 ms. Although this difference is not significant, caution would dictate that absent a dis-benefit, the safer course would be to not provide prior system awareness training.

5.4.2 Prior Exposure

The results of this study point to an advantage in terms of longer commitment times to allow the crash warning events to materialize when prior exposure to the alerts is given at the beginning of the drive.

5.4.3 Number of Events

The results of this study point to the use of multiple lane departure events without concern about the influence of the first event. However, caution is warranted with multiple forward crash events, as the results indicate that drivers may be more cautious after the initial event. It should be noted that for forward crash events, we cannot prove guidance on multiple events where some would be less severe than those used in this study.

6 Alert Timing and Protocol Sensitivity to Systems

6.1 Specific Method

The aim of this study was to test the protocol elements identified in prior studies across two warning timings to provide an understanding of how warning timing affects evaluation of the crash warning DVIs. This study examined alert modality and onset for both the FCW and LDW systems through six levels of alert modality and two levels of alert onset. The incentive structure, distraction task, and level of familiarity used during this data collection were those determined by the results of Preliminary Study 2 and Main Study 1. After the surprise events, false alarm events were presented to the driver to examine response false positive or nuisance events.

6.1.1 Hypotheses

There were four main hypotheses for this study:

- The protocol will be able to differentiate between warning DVIs and between the DVIs and the baseline no alert condition in terms of initial driver response.
- Earlier warnings will produce a faster response to lane departures and forward collision events.
- There will be no interactive effects between DVI and warning timing.
- Drivers with a crash warning DVI will respond differently to false alarm events than drivers in the baseline no alert condition.

6.1.2 Experimental Design

Main Study 2 had a 2x6 between-subject experimental design (see Table 24). Two levels of alert onset, 2.1 s and 3.5 s TTC, were presented with six alert modalities: no alert, audio, visual, two haptic, and an active haptic for both the FCW and LDW systems. The two levels of alert onset were used for the FCW and LDW as described previously. All six levels of alert modality for both the FCW and LDW systems were used as described previously.

Table 24 Main Study 2 Experimental Design

Alert Onset		Alert Modality: No alert	Audio	Visual	Haptic 1	Haptic 2	Active Haptic
	Early	8 participants	8 participants	8 participants	8 participants	8 participants	8 participants
	Late	8 participants	8 participants	8 participants	8 participants	8 participants	8 participants

6.1.3 Dependent Measures

The following measures were analyzed for the FCW and LDW events:

- Time to end of visual commitment from warning
- Duration of first visual commitment
- Engagement duration
- Visual commitment duration
- Glances back to roadway
- Time-to-collision at the end of visual commitment
- Collision
- Minimum time to collision
- Adjusted minimum TTC
- Brake reaction time
- Maximum lane exceedance
- Area of lane exceedance
- Duration of lane exceedance
- Steering reaction time

Additionally, acceptance data were collected and evaluated.

6.1.4 Participants

Ninety-six participants completed all study procedures successfully. One-hundred thirteen participants were enrolled, and seventeen participants were dropped for the reasons documented in Table 25.

Table 25. Participants Enrolled by Condition

	Early Warning												Late Warning												
	No Warning		Auditory		Visual		Haptic 1		Haptic 2		Haptic Active		No Warning		Auditory		Visual		Haptic 1		Haptic 2		Haptic Active		Total
	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	
Enrolled	6	4	6	4	5	4	4	5	6	4	4	4	4	5	6	5	5	4	6	4	5	4	4	5	113
Took Lorazapan during visit																1									1
Simulator issues	1							1																	2
No FCW event	1				1												.5		1		1			1	5.5
Sim sick									1					1	1										3
Bad video			1																						1
Short visual commit(s)			1												1										2
Didn't engage in tasks									1										1						2
No LDW event																	.5								.5
Completed	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	96

6.1.5 Apparatus

These remained the same as used in the first main study (see Section 5).

6.1.6 Experimental Procedures

The general experimental procedures were described in Section 2. Study-specific procedures for this experiment are documented below.

6.1.6.1 Experimental Ruse and Deception

Participants were told that the goal of the research was to evaluate several new in-vehicle technologies, when in fact their response to surprise LDW and FCW events was being evaluated.

6.1.6.2 Headway

Participants were instructed to maintain position in the green zone of the headway display provided.

6.1.6.3 Training

Subjects were provided a training presentation that provided details on the drive, navigation instruction, headway display, secondary task and general procedures. No training on the warning DVIs was given, as determined by the results from Main 1.

Additionally, participants practiced with the number recall task before going into the simulator to become comfortable with performing the task. Participants were prompted to engage with the tasks consistent with the method in the simulator. They were asked to practice until they could perform the task successfully. The criterion for the task is documented in Table 26.

Table 26. Criterion for Distraction Task Training

Task	**Criterion**
Number Recall	All five numbers correct with no sequence errors

6.1.6.4 Compensation

Compensation for this study was selected based on the results of the prior study. Base compensation was set at $45. The base pay was pro-rated. If participation lasted less than 1 hour, participants earned $10. If participation lasted for over 1 hour, participants earned the full base pay.

6.1.7 Scenarios

Scenarios used for this study were the same as those used in Main 1 (see Section 5.1.7).

6.1.8 Analysis Plan

After verification of the data, two primary analyses were conducted to address the hypotheses: one for the first three hypotheses and one for the false alarm hypothesis. The analyses focused on the main effects of warning DVI and warning timing and their interaction. The analysis focused on the extent to which changes in warning timing affect the ability of the protocol to differentiate between the DVIs. If the main effect for warning DVI was significant, a simple effects test was conducted to determine how warning timing affects DVI performance in absolute and relative terms. The primary measures of interest were driver's initial response, including time to end of visual commitment, and reaction time. The output of this study was an understanding of how warning timing affects the evaluation of crash warning DVIs, and the selection of warning timing and DVIs for use in the final study.

6.2 Results

Our recommendation for timing is dependent on the type of warning (LDW vs FCW). For LDW events late warnings may be best to reduce nuisance alarms, but for FCW events the warning timing may not matter greatly and the system timing may be most appropriate. The following results form the basis of that recommendation.

6.2.1 Lane Departure Events

When looking at the two key endpoints for response to the alert for lane departure events, there was a significant effect for timing and for warning type. There was also a significant interaction between timing and warning type for steering reaction (p=0.0144) time but not for time to visual commitment end (p=0.2764). As can be seen in Figure 49, visual, auditory, vibrating steering wheel and steering torque had faster reaction times with late warnings; seat vibration had a faster reaction time with the early warning. In general, later warnings resulted in faster reaction times but not universally. Additionally, all the warning types resulted in better performance than when no warning was provided; however, there is little difference in reaction time when the warning is provided early, but greater differentiation with the late warning. Due to the complexity of the interaction the main effects for warning timing (p=0.0099), and warning type (p=0.0027) will not be considered.

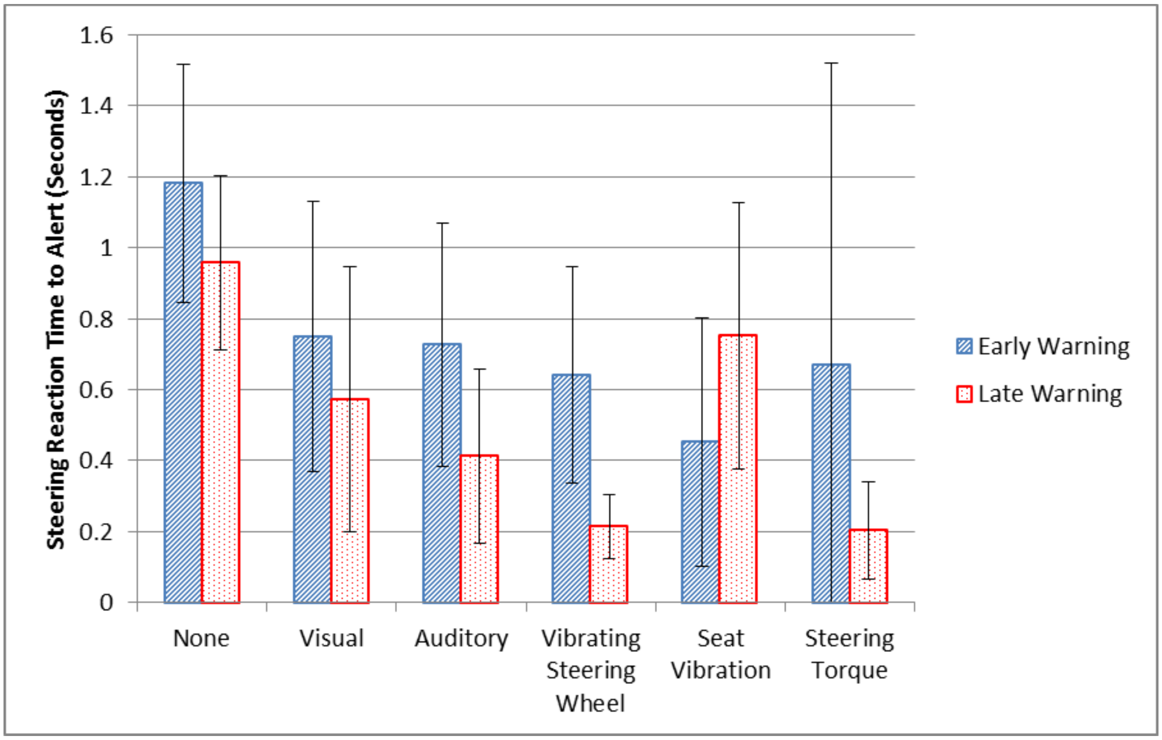

Figure 49. Interaction between Warning Timing and Warning Type on Steering Reaction Time

When considering the effect of warning timing on time to visual commitment end, there was a significant main effect (p=0.0006). For late warnings, drivers end their visual commitment faster in response to the warning than when an early warning is provided.

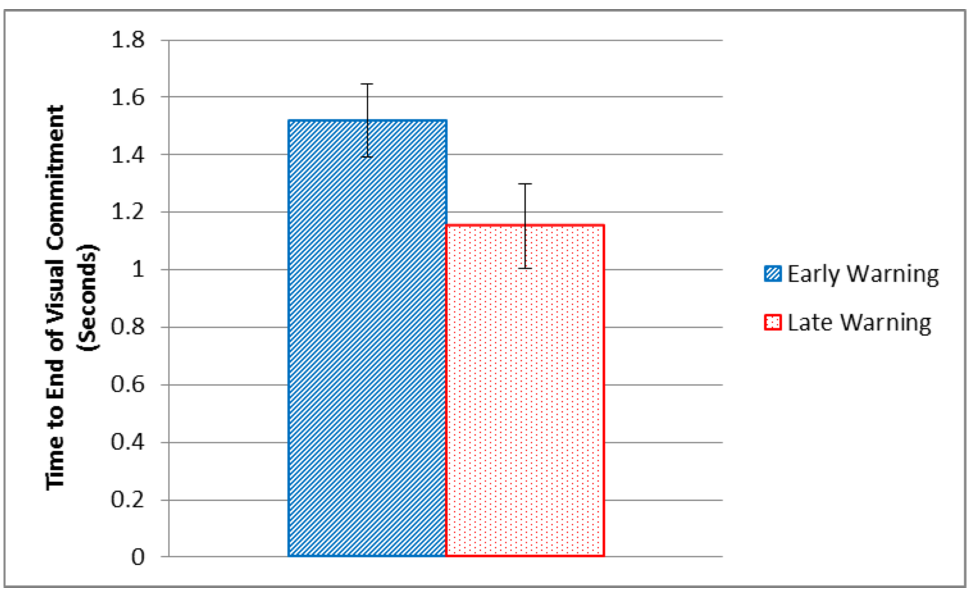

Figure 50. Effect of Warning Timing on Time to Visual Commitment End

When considering the interaction of timing with other independent measures there were significant interactions between warning timing, warning type and gender, and between warning timing, warning type and event. For the interaction between warning and timing with gender, there were significant effects on initial visual commitment duration (p=0.0382), and engagement duration (p=0.0344). As can be seen in Figure 51 and Figure 52, in general males engage with the secondary task longer than females, but that is not uniformly true across conditions. This is lack of uniformity is particularly important when considering the early warnings where, for females, durations were not always shorter when a warning was provided.

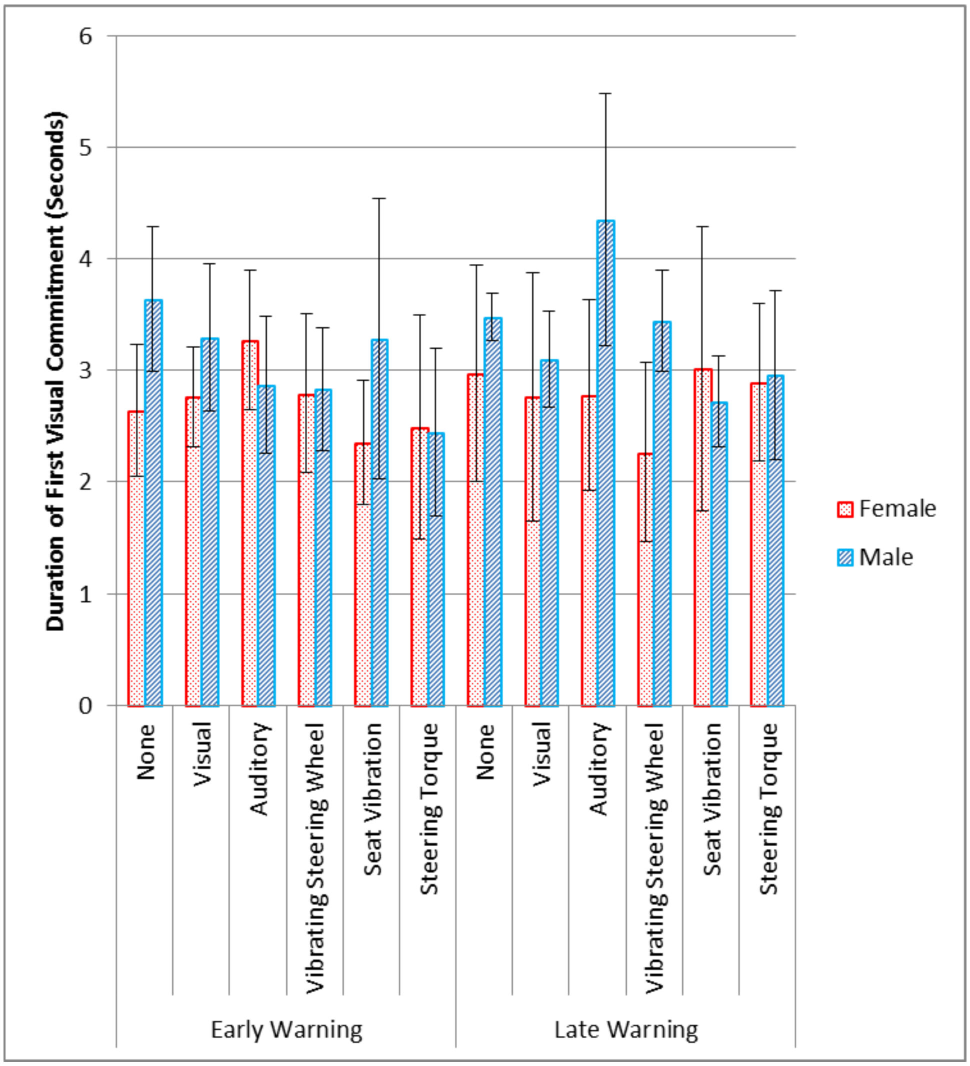

Figure 51. Initial Visual Commitment Duration as Function of Warning Timing, Warning Type and Gender

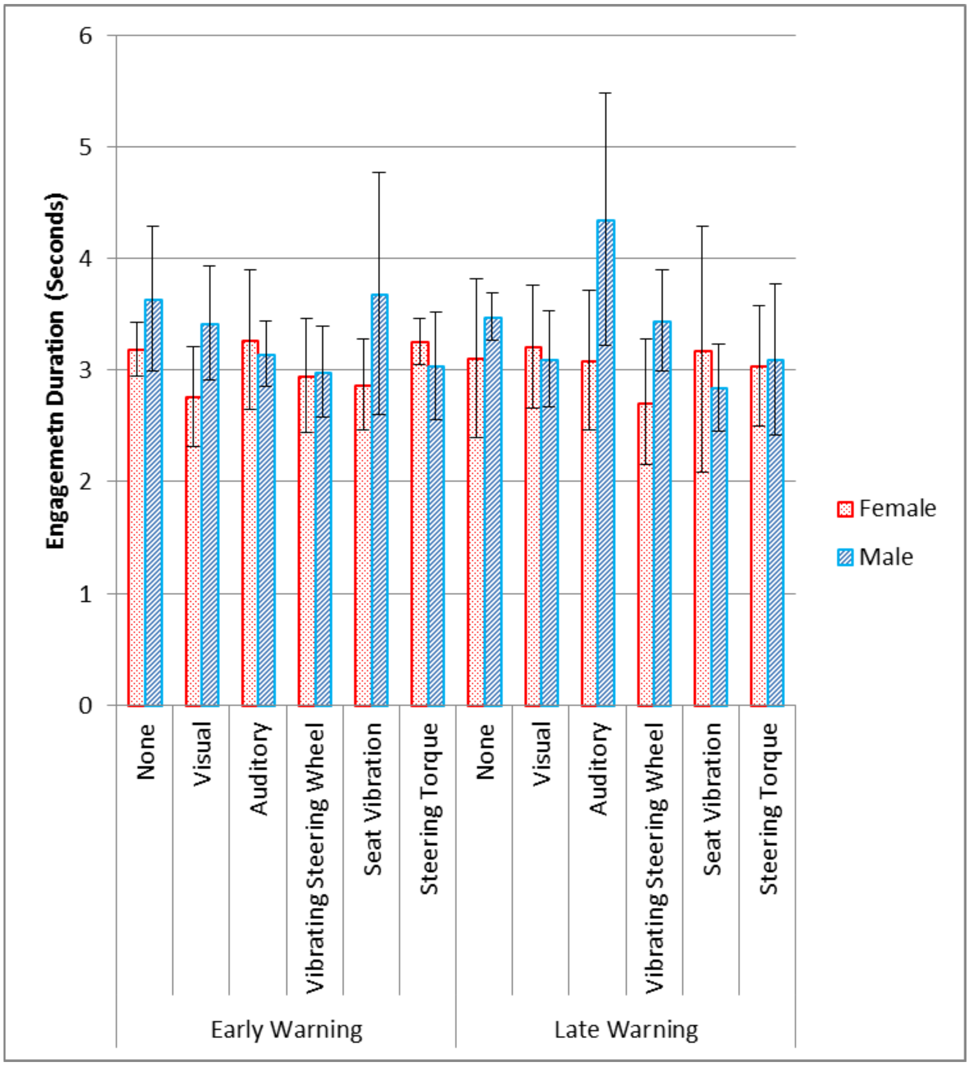

Figure 52. Engagement Duration as Function of Warning Timing, Warning Type and Gender

Additionally, there was one main effect for gender. There was a significant difference for time to visual commitment end (p=0.0006). Female drivers ended their visual commitment faster than males in response to the alert on average (see Figure 53).

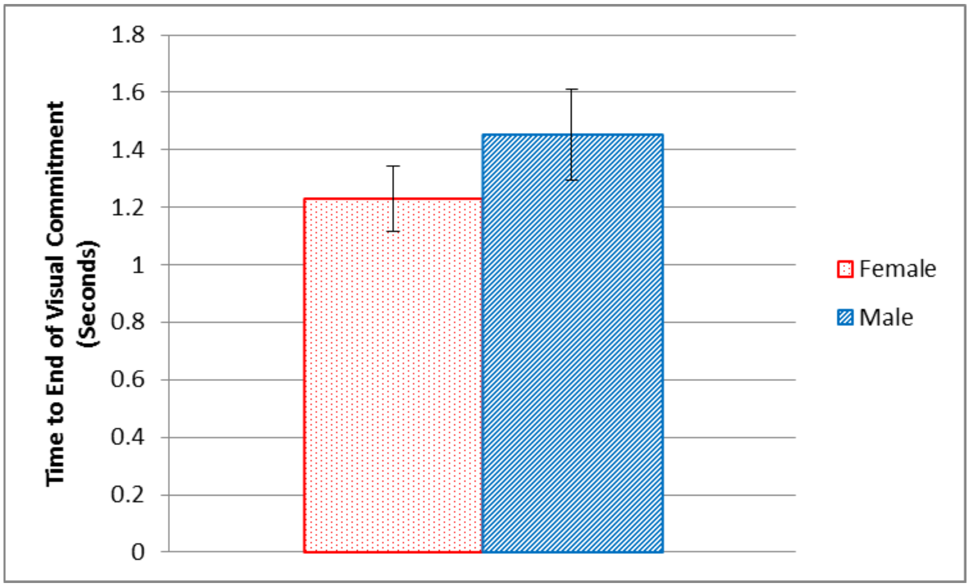

Figure 53. Effect of Gender on Time to Visual Commitment End

Although there were significant interactions between warning and timing with event for initial visual commitment duration (p=0.0297), and engagement duration (p=0.0240), no clear patterns related to the protocol emerge. As such, the graphs are not provided here. There was one main effect of event that did emerge for time to visual commitment end (p=0.0249). As can be seen in Figure 54, subjects take longer to respond to the alert for the second event, suggesting no learning associated with the first event that primes the driver for the subsequent lane departure event.

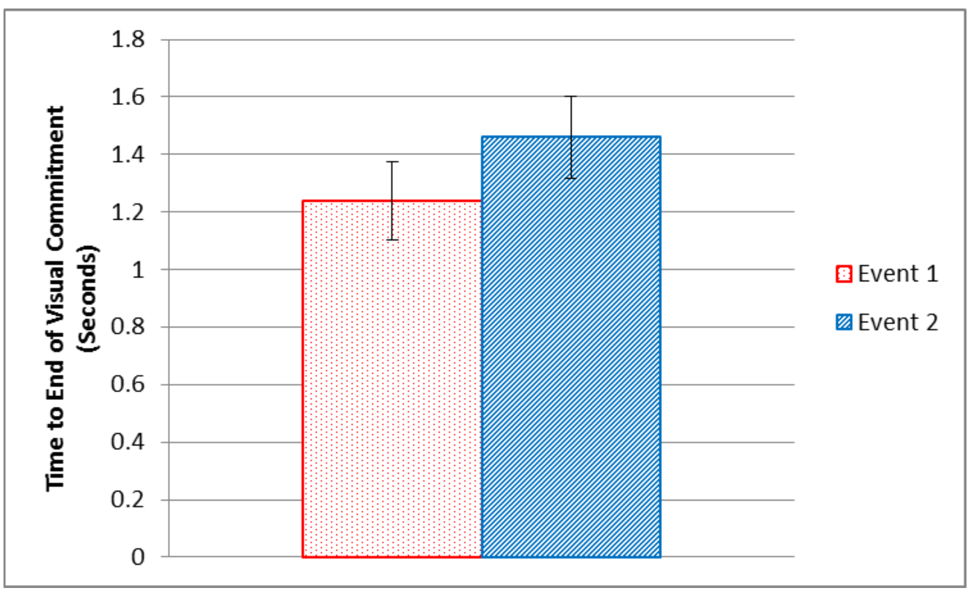

Figure 54. Effect of Event on Time to Visual Commitment End

6.2.2 Forward Crash Event

When looking at the two key endpoints for response to the alert for forward crash events, there was a significant effect for timing but not for warning type. There were no interactions directly between timing and warning type for either measure. There was a significant effect of warning timing for brake reaction time (p=0.0280), but not for time to visual commitment end (p=0.2114). As can be seen in Figure 55, late warnings resulted in faster brake reaction times compared to early warnings. There were no significant effects for warning type for either time to visual commitment end (p=0518) or brake reaction time (p=0.5366).

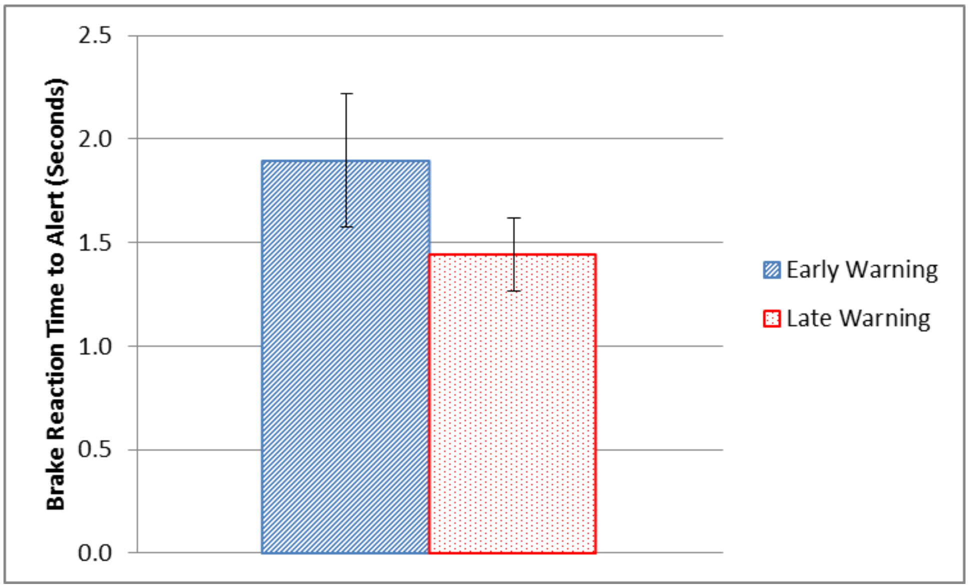

Figure 55. Effect of Warning Timing on Brake Reaction Time

There was a three-way interaction between timing, warning type and gender for several variables. Significant differences were found for visual commitment duration (p=0.0187), initial visual commitment duration (p=0.0066) and engagement duration (p=0.0156) as well as for adjusted minimum time to collision (p=0.0.351). Since the first three of these measures were highly correlated, only initial visual commitment duration, with the lowest p-value, will be presented. Figure 56 shows the complex relationship for the initial visual commitment with no clear patterns emerging. Figure 57 shows the relationship for adjusted minimum time-to-collision. As can be seen late warnings tend to result in smaller values, and males have smaller values than females in all but three cases.

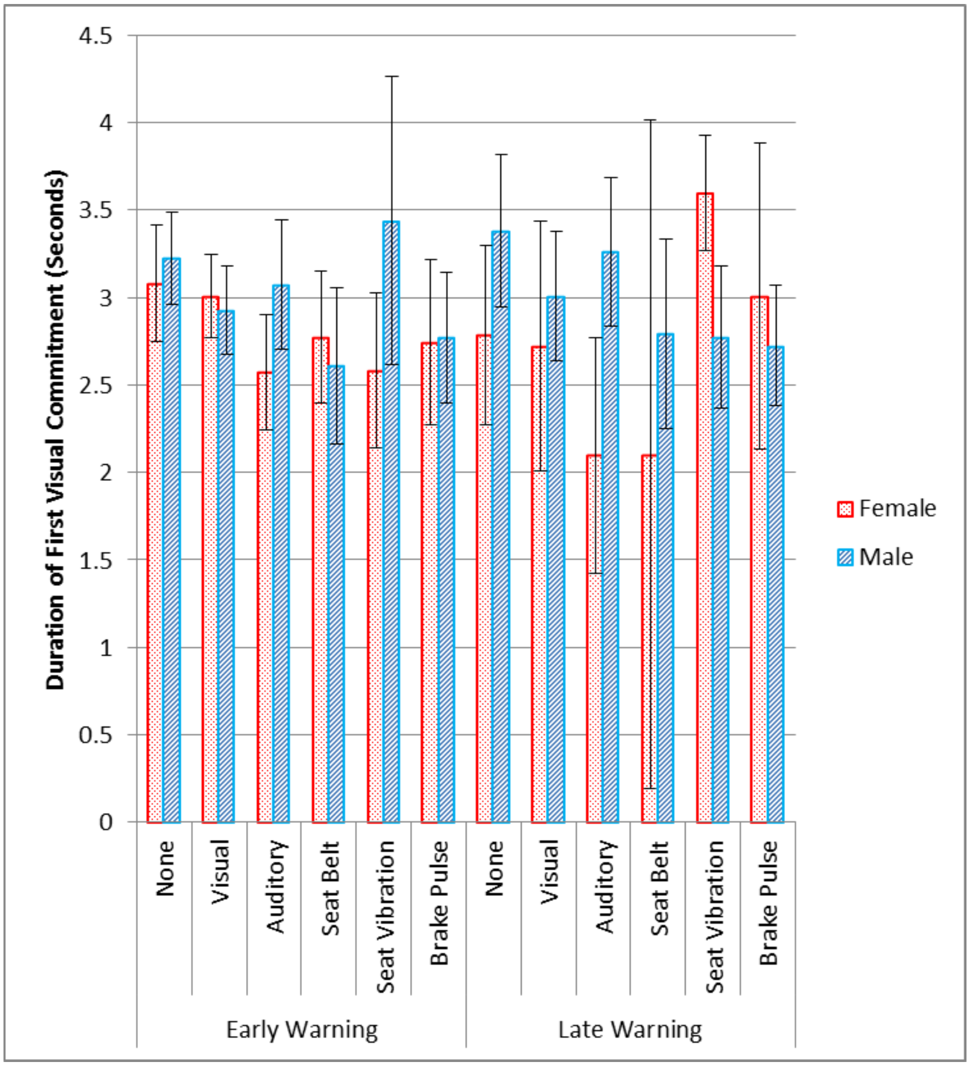

Figure 56. Effect of Warning Timing, Warning Type and Gender on Initial Visual Commitment Duration

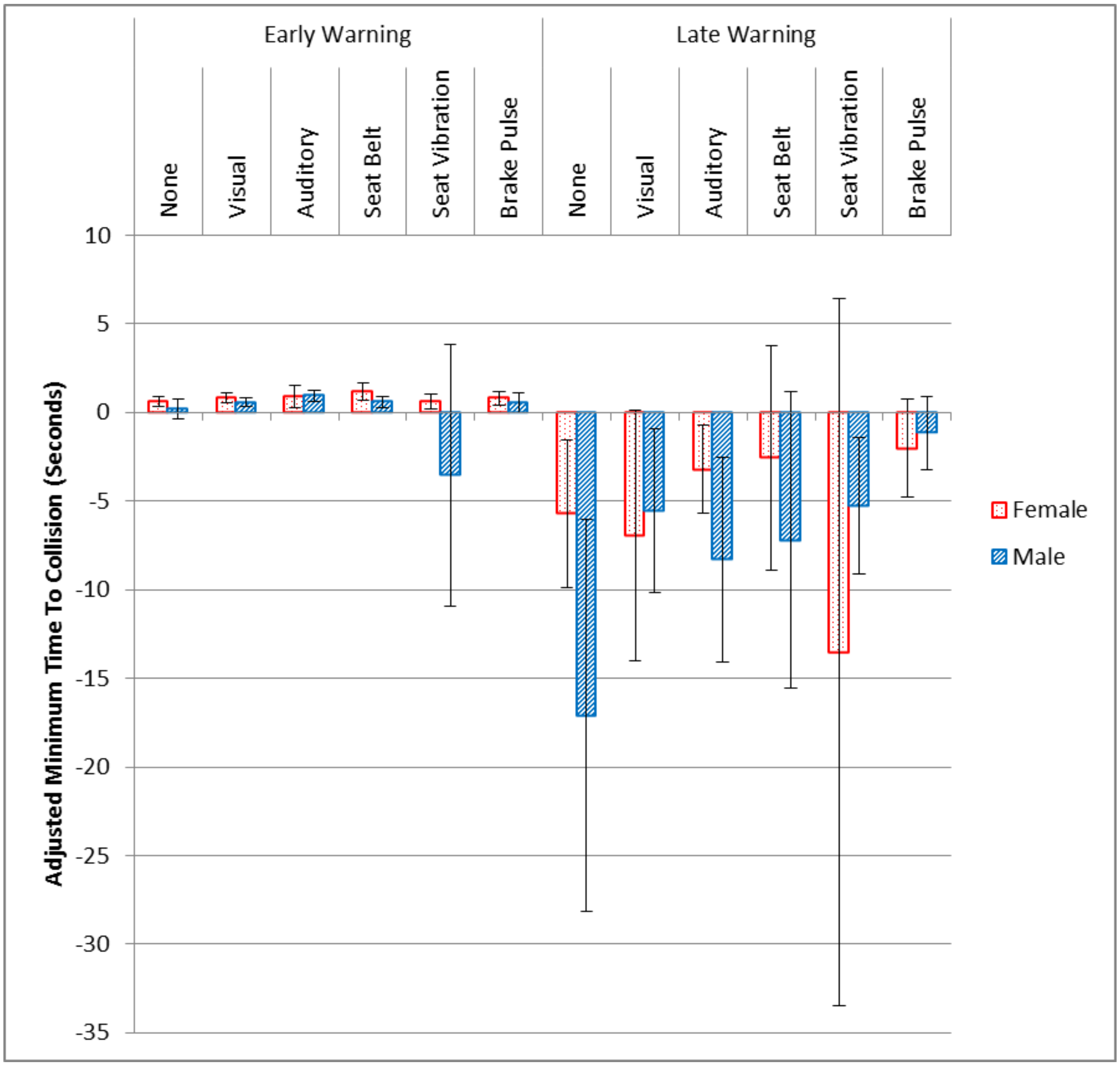

Figure 57. Effect of Warning Timing, Warning Type and Gender on Adjusted Minimum Time-to-Collision

There were main effects for timing and warning type for several additional measures. Timing had significant effects on TTC at visual commitment end ($p<0.0001$), minimum TTC ($p< 0.0001$), and adjusted minimum TTC ($p< 0.0001$). As can be seen in Figure 58 and Figure 59, late warnings result in more severe situations when visual commitment ends and worse outcomes/responses.

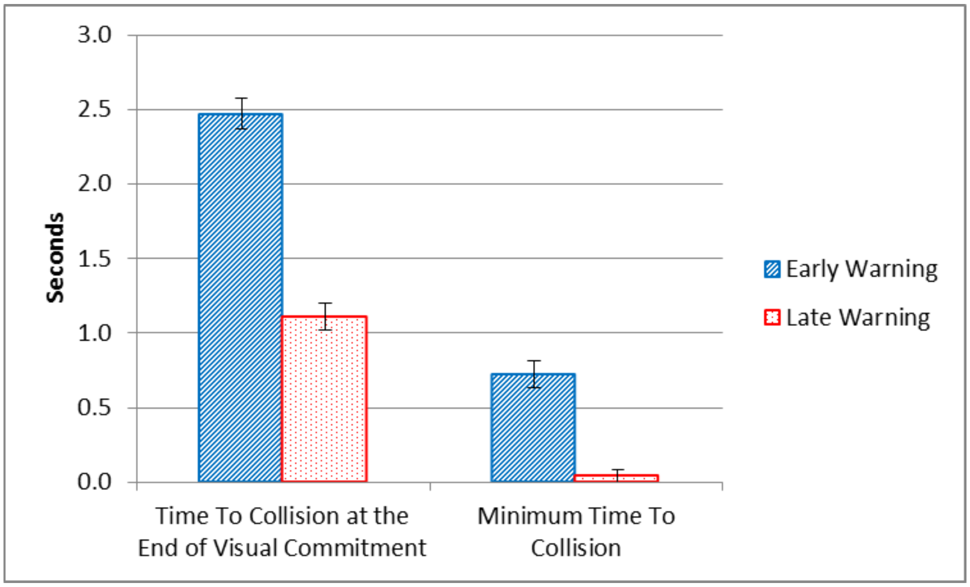

Figure 58. Effect of Warning Timing on TTC at End of Visual Commitment and Minimum TTC

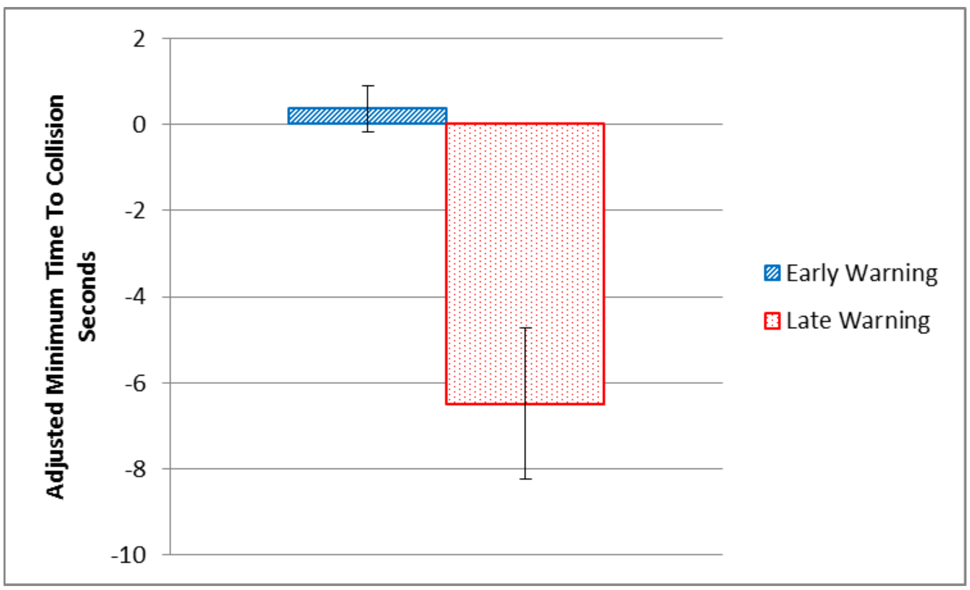

Figure 59. Effect of Warning Timing on Adjusted minimum TTC

In addition to these measures, there were also significant differences associated with event. There were significant effects of event interacting with warning type on time to visual commitment end (p=0.0092) and TTC at visual commitment end (p=0.0118). As can be seen in Figure 60, in some warning types, subjects return their attention to the road faster for the second forward crash event but for the other half of the warning types, there is no decrease or an increase in time from the first to the second event. This phenomenon is reflected in TTC at visual commitment end (see Figure 61), with higher TTCs associated with faster return of attention to the road.

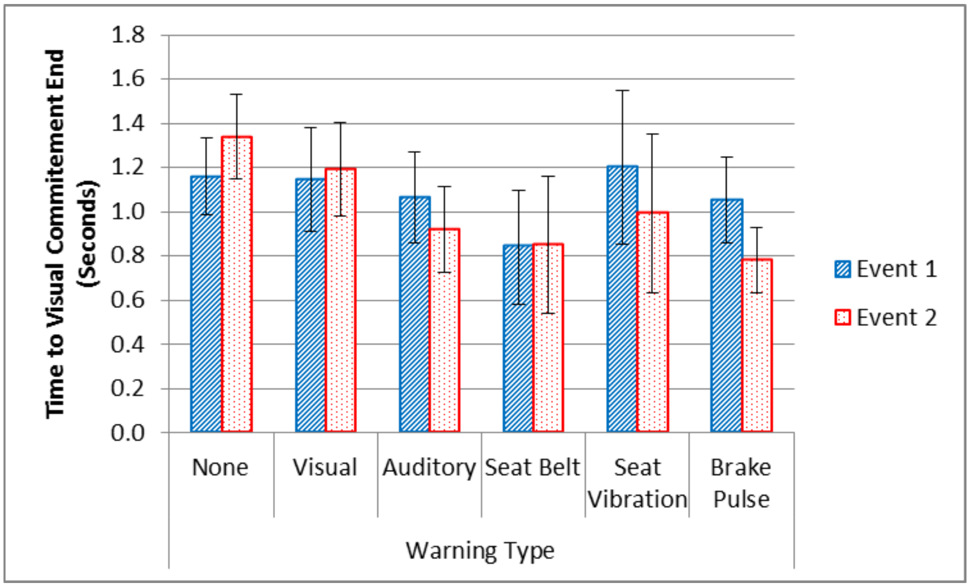

Figure 60. Effect of Event and Warning Type on Time to Visual Commitment End

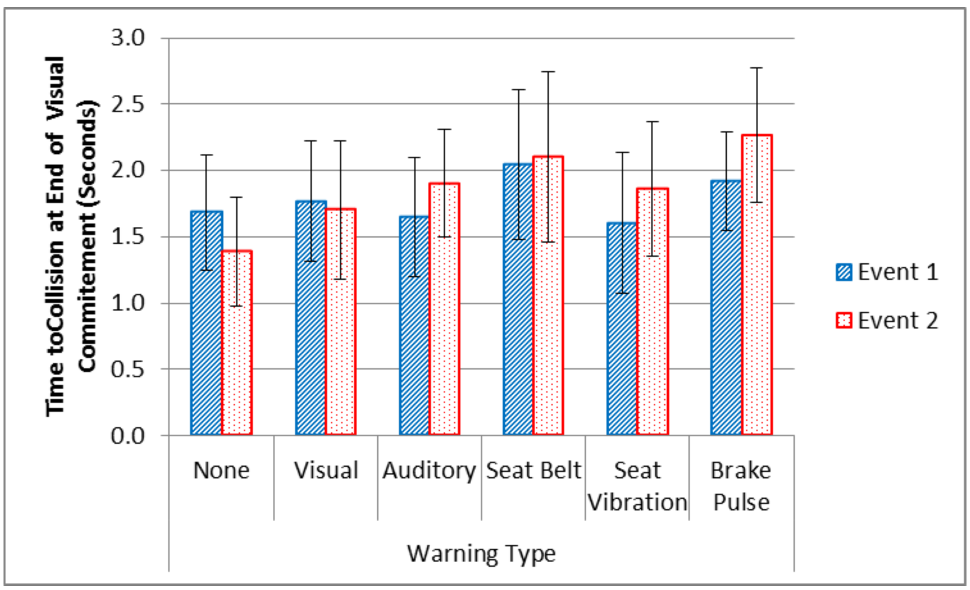

Figure 61. Effect of Event and Warning Type on TTC at Visual Commitment End

There is also a significant interaction between timing and event for minimum TTC ($p = 0.0373$). As can be seen in Figure 62, minimum TTC is greater for the second event with the early warning, but there is little difference in minimum TTC for the late warning.

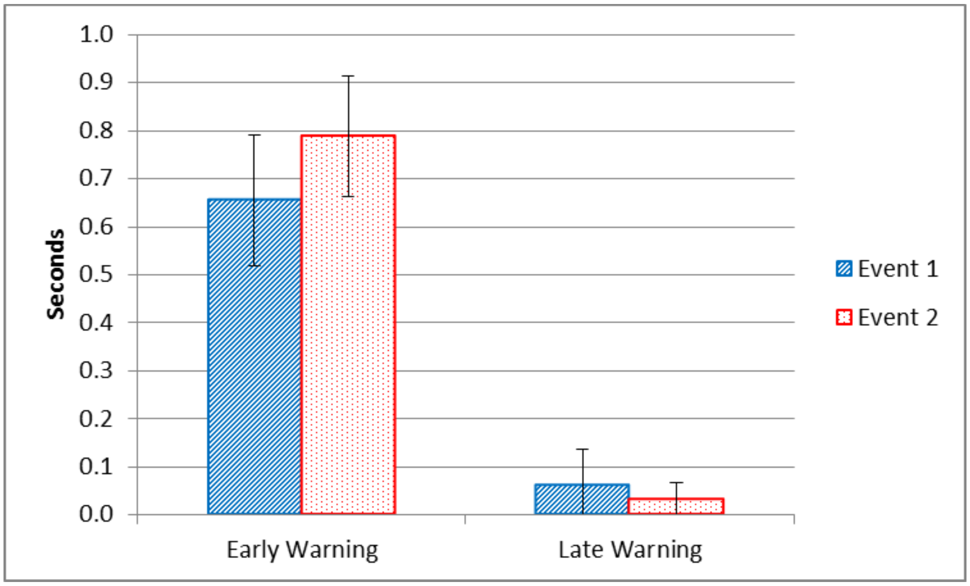

Figure 62. Effect of Warning Timing and Event on Minimum TTC

The main effects of timing have been discussed as part of the preceding three significant interactions.

6.2.3 False Alarm Events

Consideration of how drivers respond to a false alarm is important in considering the effectiveness of the warning system DVIs. Time to end of visual commitment and response reaction time (steering for lateral events and braking for longitudinal events) were analyzed for both the lane departure and forward crash events. There was one significant effect of interest for steering reaction time: an interaction between warning type and timing ($p = 0.02821$) and a main effect of warning type ($p<0.0001$). The interaction shows no difference between timing for the no warning condition indicating the nominal timing of a steering input associated with general vehicle control (see Figure 63), but significant variability in steering reaction times for conditions that received the false alarm. The auditory alert appeared least likely to trigger an earlier steering reaction relative to the false alert than would normally have been observed with general vehicle control in the situation. This is more clearly illustrated in in Figure 64. Participants with auditory or no warning had similar steering reaction times that were significantly longer than the other warning conditions. There was also a more complex effect for time to end of visual commitment ($p=0.0348$). The three-way interaction for time to visual commitment end is illustrated in and shows a complex interaction making it difficult to draw broad inferences.

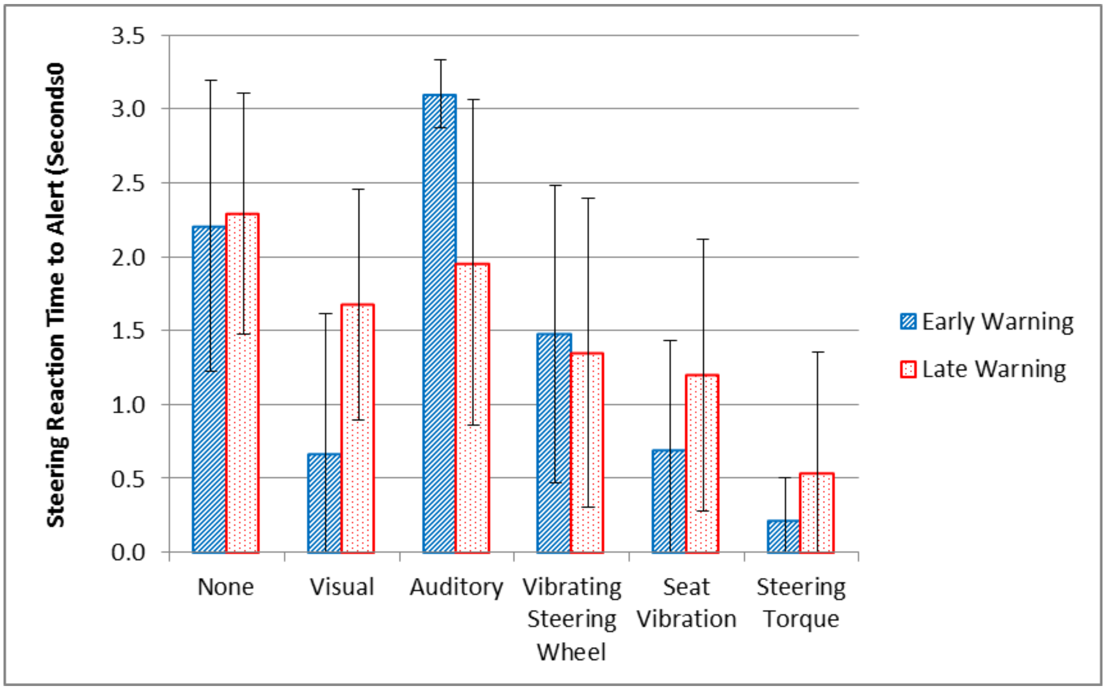

Figure 63. Effect of Warning Type and Timing on Steering Reaction Time for False Alarm

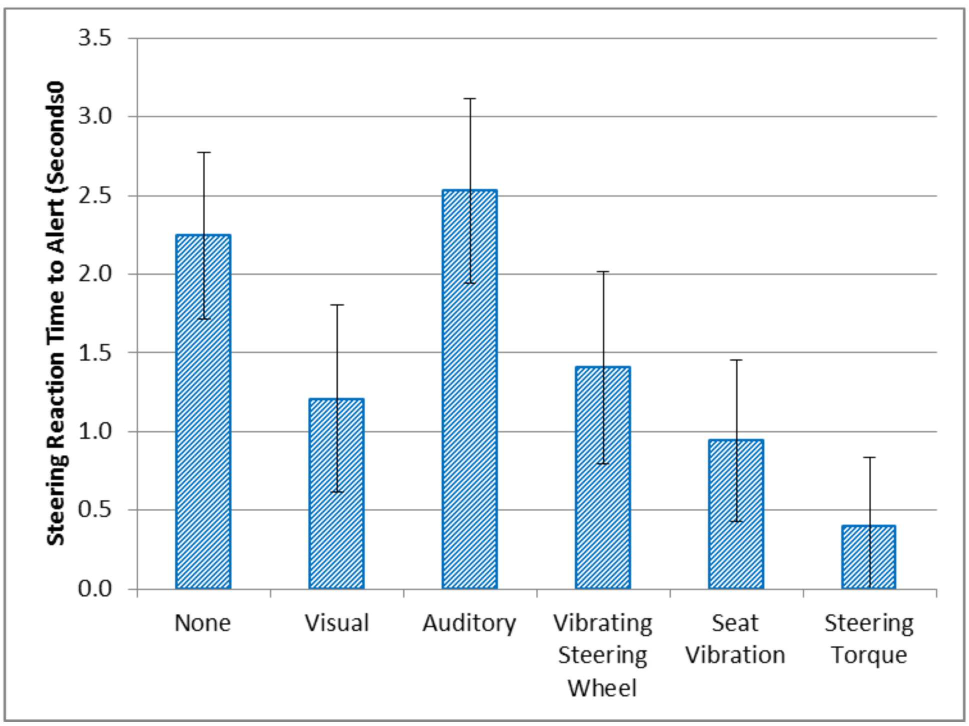

Figure 64. Effect of Warning Type on Steering Reaction Time for the LDW False Alarm Event

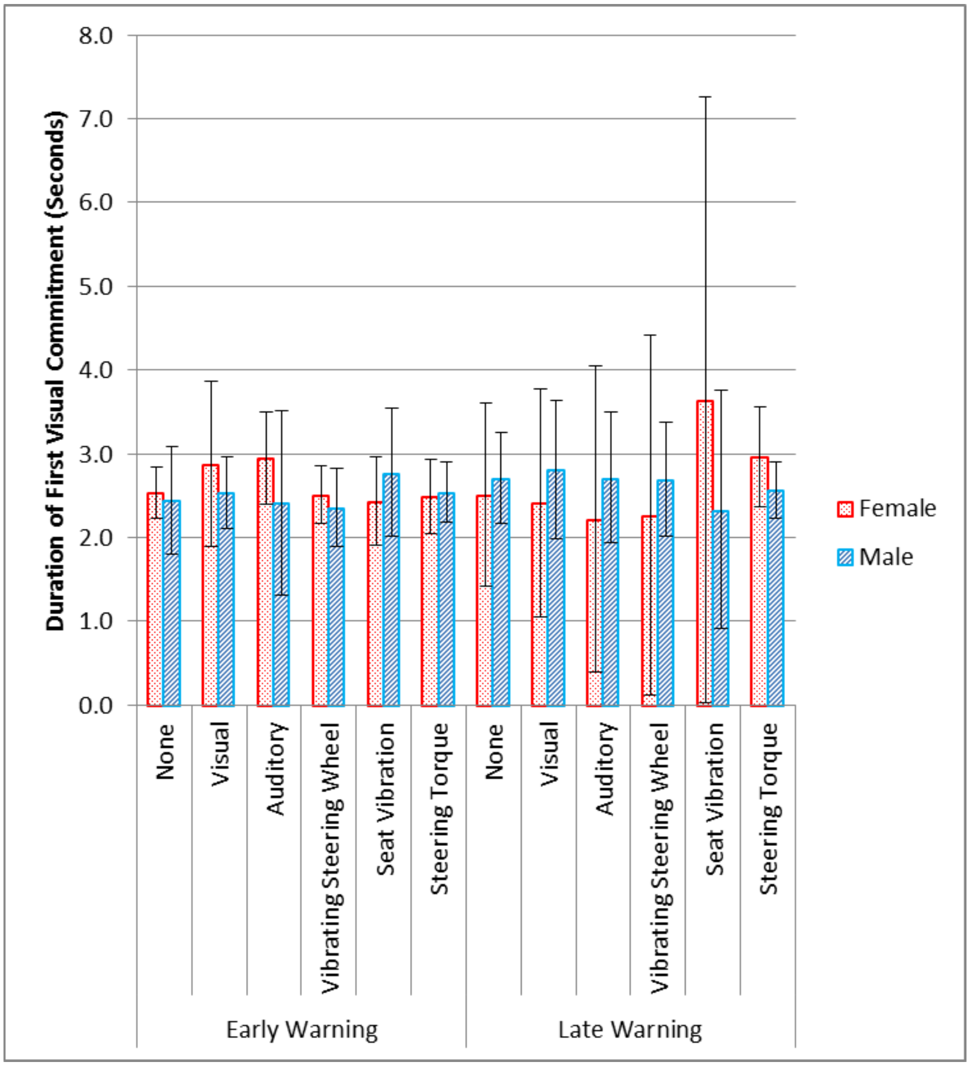

Figure 65. Effect of Warning Timing, Warning Type and Gender on Time to Visual Commitment End for the LDW False Alarm Event

6.3 **Acceptance**

Acceptance surveys were administered to all subjects. Those who were in the no warning condition received a shortened survey with only one question about response to the events. These surveys asked a variety of question about the driver's perceptions of the system. The following sections detail some of the key results from that analysis and composite acceptance measures for both LDW and FCW. Only the significant effects of Warning Type are discussed in this section.

6.3.1 Lane Departure Warning System

When looking at the acceptance data for lane departure systems, there were significant effects related to warning type for seven of the survey questions. These are documented in Table 27.

Table 27. Summary of Significant Effects of Warning Type for Acceptance Questions

Question	Scale	Left Anchor	Right Anchor	p
The alert (Attention)	7 point	Did not catch my attention	Caught my attention	<.00001
The alert was (Distracting)	7 point	Very Distracting	Not Distracting	.0011
My ability to hear/feel alert was (Hear/Feel))	7 point	Very Difficult	Very Easy	<.0001
The intensity of the alert was (Intensity)	7 point	Too Weak	Too Strong	<.0001
To what extent did you rely on the lane departure warning system? (Rely)	5 point	Not At All	Extremely	0.0329
What was your level of confidence in the lane departure warning system? (Confidence)	5 point	Not At All Confident	Extremely Confident	0.0095
What was your degree of self-confidence to handle lane departures? (Self-Confidence)	5 point	Not At All Confident	Extremely Confident	0.0377

The first three significant effects are shown in Figure 66. The steering torque alert was perceived as less able to catch the driver's attention than the other four alerts. The steering torque alert was also perceived as less distracting than all but the visual alert, and the visual alert was perceived as less distracting than the auditory alert. The auditory, seat vibration, and vibrating steering wheel were perceived as easier to hear/feel than the visual and steering wheel torque alerts, and the visual alert was viewed better than the steering wheel torque.

The next significant effect is shown in Figure 67 for alert intensity. For this comparison, values closer to four are optimum. The steering wheel torque alert was rated lower than the other alert with a value indicating the perception of the alert being too weak. The visual, seat vibration and vibrating steering wheel all had means near the optimum point on the scale. The auditory was rated highest but was only significantly greater than the visual alert in terms of being too intense.

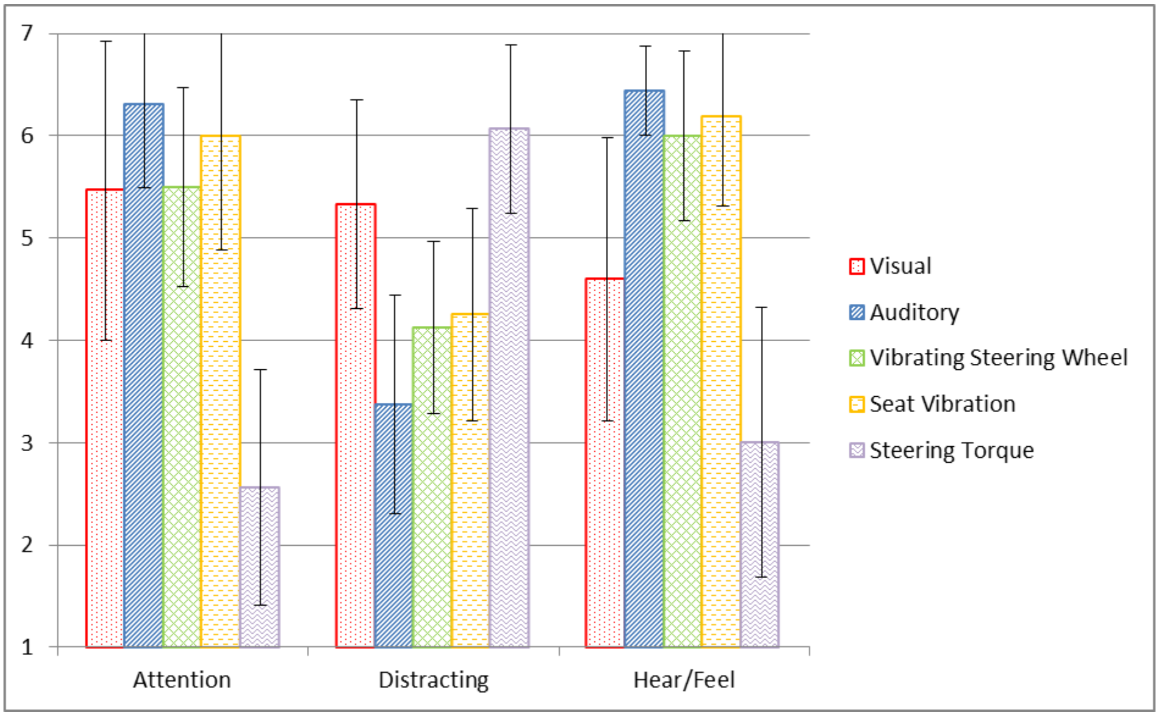

Figure 66. Driver Perception of Ability of Alert to Catch Attention and Avoid Distraction, and Ease of Hearing or Feeling the Alert (Closer to Seven is Better)

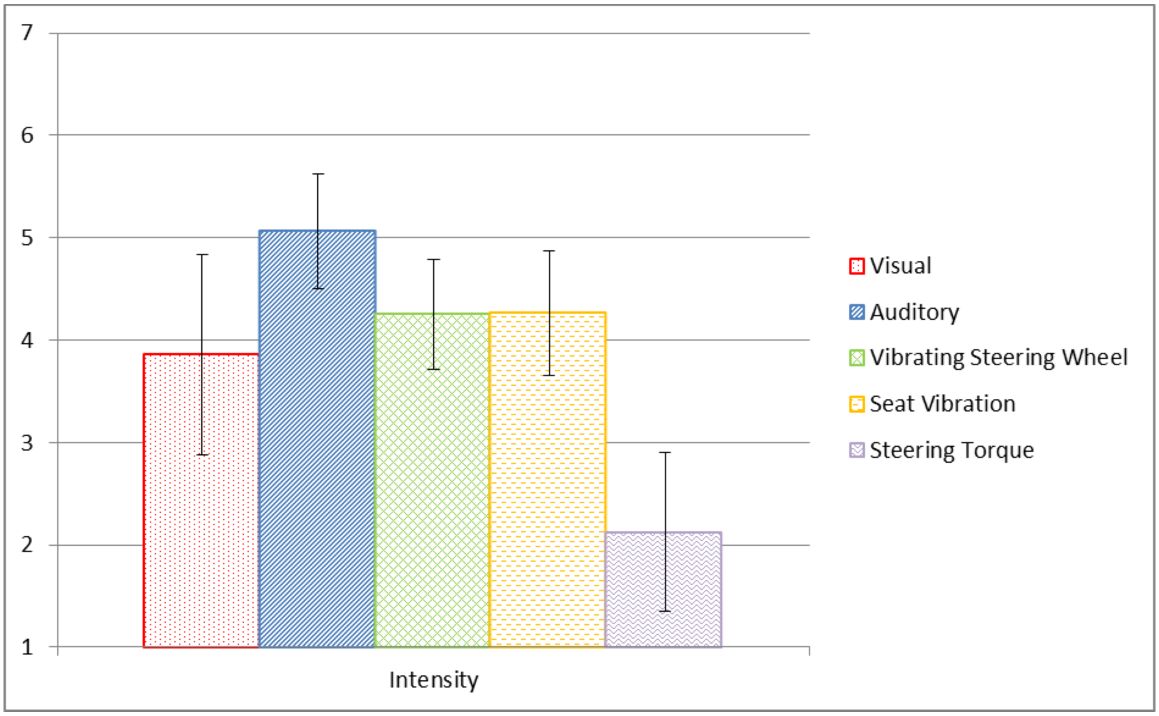

Figure 67. Driver Perception of Alert Intensity (Closer to Four is Better)

The final three significant effects are shown in Figure 66 and relate to the drivers willingness to rely on the alert, their confidence in the system and their self-confidence to handle the lane departure. With regard to willingness to rely on the alert, all of the alerts had means below the midpoint of the scale. The steering wheel torque showed the lowest overall score and was worse than all but the visual alert. Regarding confidence in the system, drivers with the seat vibration alert expressed more confidence than the drivers with the visual and the steering wheel torque alerts. With regard to self-confidence to handle the lane departure, the averages were at or above the midpoint, and drivers with the auditory alert expressed more self-confidence than the drivers with the vibrating steering wheel and the steering wheel torque alerts.

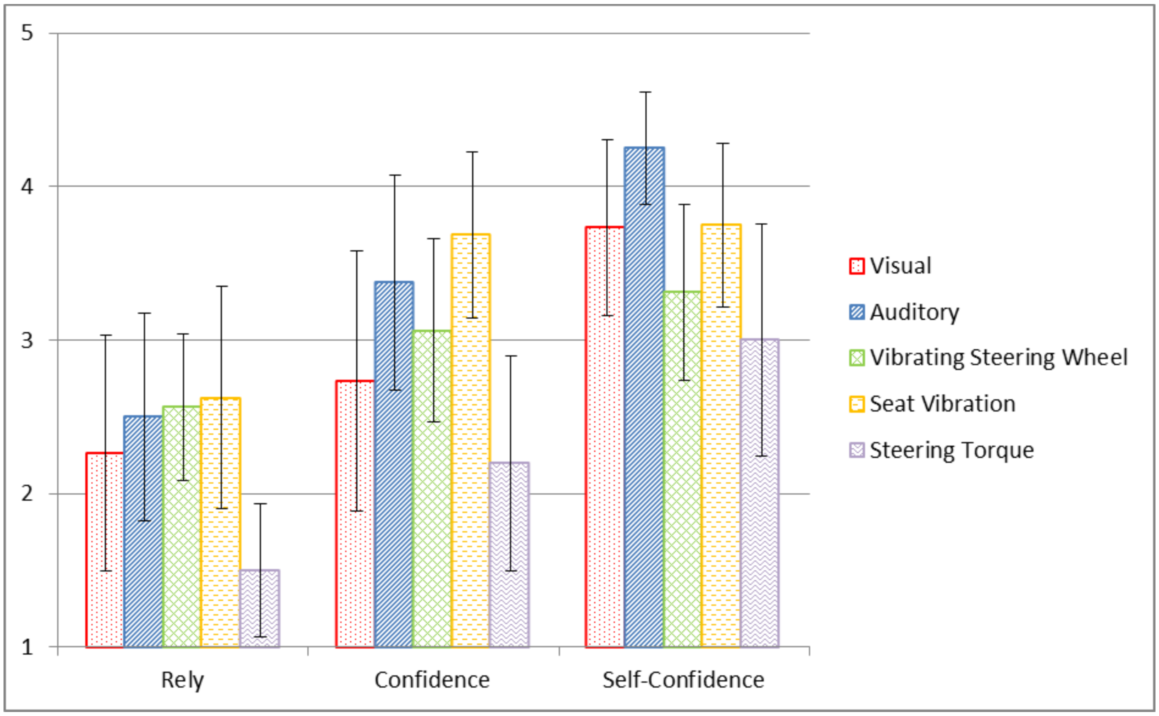

Figure 68. Driver Perception of How Much Driver Relied on Alert, Confidence in the System, and Self-Confidence (Closer to Five is Better)

With the results of the various sub-scales showing some differences in outcome, it was desirable to have a composite measure of acceptance. The aim was to combine the measures in such a way as to differentiate between the warning types. A variety of linear and not linear combinations of the significant effects were examined. Two key metrics were identified for inclusion in the composite LDW acceptance measure: ability to hear/feel, and confidence in the system.

$$LDW\ Acceptance = Hear/Feel + Confidence$$

Using this composite measure of acceptance there was a significant difference between warning types (p=0.0002). The composite measure shows (see Figure 69) the steering wheel torque alert with the significantly lower acceptance compared to the other alerts, and with the auditory and seat vibration alerts having significantly greater acceptance than the visual alert.

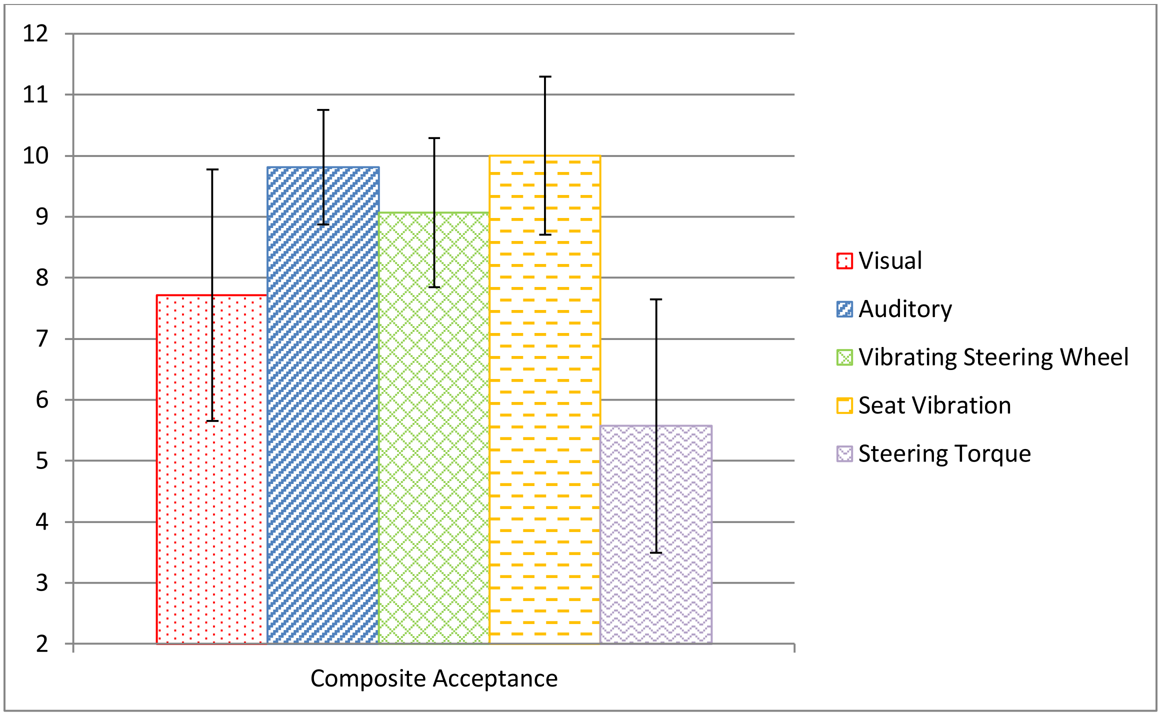

Figure 69. Composite LDW Acceptance by Warning Type (Closer to Twelve is Better)

6.3.2 Forward Crash Warning System

When looking at the acceptance data for forward crash warning systems, there was only one significant effect related to warning type. There was a significant effect ($p = 0.0415$) for the ability to hear/feel the alert. The differences between alerts are illustrated in Figure 70. The results showed that the auditory alert was significantly easier to hear/feel than brake pulse alert and seat vibration; and that the seat belt alert was easier to hear/feel than the brake pulse alert. There were no other significant effects, and with only one measure showing differences in acceptance between alerts no attempt was made for a composite measure.

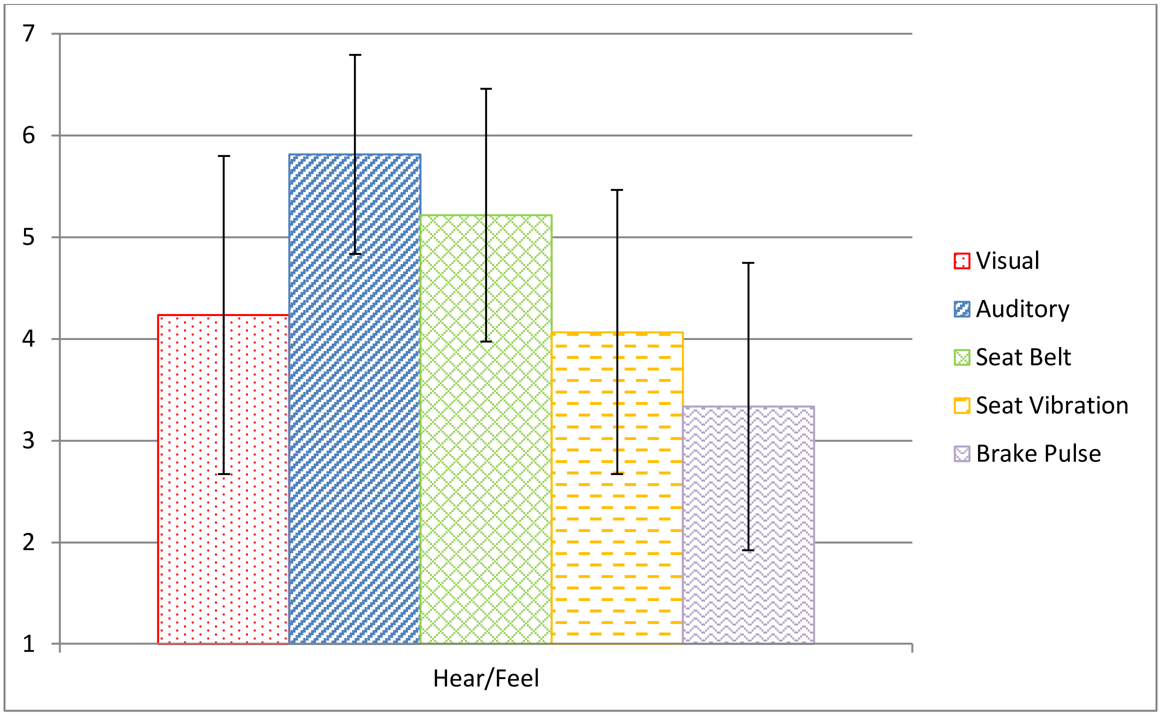

Figure 70. Driver Perception of the Ease of Hearing or Feeling the Alert (Closer to Seven is Better)

6.4 Consideration of a Composite Measure

One of the aims of the research was to explore a composite measure that could be used across DVIs and System type to identify differences between DVIS when considering both effectiveness and acceptance. Exploration of this during the analysis of the results from this study has shown that there is not a consistent pattern of results between systems for effectiveness and acceptance that would provide the basis for developing a composite measure. Time to End of Visual Commitment from alert provided a strong ability to evaluate the effectiveness of DVIs across systems, but the outcome and response measures for the LDW and FCW systems differ significantly. When considering the data overall, an evaluation of the means may be misguided from a protocol perspective. The aim of these systems is to reduce, or “pull in” the tails of the distributions to avoid more negative outcomes such as rear end crashes and striking oncoming cars. For this reason, rather than a composite measure considering the means, it is recommended that the protocol consider changes in the distributions such as moving the median and the first or third quartiles.

6.5 Discussion

When considering the timing of the alerts and the impact on evaluation of DVIs consideration needs to be given to the complexities of the interaction between timing and warning type for both lane departure and forward crash events. LDW DVIs seemed to show the greatest impact of warning timing with the two timings providing different determinations as to the ordering of benefit of the DVI to initiate a driver response. This may be in part because the earlier warning resulted in more alarms not associated with the planned events across the drive. The presence of these potential nuisance alarms could have changed how drivers responded to more critical alerts such as the forced departures. This would argue toward a later warning to minimize the impacts of these potential nuisance alarms. For forward crash events, there was no clear indication that one of timings used in this study would be better than the other for evaluating the DVIs, but instead that it would shift the values based on the timing. Overall, when considering the acceptance of the LDW and FCW systems, there was not a clear differentiation amongst the alerts, but some were more acceptable than others particularly for the LDW systems. The steering torque alert was viewed least acceptably with the visual alert performing only slightly better. For the FCW no clear conclusions can be drawn with regard to overall acceptance, but the auditory and seat belt alerts were regarded better than some of the other alert types with regard to ease of detection.

6.6 Protocol Implications

6.6.1 Warning Timing

Our recommendation for timing is that for LDW systems, very early alert timing that results in many nuisance alarms not be used, but instead a later alert be used. This later warning need not be the used in a final protocol for evaluating DVIs, but something near that value would seem to work effectively based on these results. When considering the evaluation of DVIs for FCW systems, warning timing in the range tested in this study would be appropriate as timing had little effect on differences between the DVIs and instead just shifted the values. For the final protocol, this could easily mean that using the timing from the production system may provide an effective comparison so long as they do not differ significantly from the range of timings tested.

6.6.2 False Alarms

The false alarm events provided limited insight to driver response to alarms not related to actual threats to the driver. The FCW false alarm event did not find differences between the warning types. The LDW false alarms provided no clear differentiation of effect for time to end of visual commitment due to a muddled three-way interaction but did allow us to differentiate in terms of steering reaction. Overall, the false alarms used seem effective for the LDW systems but not for the FCW system.

7 Motion Feedback Considerations

7.1 Specific Method

The aim of this study was to examine the effect of motion on driver response to crash warning DVI. The third main study revisited experimental platform by replicating a portion of the final protocol on NADS-1 at two levels of lower fidelity: limited motion and no motion. The incentive structure, distraction task, and level of familiarity used during this data collection were those identified previously and used in Main Study 2.

7.1.1 Hypotheses

There were three main hypotheses for this study:

- For DVIs that do not provide vestibular inputs, there will be no significant differences in initial driver response across simulator platforms.
- For DVIs that provide vestibular inputs, there will be a significant difference in initial driver response between simulator configurations that provide motion cueing relative to the no motion configuration.
- There will be a significant difference between simulator configurations in terms of collisions, minimum time-to-collision, and area of exceedance.

7.1.2 Experimental Design

The experimental design was a 3x3 between-subject design, shown in Table 28. The independent variables were three levels of platform (NADS-1, NADS-1 limited motion, and NADS-1 with no motion) and three levels of alert modality (no alert and two modalities shown to be the most effective based on the results of Main Study 2). Platform had three levels: NADS-1, NADS-1 limited motion, and NADS-1 no motion. No new data were collected on NADS-1 with full motion for this study. The two alert modalities in addition to no alert were decided based on the second main study.

Table 28. Main Study 3 Experimental Design

Platform		Alert Modality: No Alert	Auditory	Seat Vibration(LDW) Seat Belt Tensioner (FCW)
	NADS-1	Collected in Main 2	Collected in Main 2	Collected in Main 2
	NADS-1 Limited motion	8 participants	8 participants	8 participants
	NADS-1 No motion	8 participants	8 participants	8 participants

7.1.3 Dependent Measures

The following measures were analyzed for the FCW and LDW events:

- Time to end of visual commitment from warning
- Duration of first visual commitment
- Engagement duration
- Visual commitment duration
- Glances back to roadway
- Time-to-collision at the end of visual commitment
- Collision
- Minimum time to collision
- Adjusted minimum TTC
- Brake reaction time
- Maximum lane exceedance
- Area of lane exceedance
- Duration of lane exceedance
- Steering reaction time

7.1.4 Participants

Forty-eight participants completed all study procedures successfully. Fifty-nine participants were enrolled, and eleven participants were dropped for the reasons documented in Table 29.

Table 29. Participants Enrolled by Condition

	Limited Motion						No Motion						
	No Warning		Auditory		Haptic3		No Warning		Auditory		Haptic3		
	F	M	F	M	F	M	F	M	F	M	F	M	Total
Enrolled	6	4	8	4	8	4	4	4	5	4	4	4	59
Simulator sickness	1		3		2								6
Didn't engage in task	1								1				2
Drive affected by illness					1								1
Bad video					1								1
No LDW event			1										1
Completed	4	4	4	4	4	4	4	4	4	4	4	4	48

7.1.5 Apparatus

These remained the same as used in the second main study (see Section 5).

7.1.6 Experimental Procedures

The general experimental procedures were described in Section 2. Study-specific procedures for this experiment are documented below.

7.1.6.1 Experimental Ruse and Deception

Participants were told that the goal of the research was to evaluate several new in-vehicle technologies, when in fact their response to surprise LDW and FCW events was being evaluated.

7.1.6.2 Headway

Participants were instructed to maintain position in the green zone of the headway display provided.

7.1.6.3 Training

Subjects were provided a training presentation that provided details on the drive, navigation instruction, headway display, secondary task and general procedures.

Additionally, participants practiced the number recall task before going into the simulator to become comfortable with performing the task. Participants were prompted to engage with the task consistent with the method in the simulator. They were asked to practice until they could perform the task successfully. The criterion for the task is documented in Table 26.

Table 30. Criterion for Distraction Task Training

Task	**Criterion**
Number Recall	All five numbers correct with no sequence errors

7.1.6.4 Compensation

Compensation for this study was selected based on the results of the prior study. Base compensation was set at $45. The base pay was pro-rated. If participation lasted less than 1 hour, participants earned $10. If participation lasted for over 1 hour, participants earned the full base pay.

7.1.7 Scenarios

Scenarios used for this study were the same as those used in Main 1 (see Section 5.1.7).

7.1.8 Analysis Plan

After verification of the data, one primary analysis was conducted to address the hypotheses. The analysis focused on the main effects of simulator platform and warning DVI and their interaction. The analysis focused on the extent to which differences between warning DVIs were consistent across simulator platform. The primary measures of interest were driver's initial response, including time to end of visual commitment, and reaction time. Additionally response and outcome measures are also evaluated

The output of this study was an understanding of the role of motion in driver response to crash warning DVIs and the final elements to include in the overall evaluation protocol.

7.2 Results

Our recommendation for motion is to provide full motion cueing for FCW evaluations but to use whatever motion capabilities are available for LDW evaluations. The following results form the basis of that recommendation.

7.2.1 Lane Departure Events

When looking at the two key endpoints for response to the alert for lane departure events, there was a significant effect for motion but not for warning type for steering reaction time. There were no significant effects for time to visual commitment end by motion or warning type. There were no significant interactions for these measures. Motion (p=0.0220) had significant impacts on steering reaction time. Figure 71 shows the impact motion on steering reaction time. As can be seen, the steering reaction to the alert is delayed when no motion cues are provided. Warning type did not have a significant effect on steering reaction time (p=0.1801). Neither motion nor warning type significantly effected time to visual commitment end (p=0.0840, p=0.0733, respectively). There were no significant interactions for either measure with motion.

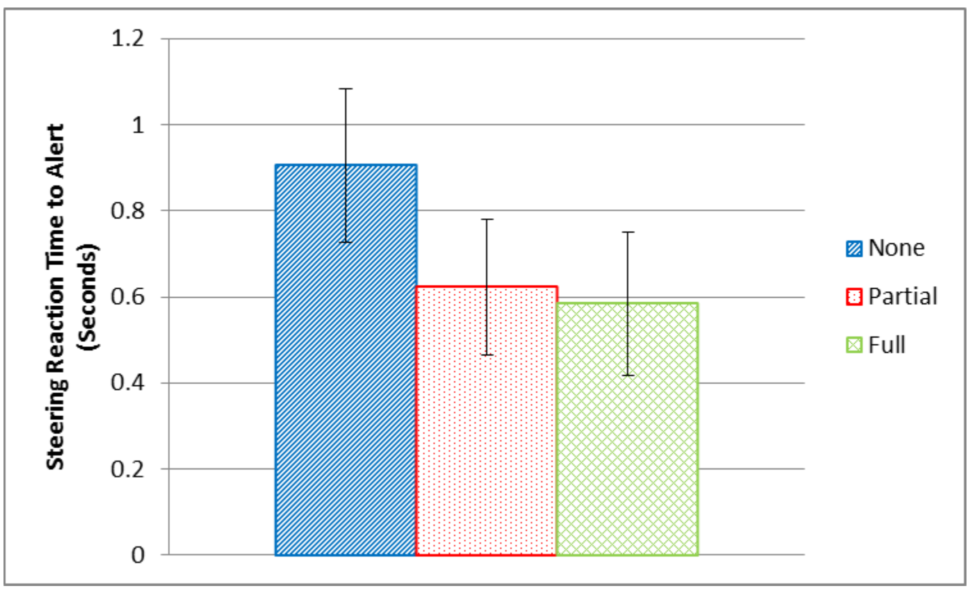

Figure 71. Effect of Motion on Steering Reaction Time

Motion had several other significant effects on visual commitment and the outcome of the lane departure events. Both the initial visual commitment duration (p=0.0032) and total visual commitment duration (p= 0.0039) were significant – engagement duration was also significant but aligned with visual commitment duration and is not reported here. Figure 72 shows the two sets of results. For overall duration, there are significantly shorter commitments with no and partial motion compared to full motion; however, for initial commitment partial motion results in a significantly shorter commitment compared to no motion and full motion. There is also a significant effect of motion on the duration of the lane exceedance (p=0.0185). For this measure, the duration of the departure is greater with no motion compared to partial motion, but full motion does not differ statistically from either no motion or partial motion.

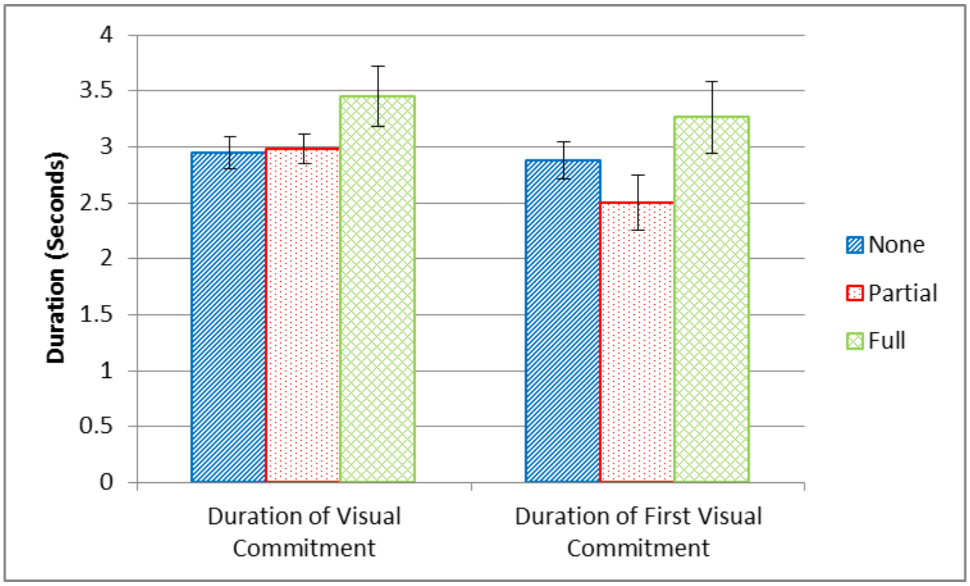

Figure 72. Effect of Motion on Visual Commitment

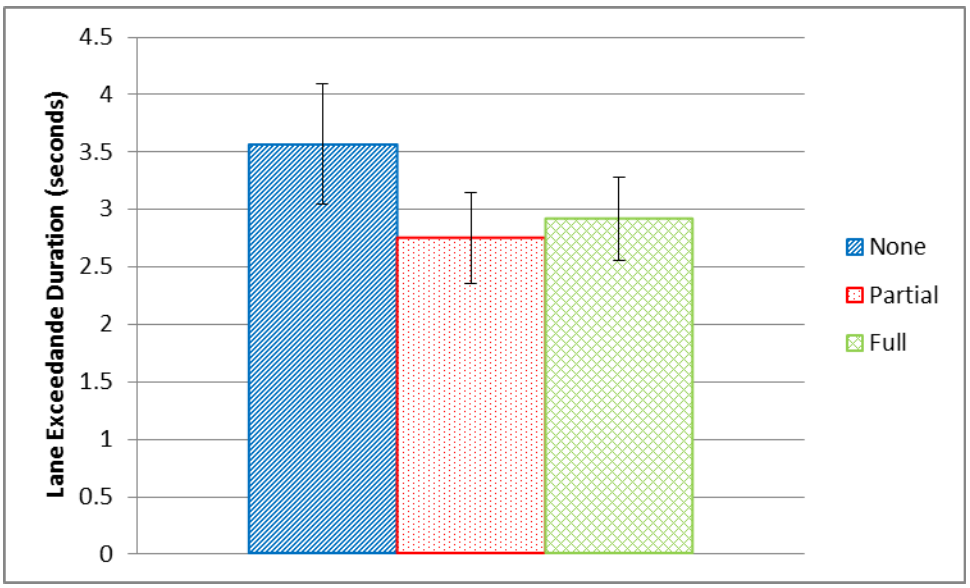

Figure 73. Effect of Motion on Duration of Lane Exceedance

There was also a significant effect of warning type on visual commitment duration (p=0.0458). As can be seen in Figure 74, the auditory alert resulted in a significantly longer commitment duration compared to the seat vibration.

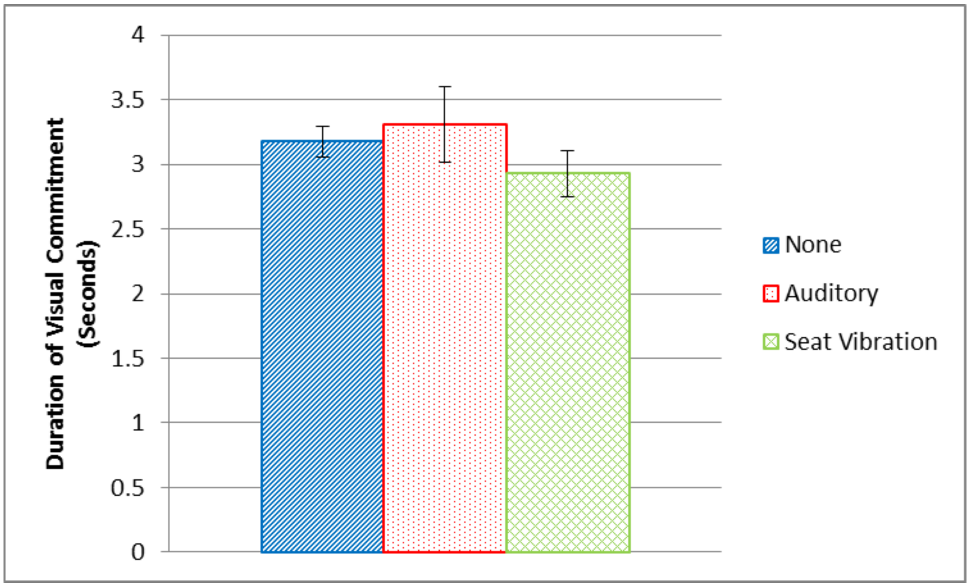

Figure 74. Effect of Warning Type on Visual Commitment Duration

7.2.2 Forward Crash Events

When looking at the two key endpoints for response to the alert for forward crash events there are a number of interactive effects that must be considered before the main effects for motion and warning type. There are two significant three way interactions that include motion and warning type. First the interaction between motion, warning type and gender is considered for time to visual commitment end (p=0.0435) – this interaction was not significant for brake reaction time (p = 0.0677). The interaction for time to visual commitment end is illustrated in Figure 75. As can be seen, the relationship is complex with consistent pattern across motion conditions, although the general trend is for auditory and seat belt tensioner to have shorter times than when no warning is present. Next the interaction between motion, gender and event is considered. This interaction is significant for both time to visual commitment end (p =0.0187) and brake reaction time (p=0.0342). These results are illustrated in Figure 76 and Figure 77, respectively. In examining these interactions, a consistent pattern that would support clear main effects is not found; however, in general, when collapsing across genders the second event has a faster response time.

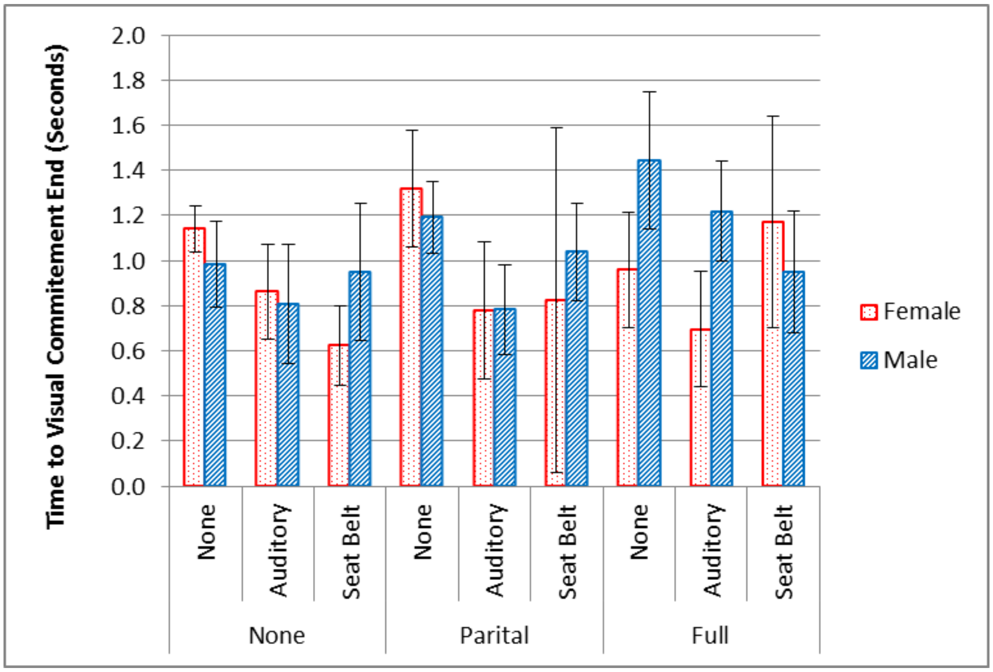

Figure 75. Effects of Motion, Warning Type and Gender on Time to Visual Commitment End

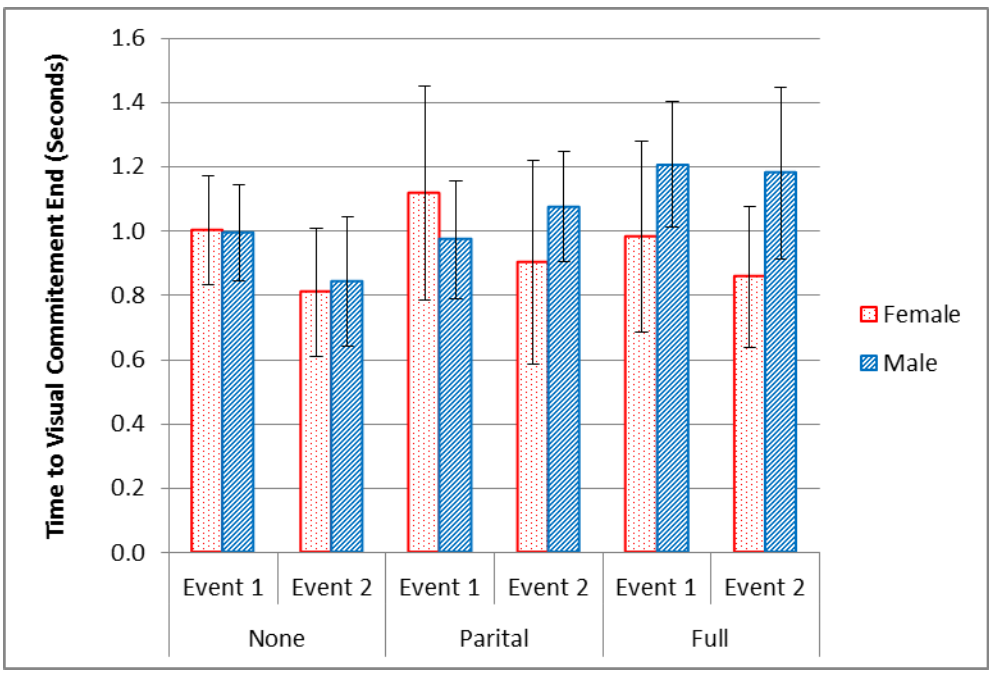

Figure 76. Effects of Motion, Event and Gender on Time to Visual Commitment End

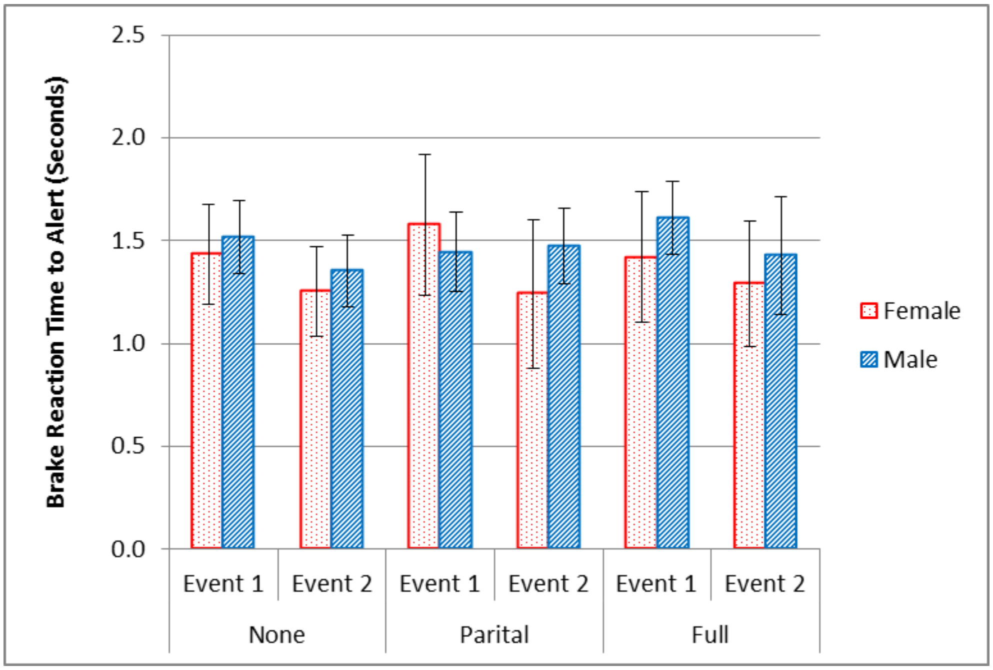

Figure 77. Effects of Motion, Event and Gender on Brake Reaction Time

When considering the other effects associated with motion and warning type, the other visual commitment measures also have complex three-way interactions between motion, warning type and gender with no clear main effect. The same is true for outcome measures such as adjusted minimum TTC. Due to their complexity and lack of additional insight, they are not presented here.

7.3 Discussion

When considering the effect of motion on the evaluation of DVIs for crash warning systems, the primary concern is for interactive effects between motion and warning type. For the lane departure events, interactive effects of this type were not a concern. The main effects of motion largely shifted the distribution but didn't change relative effectiveness of the DVIs. When looking at impact of no motion, there tend to be shorter engagements with secondary task but more severe outcomes (longer duration lane exceedances). When looking at the impact of partial motion, there tend to be shorter engagements and less severe outcomes. It is important to note that one limitation of this study is that although it precisely controls for the study of motion effects, it does not provide insight into how, for example, a simulator with a smaller forward field of view would perform, even if it had the same motion capabilities as NADS-1.

The concern about interactive effects becomes particularly acute for the forward crash events. The plethora of interactive effects associated with motion and/or warning type makes definitive determinations difficult. For example, females tend to have decreasing TTVCE with motion for auditory, but increasing for seat belt; whereas, males are more consistent across motion for seat belt, but longer time to visual commitment end with increasing motion cueing for others. NADS-1 with full motion capabilities is the closest of the three motion configurations to real world driving and absent information indicating similar results with less motion, care must be taken when collecting, analyzing, and interpreting data on DVIs for FCW systems.

7.4 Protocol Implications

7.4.1 Motion

Based upon the results of this study, two recommendations can be made regarding motion. Lack of full motion seems to have little effect on relative performance of the LDW DVIs indicating that partial or no motion is likely acceptable for these types of evaluations. The same is not true for FCW evaluations. The complex interactions point to the need to match the real world as closely as possible. This would argue for using the highest fidelity motion cueing available.

8 Crash Warning Evaluation in a Connected Vehicle Environment

8.1 Specific Method

The aim of this study was to test the protocol elements executed in the Main 2 study using distraction tasks that did not interfere with assessing visual FCW presented in the driver's forward view to provide an understanding of how distraction task type affects evaluation of the crash warning DVIs. This study presented alert modality for both the FCW and LDW systems through three levels of alert modality to participants. However, only the FCW events are included in the current analysis. The incentive structure and level of familiarity used during this data collection were those used in Main 2. After the surprise events, false alarm events were presented to the driver to examine response false positive or nuisance events.

8.1.1 Hypotheses

There was one main hypothesis for this study:

- The protocol and warning set developed to date is robust enough to detect differences in driver response to a visual and/or haptic crash warning compared to a no-warning baseline condition while the driver is engaged in a cognitively and visually demanding information search task emulating a Connected Vehicle system

8.1.2 Experimental Design

The CWIM-CV had a 3-level between-subject experimental design (see Table 31). Three levels of alert modalities were used; no alert, visual, and haptic for both the FCW and LDW systems. Although the LDW events will remain in the study drive, they are not included in this experimental design and are not be part of the data reduction or analysis.

Table 31 Experimental Design

Alert Modality		
No alert	Visual	Haptic
8 participants	8 participants	8 participants

8.1.3 Dependent Measures

The following measures were analyzed for the FCW events:

- Time to end of visual commitment from warning

- Duration of first visual commitment
- Engagement duration
- Visual commitment duration
- Glances back to roadway
- Time-to-collision at the end of visual commitment
- Collision
- Minimum time to collision
- Adjusted minimum TTC
- Brake reaction time

8.1.4 Participants

Twenty-four participants completed all study procedures successfully. Twenty-nine participants were enrolled, and five participants were dropped for the reasons documented in Table 32.

Table 32. Participants Enrolled by Condition

	No Warning		Visual		FCW – Seat Belt Tensioner		
	F	M	F	M	F	M	
Enrolled	5	5	6	4	4	5	29
Simulator Sickness	1		1				2
Bad FCW events		1	1			1	3
Completed	4	4	4	4	4	4	24

8.1.5 Apparatus

These remained the same as used in the first main study (see Section 5).

8.1.6 Experimental Procedures

The general experimental procedures were described in Section 2. Study-specific procedures for this experiment are documented below.

8.1.6.1 Experimental Ruse and Deception

Participants were told that the goal of the research was to evaluate several new in-vehicle technologies, when in fact their response to surprise LDW and FCW events was being evaluated.

8.1.6.2 Headway

Participants were instructed to maintain position in the green zone of the headway display provided.

8.1.6.3 Training

Subjects were provided a training presentation that provided details on the drive, navigation instruction, headway display, secondary tasks and general procedures.

Additionally, participants practiced with the distraction tasks before going into the simulator to become comfortable with performing each task. Participants were prompted to engage with the tasks consistent with the method in the simulator. They were asked to practice until they could perform each task successfully. The criterion for the task is documented in Table 33.

Table 33. Criterion for Distraction Task Training

Task	Criterion
Information Task	Familiar with information on twelve secondary screens
Message Task	Successfully tapped screen to display message and read message aloud

8.1.6.4 Compensation

Compensation for this study was selected based on the results of the prior study. Base compensation was set at $45. The base pay was pro-rated. If participation lasted less than 1 hour, participants earned $10. If participation lasted for over 1 hour, participants earned the full base pay.

8.1.7 Scenarios

Scenarios used for this study were the same as those used in Main 1 (see Section 5.1.7) with the exception that the CV information search task and message reading task were used in the order shown in Table 34. The information search task always associated with the FCW and LDW events.

Table 34. Scenario Order of Events

Event Number	Event Order 1
1	Information Search 1
2	Message Reading 1
3	Message Reading 2
4	Information Search 2
5	Information Search 3
6	Message Reading 3
7	Message Reading 4
8	Information Search 4
9	Information Search 5
10	Information Search 6
11	Information Search 7
12	Message Reading 5
13	Information Search 8
14	Information Search 9
15	Information Search 10
16	Message Reading 5
17	Information Search 11
18	Information Search 12
19	Information Search 13
20	Message Reading 6
21	Information Search 14
22	Information Search 15

8.1.8 Analysis Plan

After verification of the data, primary analyses were conducted to address the hypothesis. The analyses focused on the on whether CV tasks could be used to evaluate the DVIs for crash warning systems. The scope of this experiment included only the analysis of the forward crash events. The output of this study was an understanding of how the use of tasks similar to those that would be used in a connected vehicle environment would affect the evaluation of crash warning DVIs.

8.2 Results

When looking at the two key endpoints for response to the alert for forward crash events several challenges in analyzing the data were encountered. As each subject had the opportunity for two braking events, there were a total of 48 possible braking events to analyze. In examination of the data, there were a total of eleven braking events (22.9%) where the end of visual commitment could be attributed the alert (seven for the first event, and 4 for the second event); additionally, there were a total of seventeen braking events (35.4%) where the braking came after the alert and could have been impacted from the alert. The distribution for both of the primary measures can be found in Table 35 and Table 36. Overall, 25% of the FCW events did not fire because the driver was not appropriately engaged in the task. The biggest challenge with the scarcity of the data is that, despite the fact that each driver was attending to the display as the event began for one of their two events, there are no usable data for the no warning condition making it impossible to assess the benefit of the system relative to the no warning condition.

Table 35. Visual Commitment Outcomes by Event

		Warning Condition		
		No Warning	HUD	Haptic
First Event	Visual Commitment Ended before Alert	0	5	4
	Null Event	3	0	0
	Event Didn't Fire	5	0	0
	Visual Commitment Ended after Alert	0	3	4
Second Event	Visual Commitment Ended before Alert	2	2	4
	Null Event	3	1	1
	Event Didn't Fire	3	4	0
	Visual Commitment Ended after Alert	0	1	3

Table 36. Brake Applications Outcomes by Event

		Warning Condition		
		No Warning	HUD	Haptic
First Event	Brake Application before Alert	0	0	0
	Null Event	3	2	2
	Event Didn't Fire	5	0	0
	Brake Application after Alert	0	6	6
Second Event	Brake Application before Alert	0	0	0
	Null Event	5	3	4
	Event Didn't Fire	3	4	0
	Brake Application after Alert	0	1	4

With this in mind, we can still examine the data from the seventeen brake applications. In analyzing this data, there was no statistical difference between the HUD and Seat Belt (p=0.4813), with the HUD having a brake reaction time of 2.32 seconds versus the seat belt tensioner having a brake reaction time 2.26 seconds. This difference between the two alerts is consistent with the difference from the Alert Timing and Protocol Sensitivity Study which showed a difference of 0.03 seconds between the two alert modes.

In trying to better understand engagement with the connected vehicle task, engagement with the secondary task is considered. Due to the nature of the task, overall duration of the task was longer for the connected vehicle task than for the numbers task by design; however examination of the initial visual commitment does shed some light on the differences between experiments. For the connected vehicles task, there was no statistical difference in initial visual commitment duration by warning type (p=0.6375), but there was by gender (0.0341) with females have shorter initial visual commitments than males. Figure 78 shows the differences by gender for both the connected vehicle task and for the numbers task. As was stated in the discussion of the Alert Timing and Protocol Sensitivity Study, there was also a statistical difference in initial visual commitment duration between females and males with the numbers task (p=0.0335); although the magnitude of the difference differed with a 250 ms difference for the numbers task and a 720 ms difference for the connected vehicle task. An even bigger difference exists between the two tasks than for gender with the initial visual commitment duration for the connected vehicles task being 1140 ms shorter than for the numbers task.

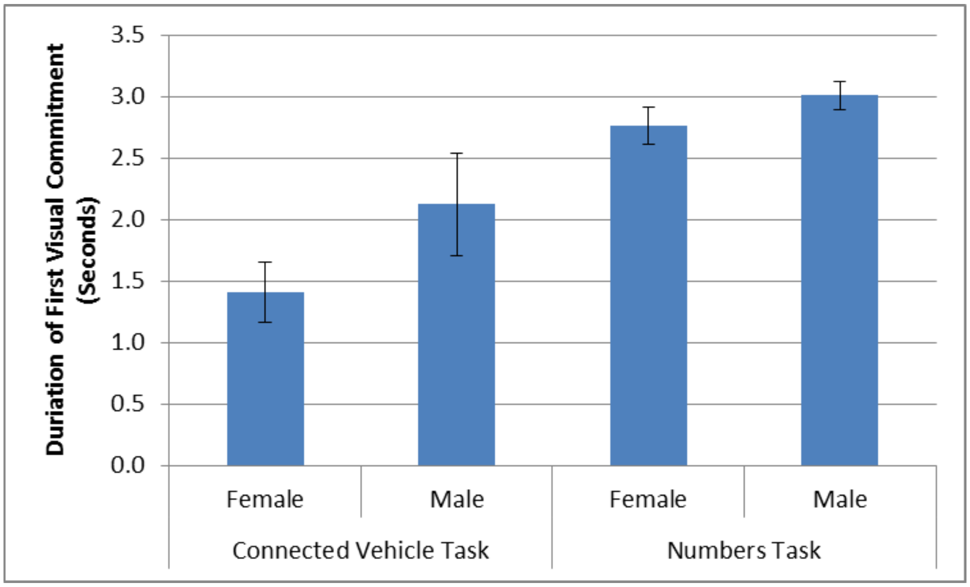

Figure 78. Initial Visual Commitment Duration by Gender and Task

8.3 Discussion

One of the premises of the CWIM effort was that drivers sometimes, if rarely, engage in tasks that require unusually long glances or choose to employ long glances away from the forward view. Whether this is due to the task design or the driver simply finds the task compelling in that moment, the protocol developed in this effort allows the evaluation of FCW and LDW DVIs within that context. During the CV portion of this effort, a task that did not require long glances and was positioned near the forward view was shown to be not well suited for this alert evaluation protocol. The CV task was designed to meet NHTSA's distraction guidelines for in-vehicle tasks, which require short glance times and tasks to be interruptible. The position of the CV task near the forward view also allowed changes in the driving environment to be detected in the driver's peripheral vision. Since this protocol was designed to evaluate FCW and LDW alerts when drivers employ longer glances away from the forward view to engage in a task that is not interruptible, it is not surprising that a task that met NHTSA distraction guidelines did not produce appropriate glance behavior. However, it should be noted that the goal of this effort was not to evaluate the distraction levels associated with specific tasks, but to evaluate DVIs within the context of tasks that require significant levels of visual commitment.

8.4 **Protocol Implications**

The main recommendation is to employ in-vehicle tasks that require long glances away from the forward view. It is possible that with large sample sizes, subtle differences in DVIs could be detected with tasks located near the forward view that require short glances.

9 General Discussion

Overall, the key implications of this line of research are that a protocol to evaluate the DVIs for crash warning systems is achievable but that that there are some nuances that will impact how the systems are evaluated. These can be categorized into six broad areas: test platform, general scenario issues, experimental procedures, motivation, measures, and sampling.

The first of these areas relates to test platform. It appears that it should be feasible to develop a protocol that could be used on either a test track on in the simulator; however, the constraints of the test track may limit the types of events that can be triggered. At least for forward crash events, the results appear similar between the environments and between a virtual test track and a virtual road course. The intent of using a test track for lane departure events is less clear due to the complexity of forcing a lane departure in conjunction with a particular task, but based on the frequency of unplanned lane departures while engaged in the tasks, it may still be possible to get the data needed. For simulators, it appears that there is some flexibility in motion fidelity. There are differences in DVI performance for FCW alerts based upon the motion configuration that need to be considered. Based on these findings, the use of the highest fidelity motion available would be recommended for forward crash events; however, lane departure events seem to work well across motion configurations. It should be noted that the experiments were all done with 360-degree visuals and a full vehicle cab, and the extent to which other simulator configurations would be effected is unknown.

The second area relates to general scenario configuration. For some of this, it is less clear exactly what is the best approach as it may be dependent upon the context of the overall evaluation. For example, what should we expect the driver to know about systems in their vehicle? Do we assume that they are aware of how the vehicle they are driving is configured and have some understanding of what the DVI is? For now, we have proceeded based on sensitivity and chosen based on the results to provide exposure but no training. If, however, if it becomes clear that one particular combination of awareness and exposure is predominant, then the protocol should be adjusted accordingly. The other major scenario configuration issue is the number of time to expose drivers to the alerts. It seems that drivers largely find the lane departure events to be the result of their engagement with the task and little differences is seen between events; however, differences between the first and second exposure to the FCW DVI in the context of a crash situation does result in differences, and as such, second exposures should probably be avoided in a final protocol.

The third area relates to experimental procedure. One of the most important considerations is the method of distracting the driver so that they can experience a surprise event during which the system DVI can be evaluated. This can prove to be challenging to do in a controlled manner as drivers have a natural inclination to be aware of their surrounding and how long drivers are willing to look away is effected by several factors including task location, and the nature of the task. Additionally, individual variability between drivers provides additional challenges. Of the distraction tasks examined in this work the number recall task performed the best overall in keeping the drivers eyes off the road long enough that events could be triggered. When comparing this experimental task to a more realistic in-vehicle task such as a proposed connected vehicle display, it did not perform well. In general, forward facing tasks do not provide the opportunity to reliably distract the participant long enough to effectively evaluate crash warning DVIs that would generally alert the driver in rare situations.

Additionally, tasks that are easily chunkable, such as the connected vehicle task, result in reduced effectiveness of the evaluation do to frequent opportunities to glance to the forward roadway. Overall, the number recall task was not perfect and still resulted in cases where the driver's attention was on the road at critical points when it should not have been. Another consideration is whether an incentive should be used to encourage drivers to remain engaged in the distraction task. Results from this research indicates that incentives can effect subject performance, but that they sometimes come with unintended consequences such as artificially encouraging subjects not to disengage with the incentivized task. Additionally appropriate instruction, training and experimental design can encourage the desired engagement with the secondary task. Based on this, the protocol should not include any financial incentive.

The fourth area relates to motivation. It is difficult in any experiment to replicate inherent driver motivation and that is only made more difficult when we consider the motivation that leads drivers to engage in a non-driving task that is of sufficient duration to result in a situation where a crash warning is necessary. The use of financial incentives is an attractive option; however, they do not provide a panacea to the issue of motivation. Participants have different motivations for volunteering to participate in a research study, and for many, the primary motivation is not financial. For those people, the incentive does not help to achieve the performance desired. Additionally, for those who have a financial motivation, they may overcompensate and not respond as expected when presented with a crash warning in the context of a study. This study found some concern to be born out in the data. As such, the use of financial incentives in this context is not recommended.

The fifth area relates to measures of DVI effectiveness. There is a plethora of measures that can be examined to assess system effectiveness and acceptance. These measures provide a variety of ways in which to examine effectiveness. As the systems are designed to alert the driver to an impending crash in an effort to get the driver to reengage with the driving task and begin an avoidance maneuver. The primary measures have thus been time to end of visual commitment and response time. It is important to understand that response time is a composite measure that includes not only the time to return visual commitment to the driving task but also the time to initiate the avoidance response. There is some evidence that this composite measure may illustrate that drivers adapt how quickly they begin their response after returning their attention to the road based on the situation. Other measures that show particular promise are adjusted minimum time to collision for FCW systems and duration of lane exceedance for LDW systems. Additional measures and additional ways of combining the measures need further examination.

The sixth relates to sampling. There were several results that showed differences by gender, particularly as it relates to engagement with the secondary task. Females appear to be less willing than males to engage in the secondary task as evidenced by longer times to begin the tasks, and shorter initial visual commitment durations. This is further complicated by the fact that gender interacts with warning type in several cases meaning that the interface that is most effective for males may not be the same one that is most effective for females.

Overall the results indicate a successful protocol can be developed but that careful consideration of competing interests must be considered.

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11 Appendix A: Phone Screenings

11.1 Test Track Comparison Study Opening

CWIM3 Screening Procedures

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

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

Overview

The purpose of this research study is to investigate headway maintenance.

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

Participating in this study involves one study visit that will last approximately 2 hours. You will be required to come to University Research Park (formerly the Oakdale Campus) to participate.

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

The base pay for participating in this study is $17.50. Additional compensation is available through incentives for task performance. The maximum available for the study is $45.

- **Willing to participate?**

  Are you still interested in participating?

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

11.2 Secondary Task and Incentive Considerations Study Opening – No Incentive

CWIM3 Screening Procedures

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

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

Overview

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

Study Information, Time Commitment and Compensation:

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

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

The compensation for completing all the study procedures is $45.

Willing to participate?

Are you still interested in participating?

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

11.3 Secondary Task and Incentive Considerations Study Opening – High Base

CWIM3 Screening Procedures

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

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

Overview

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

Study Information, Time Commitment and Compensation:

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

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

The base pay for participating in this study is $27.50. Additional compensation is available through incentives for task performance. The maximum compensation available for the study is $45.

Willing to participate?

Are you still interested in participating?

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

11.4 Secondary Task and Incentive Considerations Study Opening – Low Base

CWIM3 Screening Procedures

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

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

Overview

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

Study Information, Time Commitment and Compensation:

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

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

The base pay for participating in this study is $17.50. Additional compensation is available through incentives for task performance. The maximum compensation available for the study is $45.

Willing to participate?

Are you still interested in participating?

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

11.5 Remaining Studies

CWIM3 Screening Procedures

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

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

Overview

The purpose of this research study is to investigate new in-vehicle technologies.

Study Information, Time Commitment and Compensation:

Participating in this study involves one study visit that will last approximately 2 hours. You will be required to come to University Research Park (formerly the Oakdale Campus) to participate.

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

You will receive $45 for completing all study procedures.

Willing to participate?

Are you still interested in participating?

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

11.6 Phone Screening Questions and Closing

Inclusion Criteria ~ General Driving Questions

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

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

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

1) **Do you possess a valid U.S. Drivers' License and have been a licensed driver for two years?** (Must answer YES)

2) **Other than vision restrictions, is your drivers' license free of restrictions?** (Must answer YES)

3) **Do you drive at least 10,000 miles per year?** (Must answer YES)

4) **Are you between the ages: 35-55?** (Must answer YES)

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

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

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

8) **Would this be the first time you have participated in any simulator driving study involving any distraction?** (Must answer YES)

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

General Inclusion Criteria is met
Proceed to Health Screening Questions Below

General Health Exclusion Criteria

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

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

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

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

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

5) Have you ever suffered brain damage from a stroke, tumor, head injury, or infection? ➤ If YES, what are the resulting effects? ➤ Do you have an active tumor? ➤ Any visual loss, blurring or double vision? ➤ Any weakness, numbness, or funny feelings in the arms, legs or face? ➤ Any trouble swallowing or slurred speech? ➤ Any uncoordination or loss of control? ➤ Any trouble walking, thinking, remembering, talking, or understanding?
Exclusion criteria: • A stroke within the past 6 months • An active tumor • Any symptoms still exist

6) Have you ever been diagnosed with seizures or epilepsy? ➤ If YES, when did your last seizure occur?
Exclusion criteria: • A seizure within the past 12 months

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

8) Do you currently have a sleep disorder such as sleep apnea, narcolepsy or Chronic Fatigue Syndrome? ➤ If YES, please describe.
Exclusion criteria: • Untreated sleep apnea • Narcolepsy • Chronic Fatigue Syndrome

9) Do you have migraine or tension headaches that require you to take medication daily? ➤ If YES, please describe.
Exclusion criteria: • Any narcotic medications

10) Do you currently have untreated depression, anxiety disorder, drug dependency, claustrophobia, or ADHD? ➤ If YES, please describe

Exclusion criteria: • Untreated depression and ADHD • Dependency or abuse of psychoactive drugs, illicit drugs, or alcohol • Agoraphobia, hyperventilation, or anxiety attacks

11) Have you experienced any pain from neck or back injuries within the last year? ➢ If YES, is it current or chronic neck or back injury?
Exclusion criteria: • Any current skeletal, muscular or neurological problems in neck or back regions • Chronic neck and back pain • Pinched nerves in neck or back • Back surgery within last year

12) Are you currently taking any prescription or over the counter medications? ➢ If YES, what is the medication? ➢ Are there any warning labels on your medications, such as potential for drowsiness?
Exclusion criteria: • Sedating medications or drowsiness label on medication UNLESS potential participant indicates they have been on the medication consistency for the last 6 months AND states they have NO drowsiness effects from this medication

13) Do you experience any kind of motion sickness? ➢ If YES, what were the conditions you experienced: when occurred (age), what mode of transportation, (boat, plane, train, car), and what was the intensity of your motion sickness? ➢ On a scale of 0 to 10, **how often** do you experience motion sickness with **0 = Never and 10 = Always** ➢ On a scale of 0 to 10, **how severe** are the symptoms when you experience motion sickness with **0 = Minimal and 10 = Incapacitated**
Exclusion criteria: • One single mode of transportation where intensity is high and present • More than 2 to 3 episodes for mode of transportation where intensity is moderate or above • Severity and susceptibility scores rank high

14) Do you have any mobility issues that would make climbing down a short ladder or walking on a narrow walk way without assistance difficult for you to perform safely?
Exclusion criteria: • none; make note on schedule to ensure extra staff on hand

15) Do you currently have any medical issues with your right shoulder that would make reaching into the backseat difficult?
Exclusion criteria: • Any right shoulder ailment that would cause discomfort when turning and reaching towards backset

Proceed to Closing

Closing

<u>MEETS ALL CRITERIA</u>

Instructions:

- Refrain from drinking alcohol for 24 hours prior to your driving session.

- Please avoid taking any **NEW** prescription or over the counter drugs for the 24 hours preceding your driving session. If you do need to take a new medication 24 hours preceding your driving session, please call us. Ibuprofen, Tylenol, aspirin, and vitamins are acceptable to take prior to driving session.
- Bring Driver's License with you to appointment.
- If you use corrective lenses for driving please bring your glasses or contacts with you to the driving session. Bring reading glasses if needed to fill out questionnaires.
- We ask that cell phones and pagers be turned off or left home or in your car outside as they are not allowed while participating in the driving study.
- Request the following of all participants:
    - Wear flat shoes to drive in
    - No hats worn or gum chewing allowed while driving
    - Refrain from wearing artificial scents (perfume or cologne) as some staff allergic to scents
- You will be required to wear a seat belt while driving.

- If your appointment is before 8am or after 5pm, the front door will be locked, therefore, please use the After Hours Call Box located at the right side on the front door. Press the call button and someone will let you in**.**
- Provide directions, explain where to park and ask them to check in at the front desk inside the main entrance.
- Inform participants to call **(319) 335-4285** if they are unable to make this appointment and need to reschedule as soon as possible (prefer 24 hour notice). Please leave a message if they receive voicemail and a staff member will return their call.

DOES NOT MEET CRITERIA:

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

12 Appendix B: Informed Consent Documents

12.1 Test Track Comparison Study

INFORMED CONSENT DOCUMENT

Project Title: **Investigating Headway Maintenance**

Principal Investigator: **Timothy Brown**

Research Team Contact: **Dawn Marshall, 335-4776**

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

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

WHAT IS THE PURPOSE OF THIS STUDY?

This is a research study. We are inviting you to participate in this research study because you are between the ages of 35 and 55 years, hold a valid U.S. driving license, drive at least 10,000 miles per year, have no need for special equipment to help you drive and are in good general health

The purpose of this research study is to investigate headway maintenance while driving. Headway maintenance is the ability of the driver to maintain a safe following distance behind a lead vehicle.

HOW MANY PEOPLE WILL PARTICIPATE?

Approximately 60 people will take part in this study at the University of Iowa.

HOW LONG WILL I BE IN THIS STUDY?

If you agree to take part in this study, your involvement will last for about 2 hours.

WHAT WILL HAPPEN DURING THIS STUDY?

Upon arrival at the National Advanced Driving Simulator (NADS) at the University Research Park (formally the Oakdale Campus), study staff will verbally review this document with you, answer any questions you may have about the study, and provide you time to read this document. If you agree to participate you will be asked to sign this document. You will receive a copy of this signed Informed Consent Document.

Next, you will be asked to show your driver's license to confirm you have a valid U.S. driver's license and then fill out a payment form which asks for your social security number. Next, you will be asked to complete a questionnaire that covers some general demographic information (birth date, age, gender, marital status, total household income last year, present employment status, type of work, ethnic origins,

highest level of education) and driving information that include questions about your driving history including the type of vehicles you drive, your license history, driving violations and accidents, and driving habits. We will also ask you several health related questions including medication, drug and alcohol use, and history of motion sickness.

Next you will be asked to watch a PowerPoint presentation on the computer that gives you an overview of the simulator cab and drive, the purpose of the study, and the task that you may be asked to complete while driving. The task that you may be asked to complete involves number recall.

Then you will be escorted into the simulator. You will be asked to position yourself in the driver's seat and make adjustments as needed so that you are able to drive comfortably. You will be asked to look out the front windshield while we set the cameras for the eye tracking system to collect information about where you are looking during the drive. You will then be asked to complete one drive of approximately 35 minutes. After the drive you will complete one survey about you feel after completing the drive.

You will be able to earn money for completion of a task during the study drive. Several times you will be asked to complete a number recall task. On the first instance you, will earn $0.63 per number successfully recalled in the order presented. After the first instance, you will earn $1.06 per number successfully recalled in the order presented. If the number sequence you indicate is incorrect you will lose $0.40. Each instance of the number recall is separate and does not influence the amount of money you earn on the other recall tasks. The amount you earn cannot be less than $0 per number recall instance.

You will also be able to earn money for maintaining a specified distance from your vehicle to the vehicle in front of you. During your drive today, you will be asked to maintain a headway of 110 feet. A display is mounted on top of the dash to provide you with your headway distance. Compensation is available if you successfully stay within 15 feet of this target (95 to 125 feet). If you can stay in that range, you will receive $2.12 per straight segment following the practice. Each straight-away is separate and does not influence the amount of money you earn on the others.

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

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

Video Recording

All driving trials will be recorded on video using digital video/audio recordings that are placed so that we are able to view your face, your interactions with the vehicle displays, and the driver's view of the forward scene. The placement of the cameras will allow the researchers to record the simulator controls and your response to driving events.

The simulator contains sensors that measure vehicle operation, vehicle motion, and your driving actions. The sensors send this information to a computer where it is recorded and stored.

These sensors and video cameras are located in such a manner that they will not affect you or obstruct your view while driving. The information collected using these sensors and video cameras are recorded for analysis by research staff and may be used as described in the Confidentiality section below.

Future Studies
We will keep on file your name and information about you, including birth date, contact phone numbers, and the annual mileage you drive each year. In the future we may contact you to see if you would be willing to complete questionnaires, interviews or drives for future studies. Agreeing to participate in this study does not obligate you to participate in any future studies.

SOCIAL SECURITY NUMBER (SSN) USAGE

You will be asked to provide your social security number on the payment form that is sent to the University of Iowa Business Office. The collection of your social security number is to document your payment for participation in this study.

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

____ I do NOT allow you to collect or use my social security number for the purposes outlined above.

WHAT ARE THE RISKS OF THIS STUDY?

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

You will be asked to answer questions about your driving habits including illegal activities such as driving while intoxicated or under the influence. You will also be asked how often you engage in activities such as reading or sending text messages while driving. Reading or sending text messages while driving is illegal for adult drivers in the state of Iowa. You may skip any questions you do not wish to answer.

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

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

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

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

WHAT ARE THE BENEFITS OF THIS STUDY?

You will not benefit from being in this study. However, we hope that, in the future, other people might benefit from this study because information gained from this study will be used to develop new technologies which could lead to safer vehicles in the future.

WILL IT COST ME ANYTHING TO BE IN THIS STUDY?

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

WILL I BE PAID FOR PARTICIPATING?

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

You will be paid a base payment of $17.50. If your participation lasts less than 1 hour, you will earn $10. If your participation last for over 1 hour, you will earn the full base pay.

Additional payment is available through incentives based on your ability to correctly complete the secondary tasks and maintain a safe headway. The maximum amount available for incentive is $27.50.

The maximum amount of compensation available for completing all the study procedures is $45. If you are unable to complete the study, the base pay will be pro-rated, however, you will still receive any and all incentives that you had previously earned through the course of your participation.

WHO IS FUNDING THIS STUDY?

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

WHAT ABOUT CONFIDENTIALITY?

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

- federal government regulatory agencies,
- the study sponsor – the National Highway Traffic Safety Administration,
- auditing departments of the University of Iowa, and
- the University of Iowa Institutional Review Board (a committee that reviews and approves research studies)

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

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

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

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

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

IS BEING IN THIS STUDY VOLUNTARY?

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

Can Someone Else End my Participation in this Study?

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

WHAT IF I HAVE QUESTIONS?

We encourage you to ask questions. If you have any questions about the research study itself, please contact: Timothy Brown (319-335-4585). If you experience a research-related injury, please contact Timothy Brown (319-335-4585).

If you have questions, concerns, or complaints about your rights as a research subject or about research related injury, please contact the Human Subjects Office, 105 Hardin Library for the Health Sciences, 600 Newton Rd, The University of Iowa, Iowa City, IA 52242-1098, (319) 335-6564, or e-mail irb@uiowa.edu. General information about being a research subject can be found by clicking "Info for Public" on the Human Subjects Office web site, http://research.uiowa.edu/hso. To offer input about your experiences as a research subject or to speak to someone other than the research staff, call the Human Subjects Office at the number above.

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

Subject's Name (printed): ____

Do not sign this form if today's date is on or after EXPIRATION DATE: 02/05/13 .

______________________________ ______________________
(Signature of Subject) (Date)

Statement of Person Who Obtained Consent

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

______________________________ ______________________
(Signature of Person who Obtained Consent) (Date)

12.2 Secondary Task and Incentive Considerations Study – No Incentive

INFORMED CONSENT DOCUMENT

Project Title: Evaluation of Driving Performance while Engaging in Secondary Tasks

Principal Investigator: Timothy Brown

Research Team Contact: Dawn Marshall, 335-4774

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

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

WHAT IS THE PURPOSE OF THIS STUDY?

This is a research study. We are inviting you to participate in this research study because you are between the ages of 35 and 55 years, hold a valid U.S. driving license, drive at least 10,000 miles per year, have no need for special equipment to help you drive and are in good general health.

The purpose of this research study is to evaluate how drivers interact with different tasks while driving.

HOW MANY PEOPLE WILL PARTICIPATE?

Approximately 35 people will take part in this study at the University of Iowa.

HOW LONG WILL I BE IN THIS STUDY?

If you agree to take part in this study, your involvement will last for about 2 hours.

WHAT WILL HAPPEN DURING THIS STUDY?

Upon arrival at the National Advanced Driving Simulator (NADS) at the University Research Park (formally the Oakdale Campus), study staff will verbally review this document with you, answer any questions you may have about the study, and provide you time to read this document. If you agree to participate you will be asked to sign this document. You will receive a copy of this signed Informed Consent Document.

Next, you will be asked to show your driver's license to confirm you have a valid U.S. driver's license and then fill out a payment form which asks for your social security number. Next, you will be asked to complete a questionnaire that covers some general demographic information (birth date, age, gender, marital status, total household income last year, present employment status, type of work, ethnic origins,

highest level of education) and driving information that includes questions about your driving history including the type of vehicles you drive, your license history, driving violations and accidents, and driving habits. We will also ask you for several health related questions including medication, drug and alcohol use, and history of motion sickness.

Next you will be asked to watch a PowerPoint presentation on the computer that gives you an overview of the simulator cab and drive, the purpose of the study, the systems installed in the vehicle and the tasks you may be asked to complete while driving. The tasks that you may be asked to complete involve catching a virtual bug, a message reading task, a number recall task and a menu search task. Several times during the drive you will be asked complete one of these four tasks

You will also be asked to maintain a specified distance from your vehicle to the vehicle in front of you. During your drive today, you will be asked to maintain a headway of 185 feet. A display is mounted on top of the dash to provide you with your headway distance. You are asked to stay within 15 feet of this target (170 to 200 feet).

Then you will be escorted into the simulator and asked to complete one drive of approximately 35 minutes. After the drive you will complete one survey about you feel after completing the drive.

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

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

Video Recording
All driving trials will be recorded on video using digital video/audio recordings that are placed so that we are able to view your face, your interactions with the vehicle displays, and the driver's view of the forward scene. The placement of the cameras will allow the researchers to record the simulator controls and your response to driving events.

The simulator contains sensors that measure vehicle operation, vehicle motion, and your driving actions. The sensors send this information to a computer where it is recorded and stored. These sensors and video cameras are located in such a manner that they will not affect you or obstruct your view while driving. The information collected using these sensors and video cameras are recorded for analysis by research staff and may be used as described in the Confidentiality section below.

Future Studies
We will keep on file your name and information about you, including birth date, contact phone numbers, and the annual mileage you drive each year. In the future we may contact you to see if you would be willing to complete questionnaires, interviews or drives for future studies. Agreeing to participate in this study does not obligate you to participate in any future studies.

SOCIAL SECURITY NUMBER (SSN) USAGE

You will be asked to provide your social security number on the payment form that is sent to the University of Iowa Business. The collection of your social security number is to document your payment for participation in this study.

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

____ I do NOT allow you to collect or use my social security number for the purposes outlined above.

WHAT ARE THE RISKS OF THIS STUDY?

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

You will be asked to answer questions about your driving habits including illegal activities such as driving while intoxicated or under the influence. You will also be asked how often you engage in activities such as reading or sending text messages while driving. Reading or sending text messages while driving is illegal for adult drivers in the state of Iowa. You may skip any questions you do not wish to answer.

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

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

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

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

WHAT ARE THE BENEFITS OF THIS STUDY?

You will not benefit from being in this study. However, we hope that, in the future, other people might benefit from this study because information gained from this study about how different tasks impact driving performance may lead to increased safety on roadways.

WILL IT COST ME ANYTHING TO BE IN THIS STUDY?

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

WILL I BE PAID FOR PARTICIPATING?

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

The compensation available for completing all the study procedures is $45. If you are unable to complete the study procedures, your pay will be pro-rated based on the amount of time that you participated. You will earn $11.25 for every 30 minutes of participation with a $10 minimum.

WHO IS FUNDING THIS STUDY?

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

WHAT ABOUT CONFIDENTIALITY?

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

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

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

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

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

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

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

IS BEING IN THIS STUDY VOLUNTARY?

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

Can Someone Else End my Participation in this Study?

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

WHAT IF I HAVE QUESTIONS?

We encourage you to ask questions. If you have any questions about the research study itself, please contact: Timothy Brown (319-335-4585). If you experience a research-related injury, please contact Timothy Brown (319-335-4585).

If you have questions, concerns, or complaints about your rights as a research subject or about research related injury, please contact the Human Subjects Office, 105 Hardin Library for the Health Sciences, 600 Newton Rd, The University of Iowa, Iowa City, IA 52242-1098, (319) 335-6564, or e-mail irb@uiowa.edu. General information about being a research subject can be found by clicking "Info for Public" on the Human Subjects Office web site, http://research.uiowa.edu/hso. To offer input about your experiences as a research subject or to speak to someone other than the research staff, call the Human Subjects Office at the number above.

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

Subject's Name (printed): ____

Do not sign this form if today's date is on or after EXPIRATION DATE: 10/16/12 .

______________________________ ______________________

(Signature of Subject) (Date)

Statement of Person Who Obtained Consent

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

______________________________ ______________________

(Signature of Person who Obtained Consent) (Date)

12.3 Secondary Task and Incentive Considerations Study – High Base

INFORMED CONSENT DOCUMENT

Project Title: Evaluation of Driving Performance while Engaging in Secondary Tasks

Principal Investigator: Timothy Brown

Research Team Contact: Dawn Marshall, 335-4774

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

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

WHAT IS THE PURPOSE OF THIS STUDY?

This is a research study. We are inviting you to participate in this research study because you are between the ages of 35 and 55 years, hold a valid U.S. driving license, drive at least 10,000 miles per year, have no need for special equipment to help you drive and are in good general health.

The purpose of this research study is to evaluate how drivers interact with different tasks while driving.

HOW MANY PEOPLE WILL PARTICIPATE?

Approximately 35 people will take part in this study at the University of Iowa.

HOW LONG WILL I BE IN THIS STUDY?

If you agree to take part in this study, your involvement will last for about 2 hours.

WHAT WILL HAPPEN DURING THIS STUDY?

Upon arrival at the National Advanced Driving Simulator (NADS) at the University Research Park (formally the Oakdale Campus), study staff will verbally review this document with you, answer any questions you may have about the study, and provide you time to read this document. If you agree to participate you will be asked to sign this document. You will receive a copy of this signed Informed Consent Document.

Next, you will be asked to show your driver's license to confirm you have a valid U.S. driver's license and then fill out a payment form which asks for your social security number. Next, you will be asked to complete a questionnaire that covers some general demographic information (birth date, age, gender, marital status, total household income last year, present employment status, type of work, ethnic origins, highest level of education) and driving information that includes questions about your driving history including the type of vehicles you drive, your license history, driving violations and accidents, and driving habits. We will also ask you for several health related questions including medication, drug and alcohol use, and history of motion sickness.

Next you will be asked to watch a PowerPoint presentation on the computer that gives you an overview of the simulator cab and drive, the purpose of the study, the systems installed in the vehicle and the tasks you may be asked to complete while driving. The tasks that you may be asked to complete involve catching a virtual bug, a message reading task, a number recall task and a menu search task.

You will be able to earn money for completion of these tasks. Several times during the drive you will be asked complete one of the four tasks. The amount of the incentive will be based on well you do the tasks. Additional information about the tasks and the incentive will be provided before you drive.

You will also be able to earn money for maintaining a specified distance from your vehicle to the vehicle in front of you. During your drive today, you will be asked to maintain a headway of 185feet. A display is mounted on top of the dash to provide you with your headway distance. Compensation is available if you successfully stay within 15 feet of this target (170 to 200 feet).

Then you will be escorted into the simulator and asked to complete one drive of approximately 35 minutes. After the drive you will complete one survey about you feel after completing the drive.

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

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

Video Recording

All driving trials will be recorded on video using digital video/audio recordings that are placed so that we are able to view your face, your interactions with the vehicle displays, and the driver's view of the forward scene. The placement of the cameras will allow the researchers to record the simulator controls and your response to driving events.

The simulator contains sensors that measure vehicle operation, vehicle motion, and your driving actions. The sensors send this information to a computer where it is recorded and stored. These sensors and video cameras are located in such a manner that they will not affect you or obstruct your view while driving. The information collected using these sensors and video cameras are recorded for analysis by research staff and may be used as described in the Confidentiality section below.

Future Studies

We will keep on file your name and information about you, including birth date, contact phone numbers, and the annual mileage you drive each year. In the future we may contact you to see if you would be willing to complete questionnaires, interviews or drives for future studies. Agreeing to participate in this study does not obligate you to participate in any future studies.

SOCIAL SECURITY NUMBER (SSN) USAGE

You will be asked to provide your social security number on the payment form that is sent to the University of Iowa Business Office. The collection of your social security number is to document your payment for participation in this study.

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

____ I do NOT allow you to collect or use my social security number for the purposes outlined above.

WHAT ARE THE RISKS OF THIS STUDY?

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

You will be asked to answer questions about your driving habits including illegal activities such as driving while intoxicated or under the influence. You will also be asked how often you engage in activities such as reading or sending text messages while driving. Reading or sending text messages while driving is illegal for adult drivers in the state of Iowa. You may skip any questions you do not wish to answer.

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

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

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

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

WHAT ARE THE BENEFITS OF THIS STUDY?

You will not benefit from being in this study. However, we hope that, in the future, other people might benefit from this study because information gained from this study about how different tasks impact driving performance may lead to increased safety on roadways.

WILL IT COST ME ANYTHING TO BE IN THIS STUDY?

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

WILL I BE PAID FOR PARTICIPATING?

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

You will be paid a base payment amount of $27.50 for participation in the study. If your participation lasts less than 1 hour, you will earn $10. If your participation last for over 1 hour, you will earn the full base pay. You may earn additional payment based on your ability to correctly complete the secondary tasks and maintain a safe headway as described in the study procedures section. The maximum amount available for this payment is $17.50. The maximum amount of compensation available for participation in the study is $45. If you are unable to complete the study, the base pay will be pro-rated as described. However, you will still receive any and all incentives that you had previously earned through the course of your participation

WHO IS FUNDING THIS STUDY?

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

WHAT ABOUT CONFIDENTIALITY?

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

- federal government regulatory agencies,
- the study sponsor – the National Highway Traffic Safety Administration,
- auditing departments of the University of Iowa, and
- the University of Iowa Institutional Review Board (a committee that reviews and approves research studies)

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

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

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

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

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

IS BEING IN THIS STUDY VOLUNTARY?

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

Can Someone Else End my Participation in this Study?

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

WHAT IF I HAVE QUESTIONS?

We encourage you to ask questions. If you have any questions about the research study itself, please contact: Timothy Brown (319-335-4585). If you experience a research-related injury, please contact Timothy Brown (319-335-4585).

If you have questions, concerns, or complaints about your rights as a research subject or about research related injury, please contact the Human Subjects Office, 105 Hardin Library for the Health Sciences, 600 Newton Rd, The University of Iowa, Iowa City, IA 52242-1098, (319) 335-6564, or e-mail irb@uiowa.edu. General information about being a research subject can be found by clicking "Info for Public" on the Human Subjects Office web site, http://research.uiowa.edu/hso. To offer input about your experiences as a research subject or to speak to someone other than the research staff, call the Human Subjects Office at the number above.

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

Subject's Name (printed): ____

Do not sign this form if today's date is on or after EXPIRATION DATE: 02/23/13 .

____ ______________________________

(Signature of Subject) (Date)

Statement of Person Who Obtained Consent

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

____ ______________________________

(Signature of Person who Obtained Consent) (Date)

12.4 Secondary Task and Incentive Considerations Study – Low Base

INFORMED CONSENT DOCUMENT

Project Title: Evaluation of Driving Performance while Engaging in Secondary Tasks

Principal Investigator: Timothy Brown

Research Team Contact: Dawn Marshall, 335-4774

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

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

<u>WHAT IS THE PURPOSE OF THIS STUDY?</u>

This is a research study. We are inviting you to participate in this research study because you are between the ages of 35 and 55 years, hold a valid U.S. driving license, drive at least 10,000 miles per year, have no need for special equipment to help you drive and are in good general health.

The purpose of this research study is to evaluate how drivers interact with different tasks while driving.

<u>HOW MANY PEOPLE WILL PARTICIPATE?</u>

Approximately 35 people will take part in this study at the University of Iowa.

<u>HOW LONG WILL I BE IN THIS STUDY?</u>

If you agree to take part in this study, your involvement will last for about 2 hours.

<u>WHAT WILL HAPPEN DURING THIS STUDY?</u>

Upon arrival at the National Advanced Driving Simulator (NADS) at the University Research Park (formally the Oakdale Campus), study staff will verbally review this document with you, answer any questions you may have about the study, and provide you time to read this document. If you agree to participate you will be asked to sign this document. You will receive a copy of this signed Informed Consent Document.

Next, you will be asked to show your driver's license to confirm you have a valid U.S. driver's license and then fill out a payment form which asks for your social security number. Next, you will be asked to complete a questionnaire that covers some general demographic information (birth date, age, gender, marital status, total household income last year, present employment status, type of work, ethnic origins, highest level of education) and driving information that includes questions about your driving history including the type of vehicles you drive, your license history, driving violations and accidents, and driving habits. We will also ask you for several health related questions including medication, drug and alcohol use, and history of motion sickness.

Next you will be asked to watch a PowerPoint presentation on the computer that gives you an overview of the simulator cab and drive, the purpose of the study, the systems installed in the vehicle and the tasks you may be asked to complete while driving. The tasks that you may be asked to complete involve catching a virtual bug, a message reading task, a number recall task and a menu search task.

You will be able to earn money for completion of these tasks. Several times during the drive you will be asked complete one of the four tasks. The amount of the incentive will be based on well you do the tasks. Additional information about the tasks and the incentive will be provided before you drive.

You will also be able to earn money for maintaining a specified distance from your vehicle to the vehicle in front of you. During your drive today, you will be asked to maintain a headway of 185 feet. A display is mounted on top of the dash to provide you with your headway distance. Compensation is available if you successfully stay within 15 feet of this target (170 to 200 feet).

Then you will be escorted into the simulator and asked to complete one drive of approximately 35 minutes. After the drive you will complete one survey about you feel after completing the drive.

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

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

Video Recording
All driving trials will be recorded on video using digital video/audio recordings that are placed so that we are able to view your face, your interactions with the vehicle displays, and the driver's view of the forward scene. The placement of the cameras will allow the researchers to record the simulator controls and your response to driving events.

The simulator contains sensors that measure vehicle operation, vehicle motion, and your driving actions. The sensors send this information to a computer where it is recorded and stored. These sensors and video cameras are located in such a manner that they will not affect you or obstruct your view while driving. The information collected using these sensors and video cameras are recorded for analysis by research staff and may be used as described in the Confidentiality section below.

Future Studies
We will keep on file your name and information about you, including birth date, contact phone numbers, and the annual mileage you drive each year. In the future we may contact you to see if you would be willing to complete questionnaires, interviews or drives for future studies. Agreeing to participate in this study does not obligate you to participate in any future studies.

SOCIAL SECURITY NUMBER (SSN) USAGE

You will be asked to provide your social security number on the payment form that is sent to the University of Iowa Business Office. The collection of your social security number is to document your payment for participation in this study.

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

____ I do NOT allow you to collect or use my social security number for the purposes outlined above.

WHAT ARE THE RISKS OF THIS STUDY?

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

You will be asked to answer questions about your driving habits including illegal activities such as driving while intoxicated or under the influence. You will also be asked how often you engage in activities such as reading or sending text messages while driving. Reading or sending text messages while driving is illegal for adult drivers in the state of Iowa. You may skip any questions you do not wish to answer.

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

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

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

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

WHAT ARE THE BENEFITS OF THIS STUDY?

You will not benefit from being in this study.

However, we hope that, in the future, other people might benefit from this study because information gained from this study about how different tasks impact driving performance may lead to increased safety on roadways.

WILL IT COST ME ANYTHING TO BE IN THIS STUDY?

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

WILL I BE PAID FOR PARTICIPATING?

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

You will be paid a base payment amount of $17.50 for participation in the study. If your participation lasts less than 1 hour, you will earn $10. If your participation last for over 1 hour, you will earn the full base pay. You may earn additional payment based on your ability to correctly complete the secondary tasks and maintain a safe headway as described in the study procedures section. The maximum amount available for this payment is $27.50. The maximum amount of compensation available for completing all the study procedures is $45. If you are unable to complete the study, the base pay will be pro-rated as described. However, you will still receive any and all incentives that you had previously earned through the course of your participation.

WHO IS FUNDING THIS STUDY?

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

WHAT ABOUT CONFIDENTIALITY?

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

- federal government regulatory agencies,
- the study sponsor – the National Highway Traffic Safety Administration,
- auditing departments of the University of Iowa, and

- the University of Iowa Institutional Review Board (a committee that reviews and approves research studies)

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

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

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

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

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

IS BEING IN THIS STUDY VOLUNTARY?

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

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

WHAT IF I HAVE QUESTIONS?

We encourage you to ask questions. If you have any questions about the research study itself, please contact: Timothy Brown (319-335-4585). If you experience a research-related injury, please contact Timothy Brown (319-335-4585).

If you have questions, concerns, or complaints about your rights as a research subject or about research related injury, please contact the Human Subjects Office, 105 Hardin Library for the Health Sciences, 600 Newton Rd, The University of Iowa, Iowa City, IA 52242-1098, (319) 335-6564, or e-mail irb@uiowa.edu. General information about being a research subject can be found by clicking "Info for Public" on the Human Subjects Office web site, http://research.uiowa.edu/hso. To offer input about your experiences as a research subject or to speak to someone other than the research staff, call the Human Subjects Office at the number above.

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

Subject's Name (printed): ____

Do not sign this form if today's date is on or after EXPIRATION DATE: 02/23/13 .

______________________________ ______________________
(Signature of Subject) (Date)

Statement of Person Who Obtained Consent

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

______________________________ ______________________
(Signature of Person who Obtained Consent) (Date)

12.5 System Training and Exposure Study

INFORMED CONSENT DOCUMENT

Project Title: Driver Perceptions of New Vehicle Technology Study 1

Principal Investigator: Timothy Brown

Research Team Contact: Dawn Marshall, 335-4774

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

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

WHAT IS THE PURPOSE OF THIS STUDY?

This is a research study. We are inviting you to participate in this research study because you are between the ages of 35 and 55 years, hold a valid U.S. driving license, drive at least 10,000 miles per year, have no need for special equipment to help you drive and are in good general health.

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

HOW MANY PEOPLE WILL PARTICIPATE?

Approximately 150 people will take part in this study at the University of Iowa.

HOW LONG WILL I BE IN THIS STUDY?

If you agree to take part in this study, your involvement will last for about 2 hours.

WHAT WILL HAPPEN DURING THIS STUDY?

Upon arrival at the National Advanced Driving Simulator (NADS) at the University Research Park (formally the Oakdale Campus), study staff will verbally review this document with you, answer any questions you may have about the study, and provide you time to read this document. If you agree to participate you will be asked to sign this document. You will receive a copy of this signed Informed Consent Document.

Next, you will be asked to show your driver's license to confirm you have a valid U.S. driver's license and then fill out a payment form which asks for your social security number. Next, you will be asked to complete a questionnaire that covers some general demographic information (birth date, age, gender, marital status, total household income last year, present employment status, type of work, ethnic origins,

highest level of education) and driving information that includes questions about your driving history including the type of vehicles you drive, your license history, driving violations and accidents, and driving habits. We will also ask you for several health related questions including medication, drug and alcohol use, and history of motion sickness.

Next you will be asked to watch a PowerPoint presentation on the computer that gives you an overview of the simulator cab and drive, the purpose of the study, the systems installed in the vehicle and the task you may be asked to complete while driving. The task that you may be asked to complete involves recalling numbers from a screen. .

Then you will be escorted into the simulator. You will be asked to position yourself in the driver's seat and make adjustments as needed so that you are able to drive comfortably. You will be asked to look out the front windshield while we set the cameras for the eye tracking system to collect information about where you are looking during the drive. You will then be asked to complete one drive of approximately 35 minutes during which you may be asked to complete tasks. After the drive you will complete one survey about you feel after completing the drive.

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

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

Video Recording
All driving trials will be recorded on video using digital video/audio recordings that are placed so that we are able to view your face, your interactions with the vehicle displays, and the driver's view of the forward scene. The placement of the cameras will allow the researchers to record the simulator controls and your response to driving events.

The simulator contains sensors that measure vehicle operation, vehicle motion, and your driving actions. The sensors send this information to a computer where it is recorded and stored.

These sensors and video cameras are located in such a manner that they will not affect you or obstruct your view while driving. The information collected using these sensors and video cameras are recorded for analysis by research staff and may be used as described in the Confidentiality section below.

Future Studies
We will keep on file your name and information about you, including birth date, contact phone numbers, and the annual mileage you drive each year. In the future we may contact you to see if you would be willing to complete questionnaires, interviews or drives for future studies. Agreeing to participate in this study does not obligate you to participate in any future studies.

SOCIAL SECURITY NUMBER (SSN) USAGE

You will be asked to provide your social security number on the payment form that is sent to the University of Iowa Business Office. The collection of your social security number is to document your payment for participation in this study.

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

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

WHAT ARE THE RISKS OF THIS STUDY?

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

You will be asked to answer questions about your driving habits including illegal activities such as driving while intoxicated or under the influence. You will also be asked how often you engage in activities such as reading or sending text messages while driving. Reading or sending text messages while driving is illegal for adult drivers in the state of Iowa. You may skip any questions you do not wish to answer.

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

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

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

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

WHAT ARE THE BENEFITS OF THIS STUDY?

You will not benefit from being in this study.

However, we hope that, in the future, other people might benefit from this study because information gained from this study about how different tasks impact driving performance may lead to increased safety on roadways.

WILL IT COST ME ANYTHING TO BE IN THIS STUDY?

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

WILL I BE PAID FOR PARTICIPATING?

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

You will be paid $45 for completing the study.

If you are unable to complete the study procedures, your pay will be pro-rated based on the amount of time that you participated. You will earn $10 for every 30 minutes of participation with a $10 minimum.

WHO IS FUNDING THIS STUDY?

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

WHAT ABOUT CONFIDENTIALITY?

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

- federal government regulatory agencies,
- the study sponsor – the National Highway Traffic Safety Administration,
- auditing departments of the University of Iowa, and
- the University of Iowa Institutional Review Board (a committee that reviews and approves research studies)

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

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

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

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

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

<u>IS BEING IN THIS STUDY VOLUNTARY?</u>

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

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

WHAT IF I HAVE QUESTIONS?

We encourage you to ask questions. If you have any questions about the research study itself, please contact: Timothy Brown (319-335-4585). If you experience a research-related injury, please contact Timothy Brown (319-335-4585).

If you have questions, concerns, or complaints about your rights as a research subject or about research related injury, please contact the Human Subjects Office, 105 Hardin Library for the Health Sciences, 600 Newton Rd, The University of Iowa, Iowa City, IA 52242-1098, (319) 335-6564, or e-mail irb@uiowa.edu. General information about being a research subject can be found by clicking "Info for Public" on the Human Subjects Office web site, http://research.uiowa.edu/hso. To offer input about your experiences as a research subject or to speak to someone other than the research staff, call the Human Subjects Office at the number above.

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

Subject's Name (printed): ____

Do not sign this form if today's date is on or after EXPIRATION DATE: 03/19/13 .

______________________________ ______________________
(Signature of Subject) (Date)

Statement of Person Who Obtained Consent

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

______________________________ ______________________
(Signature of Person who Obtained Consent) (Date)

12.6 Alert Timing and Protocol Sensitivity to Systems Study

INFORMED CONSENT DOCUMENT

Project Title: **Driver Perceptions of New Vehicle Technology Study 2**

Principal Investigator: **Timothy Brown**

Research Team Contact: **Rose Potter, 335-4666**

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

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

WHAT IS THE PURPOSE OF THIS STUDY?

This is a research study. We are inviting you to participate in this research study because you are between the ages of 35 and 55 years, hold a valid U.S. driving license, drive at least 10,000 miles per year, have no need for special equipment to help you drive and are in good general health.

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

HOW MANY PEOPLE WILL PARTICIPATE?

Approximately 150 people will take part in this study at the University of Iowa.

HOW LONG WILL I BE IN THIS STUDY?

If you agree to take part in this study, your involvement will last for about 2 hours.

WHAT WILL HAPPEN DURING THIS STUDY?

Upon arrival at the National Advanced Driving Simulator (NADS) at the University Research Park (formally the Oakdale Campus), study staff will verbally review this document with you, answer any questions you may have about the study, and provide you time to read this document. If you agree to participate you will be asked to sign this document. You will receive a copy of this signed Informed Consent Document.

Next, you will be asked to show your driver's license to confirm you have a valid U.S. driver's license and then fill out a payment form which asks for your social security number. Next, you will be asked to complete a questionnaire that covers some general demographic information (birth date, age, gender, marital status, total household income last year, present employment status, type of work, ethnic origins,

highest level of education) and driving information that includes questions about your driving history including the type of vehicles you drive, your license history, driving violations and accidents, and driving habits. We will also ask you for several health related questions including medication, drug and alcohol use, and history of motion sickness.

Next you will be asked to watch a PowerPoint presentation on the computer that gives you an overview of the simulator cab and drive, the purpose of the study, the systems installed in the vehicle and the task you may be asked to complete while driving. The task that you may be asked to complete involves recalling numbers from a screen.

Then you will be escorted into the simulator. You will be asked to position yourself in the driver's seat and make adjustments as needed so that you are able to drive comfortably. You will be asked to look out the front windshield while we set the cameras for the eye tracking system to collect information about where you are looking during the drive. You will then be asked to complete one drive of approximately 35 minutes during which you may be asked to complete tasks. After the drive you will complete one survey about you feel after completing the drive.

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

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

Video Recording

All driving trials will be recorded on video using digital video/audio recordings that are placed so that we are able to view your face, your interactions with the vehicle displays, and the driver's view of the forward scene. The placement of the cameras will allow the researchers to record the simulator controls and your response to driving events.

The simulator contains sensors that measure vehicle operation, vehicle motion, and your driving actions. The sensors send this information to a computer where it is recorded and stored.

These sensors and video cameras are located in such a manner that they will not affect you or obstruct your view while driving. The information collected using these sensors and video cameras are recorded for analysis by research staff and may be used as described in the Confidentiality section below.

Future Studies

We will keep on file your name and information about you, including birth date, contact phone numbers, and the annual mileage you drive each year. In the future we may contact you to see if you would be willing to complete questionnaires, interviews or drives for future studies. Agreeing to participate in this study does not obligate you to participate in any future studies.

SOCIAL SECURITY NUMBER (SSN) USAGE

You will be asked to provide your social security number on the payment form that is sent to the University of Iowa Business Office. The collection of your social security number is to document your payment for participation in this study.

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

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

WHAT ARE THE RISKS OF THIS STUDY?

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

You will be asked to answer questions about your driving habits including illegal activities such as driving while intoxicated or under the influence. You will also be asked how often you engage in activities such as reading or sending text messages while driving. Reading or sending text messages while driving is illegal for adult drivers in the state of Iowa. You may skip any questions you do not wish to answer.

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

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

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

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

WHAT ARE THE BENEFITS OF THIS STUDY?

You will not benefit from being in this study.

However, we hope that, in the future, other people might benefit from this study because information gained from this study about how different tasks impact driving performance may lead to increased safety on roadways.

WILL IT COST ME ANYTHING TO BE IN THIS STUDY?

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

WILL I BE PAID FOR PARTICIPATING?

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

You will be paid $45 for completing the study.

If you are unable to complete the study procedures, your pay will be pro-rated based on the amount of time that you participated. You will earn $10 for every 30 minutes of participation with a $10 minimum.

WHO IS FUNDING THIS STUDY?

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

WHAT ABOUT CONFIDENTIALITY?

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

- federal government regulatory agencies,
- the study sponsor – the National Highway Traffic Safety Administration,
- auditing departments of the University of Iowa, and
- the University of Iowa Institutional Review Board (a committee that reviews and approves research studies)

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

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

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

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

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

IS BEING IN THIS STUDY VOLUNTARY?

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

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

WHAT IF I HAVE QUESTIONS?

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

If you have questions, concerns, or complaints about your rights as a research subject or about research related injury, please contact the Human Subjects Office, 105 Hardin Library for the Health Sciences, 600 Newton Rd, The University of Iowa, Iowa City, IA 52242-1098, (319) 335-6564, or e-mail irb@uiowa.edu. General information about being a research subject can be found by clicking "Info for Public" on the Human Subjects Office web site, http://research.uiowa.edu/hso. To offer input about your experiences as a research subject or to speak to someone other than the research staff, call the Human Subjects Office at the number above.

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

Subject's Name (printed): ______________________________

Do not sign this form if today's date is on or after EXPIRATION DATE: 03/20/13 .

______________________________ ______________________________
(Signature of Subject) (Date)

Statement of Person Who Obtained Consent

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

______________________________ ______________________________
(Signature of Person who Obtained Consent) (Date)

12.7 Motion Feedback Considerations

INFORMED CONSENT DOCUMENT

Project Title: Driver Perceptions of New Vehicle Technology Study 3

Principal Investigator: Timothy Brown

Research Team Contact: Rose Schmitt, 335-4666

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

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

WHAT IS THE PURPOSE OF THIS STUDY?

This is a research study. We are inviting you to participate in this research study because you are between the ages of 35 and 55 years, hold a valid U.S. driving license, drive at least 10,000 miles per year, have no need for special equipment to help you drive and are in good general health.

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

HOW MANY PEOPLE WILL PARTICIPATE?

Approximately 150 people will take part in this study at the University of Iowa.

HOW LONG WILL I BE IN THIS STUDY?

If you agree to take part in this study, your involvement will last for about 2 hours.

WHAT WILL HAPPEN DURING THIS STUDY?

Upon arrival at the National Advanced Driving Simulator (NADS) at the University Research Park (formally the Oakdale Campus), study staff will verbally review this document with you, answer any questions you may have about the study, and provide you time to read this document. If you agree to participate you will be asked to sign this document. You will receive a copy of this signed Informed Consent Document.

Next, you will be asked to show your driver's license to confirm you have a valid U.S. driver's license and then fill out a payment form which asks for your social security number. Next, you will be asked to complete a questionnaire that covers some general demographic information (birth date, age, gender, marital status, total household income last year, present employment status, type of work, ethnic origins,

highest level of education) and driving information that includes questions about your driving history including the type of vehicles you drive, your license history, driving violations and accidents, and driving habits. We will also ask you for several health related questions including medication, drug and alcohol use, and history of motion sickness.

Next you will be asked to watch a PowerPoint presentation on the computer that gives you an overview of the simulator cab and drive, the purpose of the study, the systems installed in the vehicle and the task you may be asked to complete while driving. The task that you may be asked to complete involves recalling numbers from a screen.

Then you will be escorted into the simulator. You will be asked to position yourself in the driver's seat and make adjustments as needed so that you are able to drive comfortably. You will be asked to look out the front windshield while we set the cameras for the eye tracking system to collect information about where you are looking during the drive. You will then be asked to complete one drive of approximately 35 minutes during which you may be asked to complete tasks. After the drive you will complete one survey about you feel after completing the drive.

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

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

Video Recording
All driving trials will be recorded on video using digital video/audio recordings that are placed so that we are able to view your face, your interactions with the vehicle displays, and the driver's view of the forward scene. The placement of the cameras will allow the researchers to record the simulator controls and your response to driving events.

The simulator contains sensors that measure vehicle operation, vehicle motion, and your driving actions. The sensors send this information to a computer where it is recorded and stored.

These sensors and video cameras are located in such a manner that they will not affect you or obstruct your view while driving. The information collected using these sensors and video cameras are recorded for analysis by research staff and may be used as described in the Confidentiality section below.

Future Studies
We will keep on file your name and information about you, including birth date, contact phone numbers, and the annual mileage you drive each year. In the future we may contact you to see if you would be willing to complete questionnaires, interviews or drives for future studies. Agreeing to participate in this study does not obligate you to participate in any future studies.

SOCIAL SECURITY NUMBER (SSN) USAGE

You will be asked to provide your social security number on the payment form that is sent to the University of Iowa Business Office. The collection of your social security number is to document your payment for participation in this study.

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

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

WHAT ARE THE RISKS OF THIS STUDY?

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

You will be asked to answer questions about your driving habits including illegal activities such as driving while intoxicated or under the influence. You will also be asked how often you engage in activities such as reading or sending text messages while driving. Reading or sending text messages while driving is illegal for adult drivers in the state of Iowa. You may skip any questions you do not wish to answer.

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

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

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

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

WHAT ARE THE BENEFITS OF THIS STUDY?

You will not benefit from being in this study.

However, we hope that, in the future, other people might benefit from this study because information gained from this study about how different tasks impact driving performance may lead to increased safety on roadways.

WILL IT COST ME ANYTHING TO BE IN THIS STUDY?

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

WILL I BE PAID FOR PARTICIPATING?

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

You will be paid $45 for completing the study.

If you are unable to complete the study procedures, your pay will be pro-rated based on the amount of time that you participated. You will earn $10 for every 30 minutes of participation with a $10 minimum.

WHO IS FUNDING THIS STUDY?

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

WHAT ABOUT CONFIDENTIALITY?

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

- federal government regulatory agencies,
- the study sponsor – the National Highway Traffic Safety Administration,
- auditing departments of the University of Iowa, and
- the University of Iowa Institutional Review Board (a committee that reviews and approves research studies)

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

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

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

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

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

IS BEING IN THIS STUDY VOLUNTARY?

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

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

WHAT IF I HAVE QUESTIONS?

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

If you have questions, concerns, or complaints about your rights as a research subject or about research related injury, please contact the Human Subjects Office, 105 Hardin Library for the Health Sciences, 600 Newton Rd, The University of Iowa, Iowa City, IA 52242-1098, (319) 335-6564, or e-mail irb@uiowa.edu. General information about being a research subject can be found by clicking "Info for Public" on the Human Subjects Office web site, http://research.uiowa.edu/hso. To offer input about your experiences as a research subject or to speak to someone other than the research staff, call the Human Subjects Office at the number above.

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

Subject's Name (printed): ______________________________

Do not sign this form if today's date is on or after EXPIRATION DATE: 03/20/13 .

______________________________ ______________________________
(Signature of Subject) (Date)

Statement of Person Who Obtained Consent

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

______________________________ ______________________________
(Signature of Person who Obtained Consent) (Date)

12.8 Crash Warning Evaluation in a Connected Vehicles Environment Study

INFORMED CONSENT DOCUMENT

Project Title: Driver Perceptions of New Vehicle Technology Study 2

Principal Investigator: Timothy Brown

Research Team Contact: Dawn Marshall, 335-4774

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

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

<u>WHAT IS THE PURPOSE OF THIS STUDY?</u>

This is a research study. We are inviting you to participate in this research study because you are between the ages of 35 and 55 years, hold a valid U.S. driving license, drive at least 10,000 miles per year, have no need for special equipment to help you drive and are in good general health.

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

<u>HOW MANY PEOPLE WILL PARTICIPATE?</u>

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

<u>HOW LONG WILL I BE IN THIS STUDY?</u>

If you agree to take part in this study, your involvement will last for about 2 hours.

<u>WHAT WILL HAPPEN DURING THIS STUDY?</u>

Upon arrival at the National Advanced Driving Simulator (NADS) at the University Research Park (formally the Oakdale Campus), study staff will verbally review this document with you, answer any questions you may have about the study, and provide you time to read this document. If you agree to participate you will be asked to sign this document. You will receive a copy of this signed Informed Consent Document.

Next, you will be asked to show your driver's license to confirm you have a valid U.S. driver's license and then fill out a payment form which asks for your social security number. Next, you will be asked to complete a questionnaire that covers some general demographic information (birth date, age, gender, marital status, total household income last year, present employment status, type of work, ethnic origins,

highest level of education) and driving information that includes questions about your driving history including the type of vehicles you drive, your license history, driving violations and accidents, and driving habits. We will also ask you for several health related questions including medication, drug and alcohol use, and history of motion sickness.

Next you will be asked to watch a PowerPoint presentation on the computer that gives you an overview of the simulator cab and drive, the purpose of the study, the systems installed in the vehicle and the task you will be asked to complete while driving. The task that you will be asked to complete involves an information search task that includes interacting with a touch screen monitor to answer yes/no questions.

Then you will be escorted into the simulator. You will be asked to position yourself in the driver's seat and make adjustments as needed so that you are able to drive comfortably. You will be asked to look out the front windshield while we set the cameras for the eye tracking system to collect information about where you are looking during the drive. You will then be asked to complete one drive of approximately 35 minutes during which you may be asked to complete tasks. After the drive you will complete one survey about you feel after completing the drive.

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

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

Video Recording

All driving trials will be recorded on video using digital video/audio recordings that are placed so that we are able to view your face, your interactions with the vehicle displays, and the driver's view of the forward scene. The placement of the cameras will allow the researchers to record the simulator controls and your response to driving events.

The simulator contains sensors that measure vehicle operation, vehicle motion, and your driving actions. The sensors send this information to a computer where it is recorded and stored.

These sensors and video cameras are located in such a manner that they will not affect you or obstruct your view while driving. The information collected using these sensors and video cameras are recorded for analysis by research staff and may be used as described in the Confidentiality section below.

Future Studies

We will keep on file your name and information about you, including birth date, contact phone numbers, and the annual mileage you drive each year. In the future we may contact you to see if you would be willing to complete questionnaires, interviews or drives for future studies. Agreeing to participate in this study does not obligate you to participate in any future studies.

SOCIAL SECURITY NUMBER (SSN) USAGE

You will be asked to provide your social security number on the payment form that is sent to the University of Iowa Business Office. The collection of your social security number is to document your payment for participation in this study.

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

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

WHAT ARE THE RISKS OF THIS STUDY?

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

You will be asked to answer questions about your driving habits including illegal activities such as driving while intoxicated or under the influence. You will also be asked how often you engage in activities such as reading or sending text messages while driving. Reading or sending text messages while driving is illegal for adult drivers in the state of Iowa. You may skip any questions you do not wish to answer.

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

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

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

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

WHAT ARE THE BENEFITS OF THIS STUDY?

You will not benefit from being in this study.

However, we hope that, in the future, other people might benefit from this study because information gained from this study about how different tasks impact driving performance may lead to increased safety on roadways.

WILL IT COST ME ANYTHING TO BE IN THIS STUDY?

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

WILL I BE PAID FOR PARTICIPATING?

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

You will be paid $45 for completing the study.

If you are unable to complete the study procedures, your pay will be pro-rated based on the amount of time that you participated. You will earn $10 for every 30 minutes of participation with a $10 minimum.

WHO IS FUNDING THIS STUDY?

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

WHAT ABOUT CONFIDENTIALITY?

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

- federal government regulatory agencies,
- the study sponsor – the National Highway Traffic Safety Administration,
- auditing departments of the University of Iowa, and
- the University of Iowa Institutional Review Board (a committee that reviews and approves research studies)

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

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

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

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

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

<u>IS BEING IN THIS STUDY VOLUNTARY?</u>

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

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

WHAT IF I HAVE QUESTIONS?

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

If you have questions, concerns, or complaints about your rights as a research subject or about research related injury, please contact the Human Subjects Office, 105 Hardin Library for the Health Sciences, 600 Newton Rd, The University of Iowa, Iowa City, IA 52242-1098, (319) 335-6564, or e-mail irb@uiowa.edu. General information about being a research subject can be found by clicking "Info for Public" on the Human Subjects Office web site, http://research.uiowa.edu/hso. To offer input about your experiences as a research subject or to speak to someone other than the research staff, call the Human Subjects Office at the number above.

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

Subject's Name (printed): ______________________________

Do not sign this form if today's date is on or after EXPIRATION DATE: 02/21/14 .

______________________________ ______________________
(Signature of Subject) (Date)

Statement of Person Who Obtained Consent

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

______________________________ ______________________
(Signature of Person who Obtained Consent) (Date)

13 Appendix C: Generic Video Release

CONSENT FOR RELEASE OF VIDEO IMAGE AND AUDIO DATA

I, the undersigned, have agreed to participate in a research project to be conducted at the University of Iowa entitled "Investigating Headway Maintenance". The purpose of this research study is to investigate headway maintenance while driving. As part of the informed consent form I have signed for that study, I have agreed to allow the University, the study sponsor, and those acting pursuant to its authority, to record and use for research purposes video image data (including my video-recorded likeness) and audio data (including my voice), as well as, in some views, superimposed performance information (referred to below as "the Recording"). The University, the study sponsor, and those acting pursuant to its authority propose to edit/alter the Recording so that neither my image nor my voice are identifiable and use the altered Recording for the following non-research purposes:

1) Public release for regulatory purposes (e.g., to assist in regulating devices);
2) Public release for educational purposes (e.g., to assist with educational campaigns for members of the general public);
3) Public release for outreach purposes (e.g., to nationally-televised programs highlighting traffic safety issues);
4) Public release for legislative purposes (e.g., to assist the U.S. Congress with law-making/rule-making activities).

Engineering or simulator data may also be released individually or in summary with that of others participating in the study, but will not be presented publicly in a way that permits personal identification, except when presented in conjunction with video image data.

I hereby authorize the University of Iowa, the study sponsor, and those acting pursuant to its authority, to use my recorded video image and audio data, with or without related engineering or simulator data, for the non-research purposes specified above.

I transfer and assign to the University of Iowa and the study sponsor any right, title, and interest I may have in and to the Recording, including the copyright, and in and to all works based upon, derived from, or incorporating the recorded data.

I irrevocably waive any right to inspect, edit, or approve said Recording in any of its forms.

I irrevocably release the University of Iowa and the study sponsor, and any of their employees, agents, and assigns, from any and all claims that I may have at any time arising out of, or related to, the Recording or use of the Recording, including, but not limited to, any claims based on the right of privacy, libel, or defamation.

____
Name of Participant

____
Signature of Participant

____
Date

14 Appendix D: Generic Payment Form

NADS PARTICIPANT COMPENSATION VOUCHER

Department Name: NADS & Simulation Center
Contact Person: Dawn Marshall
Campus Address: 127 NADS
Campus Phone: 54778

TO RECEIVE COMPENSATION, PLEASE PROVIDE THE FOLLOWING INFORMATION:

Name: ____
LAST FIRST MIDDLE INITIAL

Social Security Number: ☐☐☐ – ☐☐ – ☐☐☐☐

MAILING ADDRESS

____
STREET

______________________________ ________ ☐☐☐☐☐
CITY STATE ZIP

(_______)___________________________
PHONE

Are you a U.S. citizen? ☐ YES ☐ NO

If NO, Immigration/VISA Status: ___________________________

Immigration/VISA # _________________________ Date of Birth: ☐☐ / ☐☐ / ☐☐☐☐

Tax Residency Country: ____

Permanent Foreign Address: ____

____

FOR NADS STAFF ONLY:

DATE: ☐☐ / ☐☐ / ☐☐☐☐

STUDY TITLE: __CWIM3 Study__________________

TOTAL COMPENSATION: $ __________________

15 Appendix E: Driving Survey

Driving History Questionnaire

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

Background Information

1) What is your birth date? ________ / ________ / _______________

Month Day Year

2) What age are you today? ___________

3) What is your gender?

❒ Male

❒ Female

4) What is your marital status? (Check only one)

❒ Single, never married

❒ Married

❒ Domestic Partnership

❒ Separated or Divorced

❒ Widowed

5) What was your total household income last year? (Check only one)

- ❒ $0- $24,999
- ❒ $25,000- $29,999
- ❒ $30,000 - $34,999
- ❒ $35,000 - $39,999
- ❒ $40,000 - $49,999
- ❒ $50,000 - $59,999
- ❒ $60,000 - $69,999
- ❒ $70,000 - $79,999
- ❒ $80,000 - $89,999
- ❒ $90,000 - $99,999
- ❒ $100,000 or more

6) What is your present employment status? (Check only one)

- ❒ Unemployed
- ❒ Retired
- ❒ Work part-time
- ❒ Work full-time
- ❒ None of the above

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

____

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

❒ American Indian/Alaska Native

❒ Asian

❒ Black/African American

❒ Hispanic/Latino

❒ Native Hawaiian/Other Pacific Islander

❒ White/Caucasian

❒ Other

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

❒ Primary School

❒ High School Diploma or equivalent

❒ Technical School or equivalent

❒ Some College or University

❒ Associate's Degree

❒ Bachelor's Degree

❒ Some Graduate or Professional School

❒ Graduate or Professional Degree

Driving Experience

10) How old were you when you started to drive? _________ years of age

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

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

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

❒ Less than once weekly

❒ At least once weekly

❒ At least once daily

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

Car	16 Motorcycle	Truck	Other: ____________
❒ Do not drive	❒ Do not drive	❒ Do not drive	❒ Do not drive
❒ Under 2,000	❒ Under 2,000	❒ Under 2,000	❒ Under 2,000
❒ 2,000 - 7,999	❒ 2,000 - 7,999	❒ 2,000 - 7,999	❒ 2,000 - 7,999
❒ 8,000 - 12,999	❒ 8,000 - 12,999	❒ 8,000 - 12,999	❒ 8,000 - 12,999
❒ 13,000 - 19,999	❒ 13,000 - 19,999	❒ 13,000 - 19,999	❒ 13,000 - 19,999
❒ 20,000 or more	❒ 20,000 or more	❒ 20,000 or more	❒ 20,000 or more

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

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

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

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

❒ No

❒ Yes (Please describe) ______________________________________

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

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

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

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

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

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

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

Violations

20) Within the past five years, how many tickets have you received for the following?

(Please check a response for each ticket)

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

Accidents

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

❒ 0 (Go to question # 29 on page 7)

❒ 1

❒ 2

❒ 3

❒ 4 or more

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

Accident 1

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

Accident 2

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

Accident 3

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

Health Status

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

0 1 2 3 4 5 6 7 8 9 10

Never Always

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

0 1 2 3 4 5 6 7 8 9 10

None Severe

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

❒ No

❒ Yes (Please list all) ____

____

25) Have you consumed any alcohol or other drugs in the past 24 hours? (Check only one)

❒ No

❒ Yes (Please list all) ____

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

Other Studies

27) Have you participated in other driving studies?

❐ No (End of questionnaire)

❐ Yes (please provide details for each study you have participated in below)

<u>Study 1</u>

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

❐ Actual car - only

❐ Another simulator - only

❐ National Advanced Driving Simulator (Motion Simulator)

❐ National Advanced Driving Simulator (Static Simulator)

❐ Both - actual car and another simulator

❐ Both - actual car and the National Advanced Driving Simulator (Motion)

Brief Description:

____

____

<u>Study 2</u>

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

❐ Actual car - only

❐ Another simulator - only

❐ National Advanced Driving Simulator (Motion Simulator)

❒ National Advanced Driving Simulator (Static Simulator)

❒ Both - actual car and another simulator

❒ Both - actual car and the National Advanced Driving Simulator (Motion)

Brief Description:

____

____

<u>Study 3</u>

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

❒ Actual car - only

❒ Another simulator - only

❒ National Advanced Driving Simulator (Motion Simulator)

❒ National Advanced Driving Simulator (Static Simulator)

❒ Both - actual car and another simulator

❒ Both - actual car and the National Advanced Driving Simulator (Motion)

Brief Description:

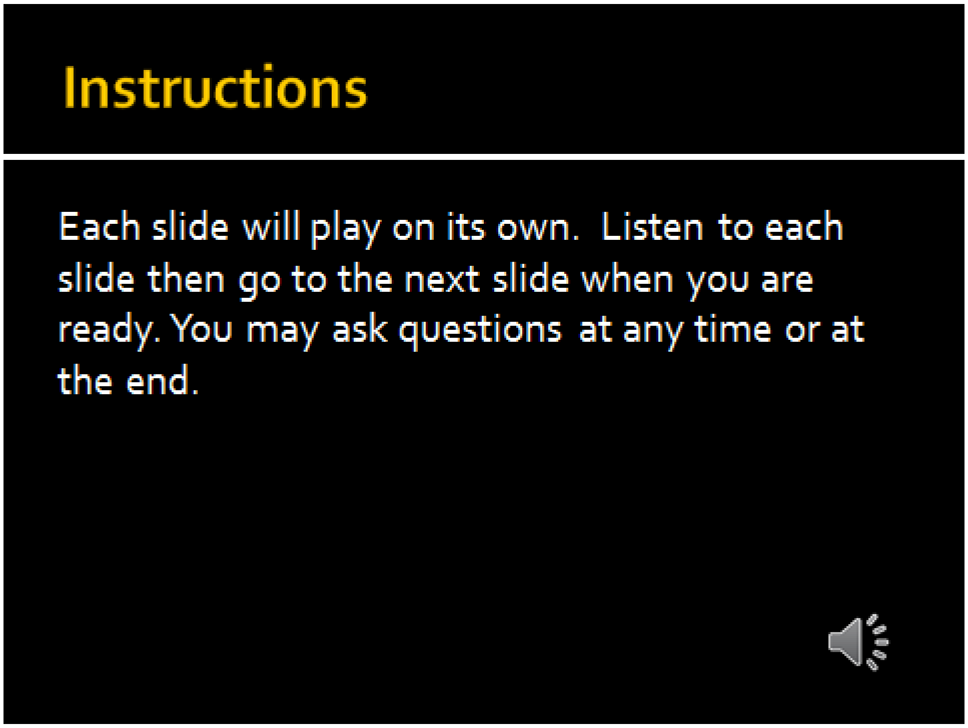
____

____

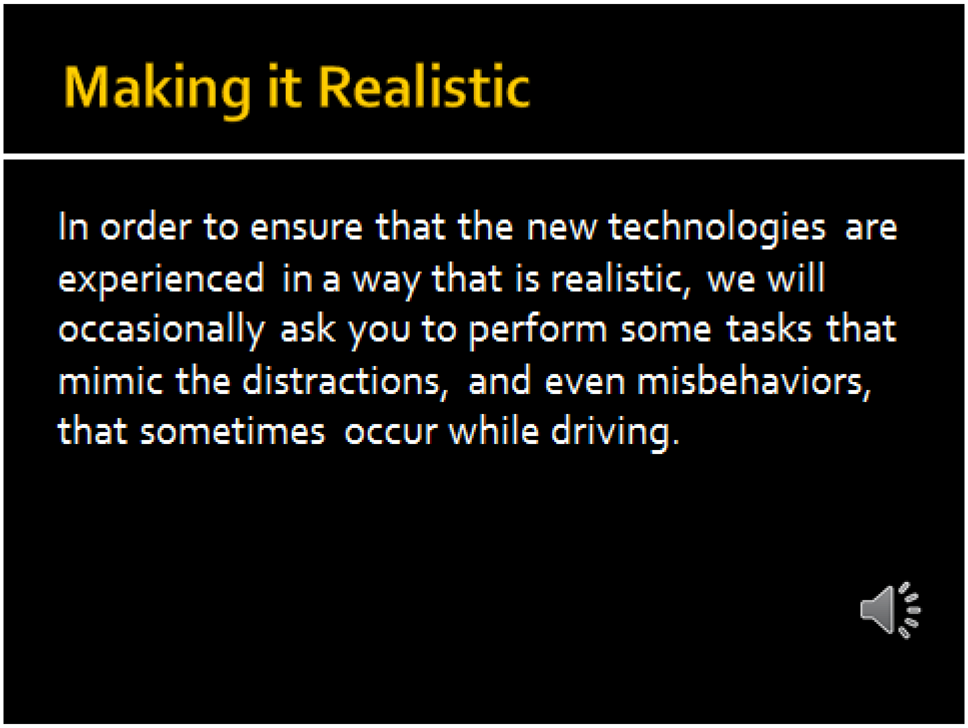
The End

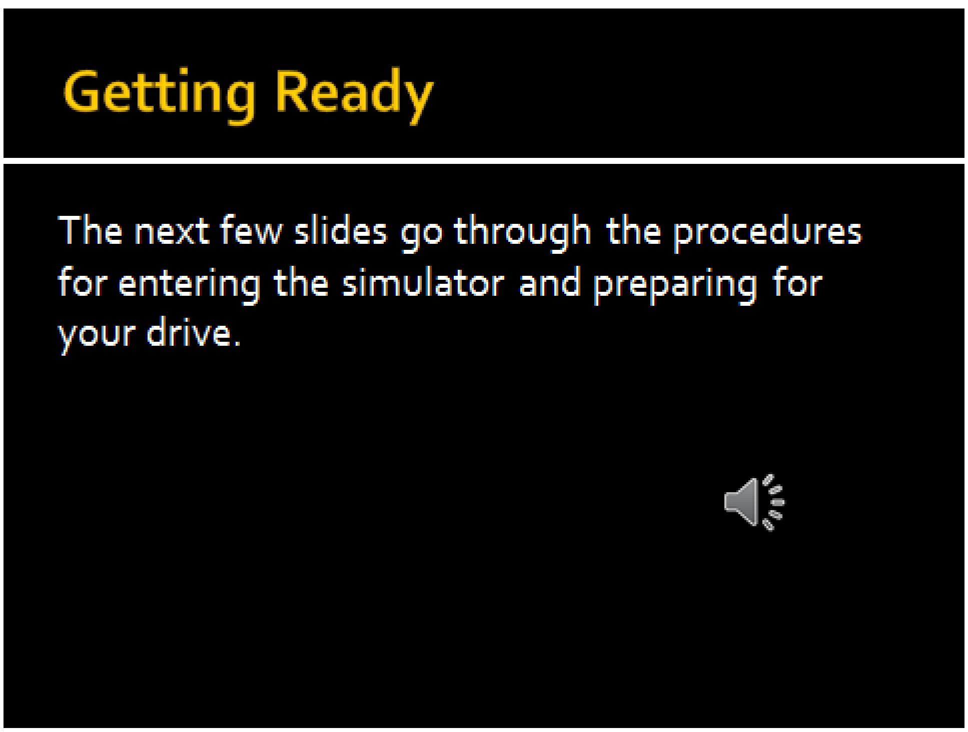
17 Appendix F: Training Presentations

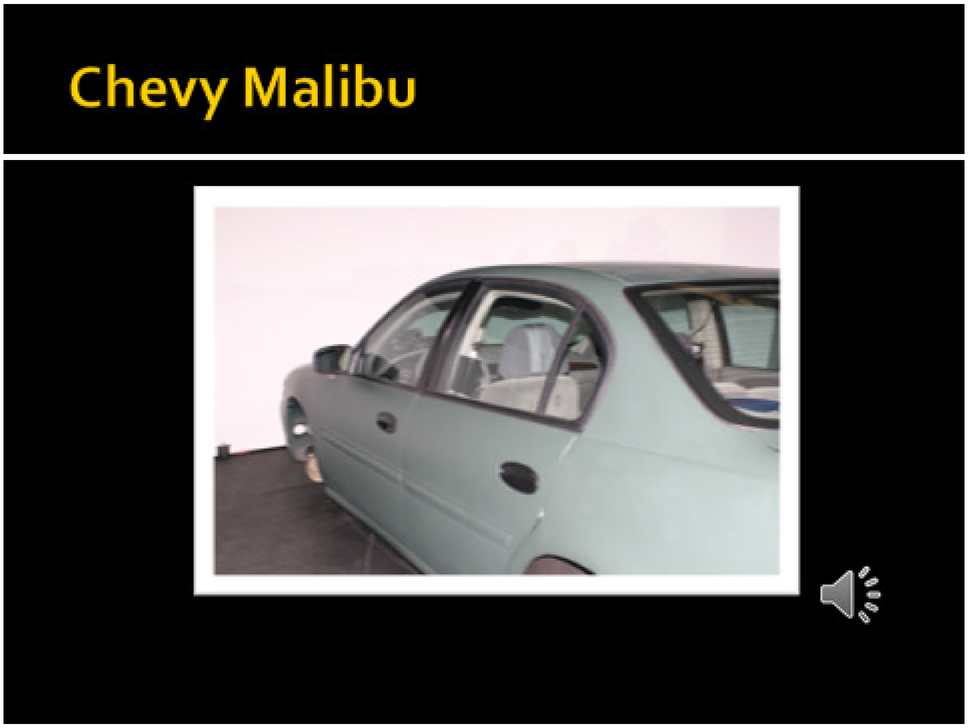
17.1 Instruction Slide

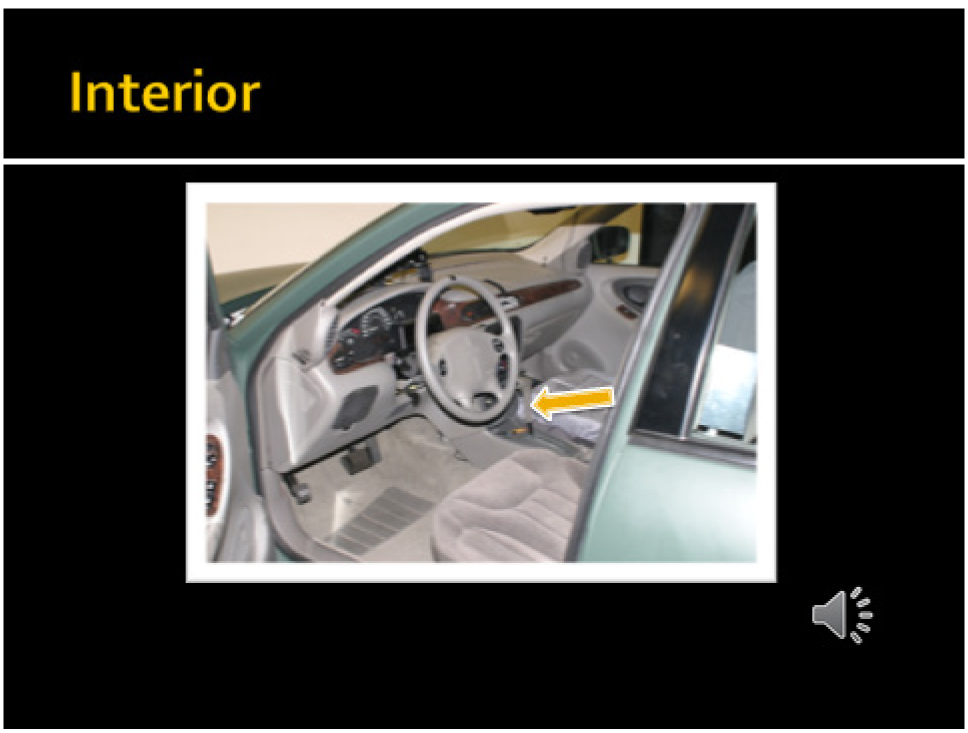


17.2 Common Slides about Simulator

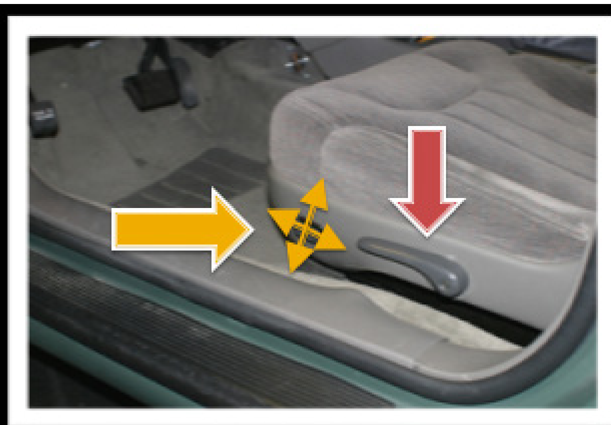




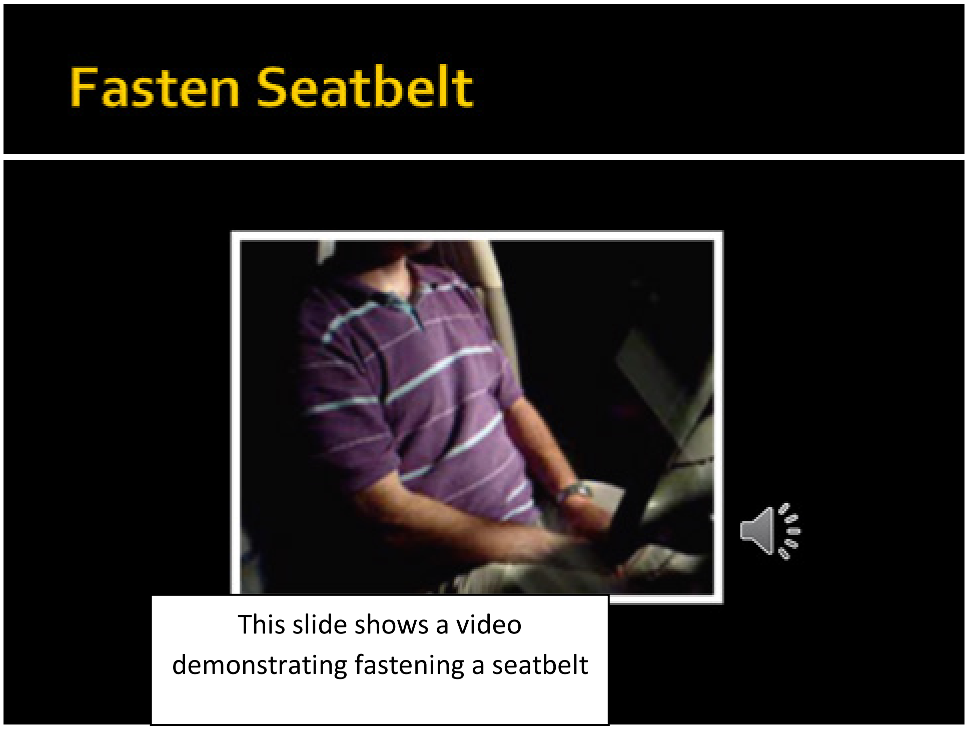

Chevy Malibu

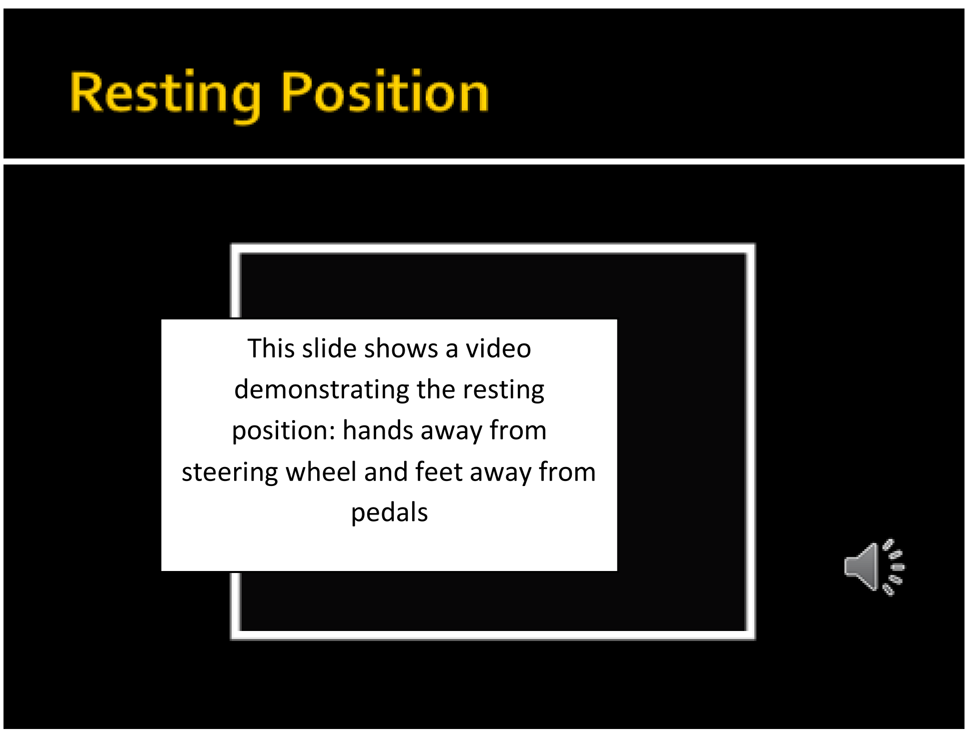

Interior

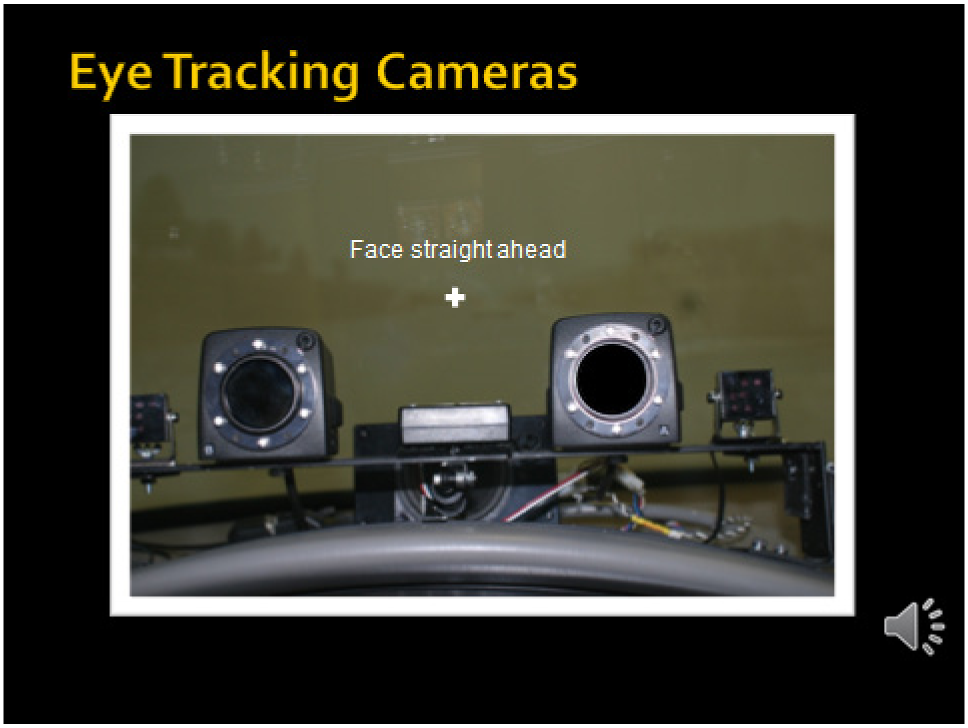
Seat Adjustments

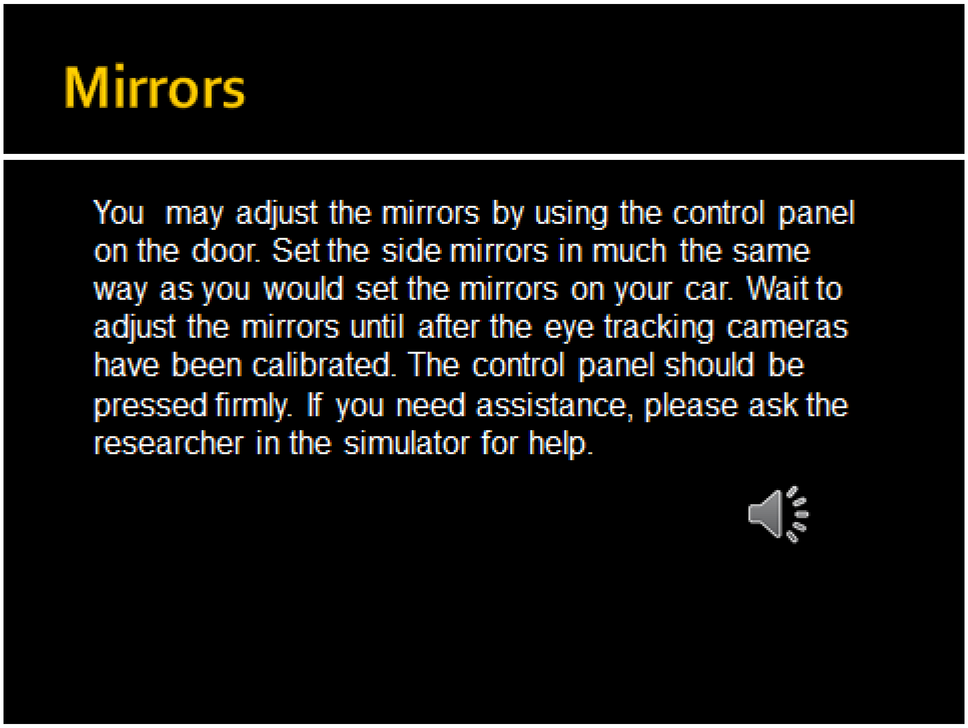


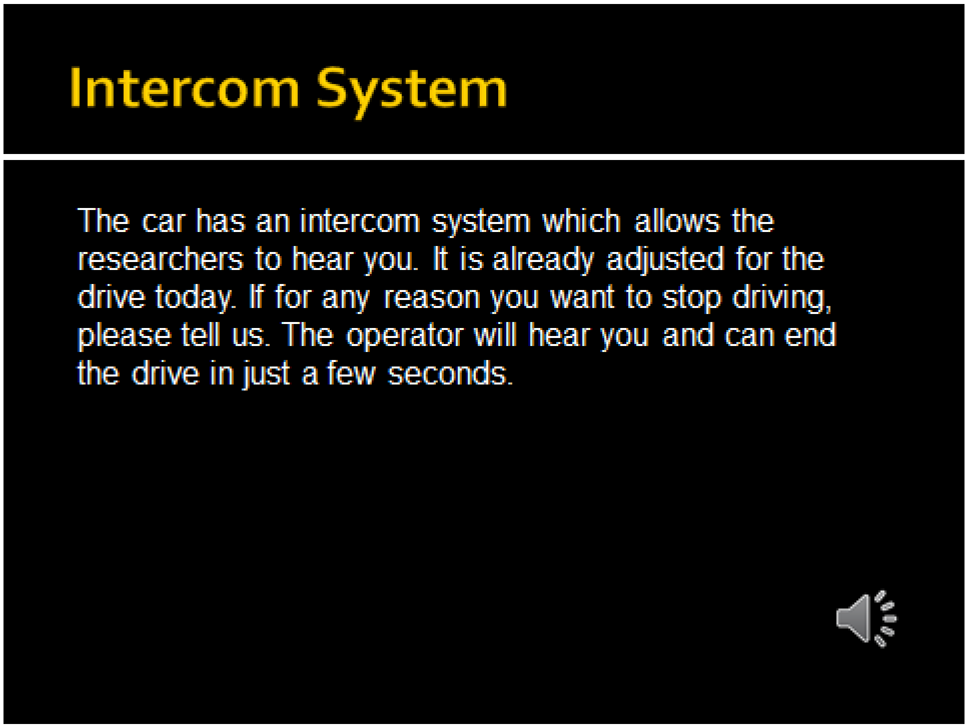
Steering Wheel Adjustments


Fasten Seatbelt
This slide shows a video demonstrating fastening a seatbelt

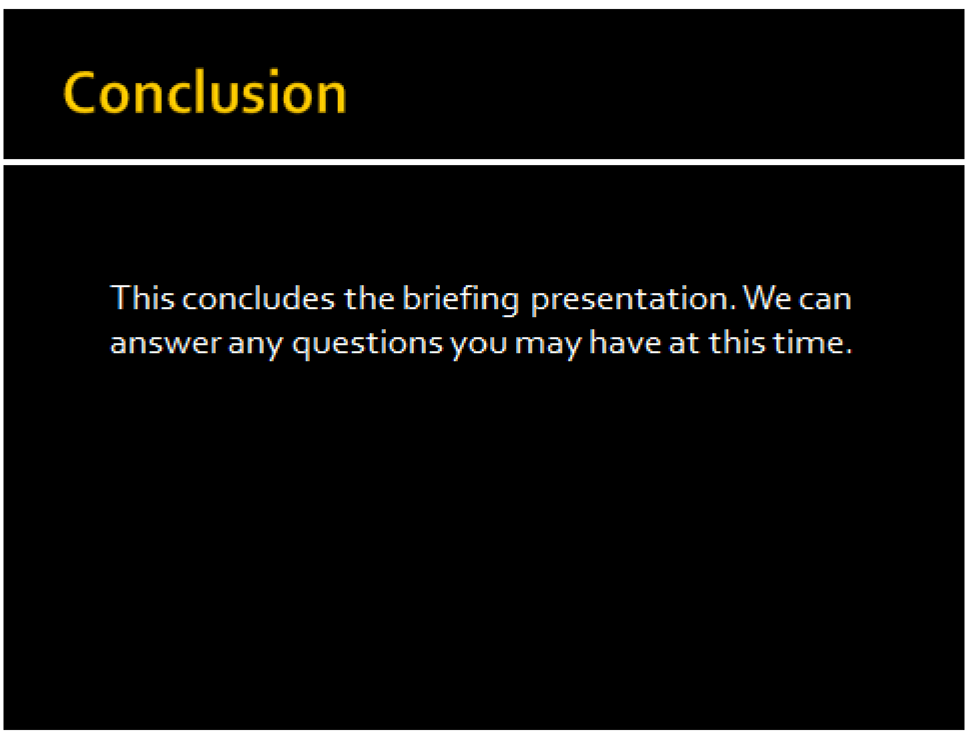

Resting Position
This slide shows a video demonstrating the resting position: hands away from steering wheel and feet away from pedals


Eye Tracking Cameras
Face straight ahead

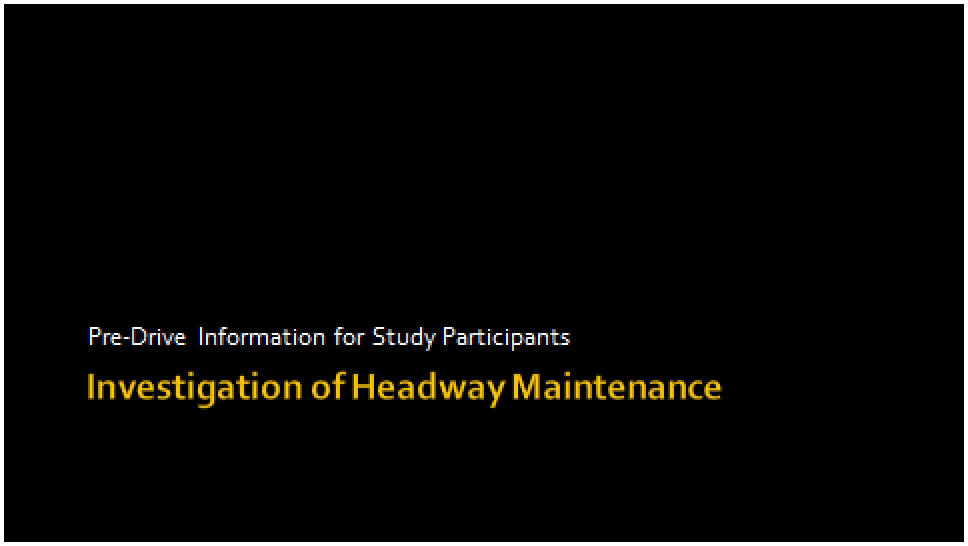

Mirrors
You may adjust the mirrors by using the control panel on the door. Set the side mirrors in much the same way as you would set the mirrors on your car. Wait to adjust the mirrors until after the eye tracking cameras have been calibrated. The control panel should be pressed firmly. If you need assistance, please ask the researcher in the simulator for help.

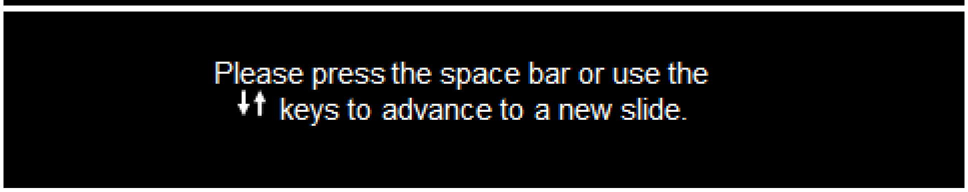


17.3 Conclusion Slide



17.4 Test Track Comparison Study



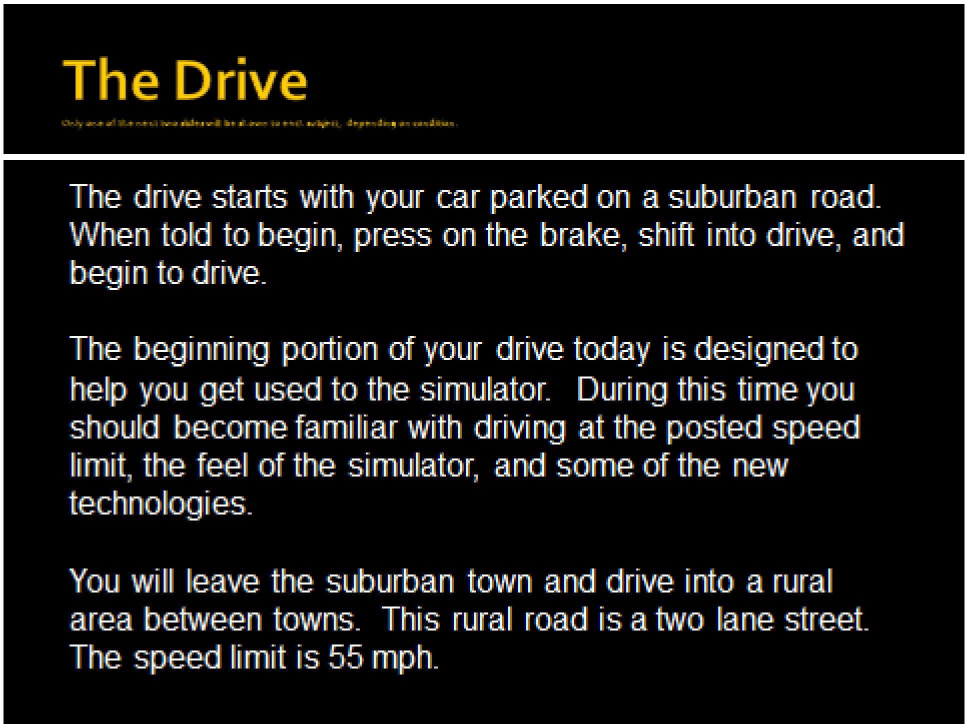


Instruction Slide Here

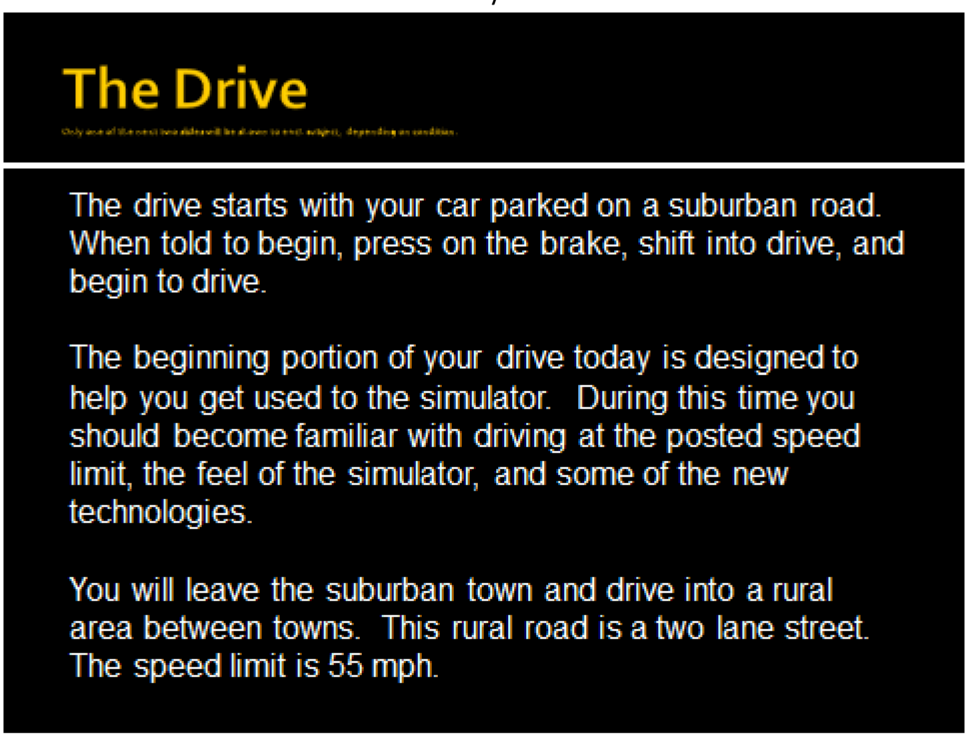
Purpose of the Study

The purpose of this research study is to investigate headway maintenance while driving.

Common Slides Here



This slide used only for road course.



This slide used only with test track course

The Drive

The drive starts with your car parked in a parking lot. When told to begin, press on the brake, shift into drive, and begin to drive.

The beginning portion of your drive today is designed to help you get used to the simulator. During this time you should become familiar driving at the posted speed limit, and the feel of the simulator. During this segment you will be able to practice maintaining a headway with the vehicle in front of you. You should maintain a distance of 110 feet throughout the entire drive.

When you reach the test track, continue to maintain a headway distance of 110 feet from the car in front of you. Several times throughout the drive you will be asked to engage in a number recall task.

Your Task – Number Recall

You will hear "Number Recall" indicating the start of the task. Five random single digit numbers are presented one at a time on a computer screen.

The computer screen is located to the left of the passenger headrest.

After all five numbers have been presented to you, your task is to recall the five numbers aloud in the correct order.

Incentive-Number Recall

Several times you will be asked to complete a number recall task.

On the first instance you, will earn $0.63 per number successfully recalled in the order presented.

After the first instance, you will earn $1.06 per number successfully recalled in the order presented.

If the number sequence you indicate is incorrect you will lose $0.40.

Each instance of the number recall is separate and does not influence the amount of money you earn on the other recall tasks. The amount you earn cannot be less than $0 per number recall instance.

Headway Maintenance

Headway maintenance is your ability to maintain a specified distance from your vehicle to the vehicle in front of you.

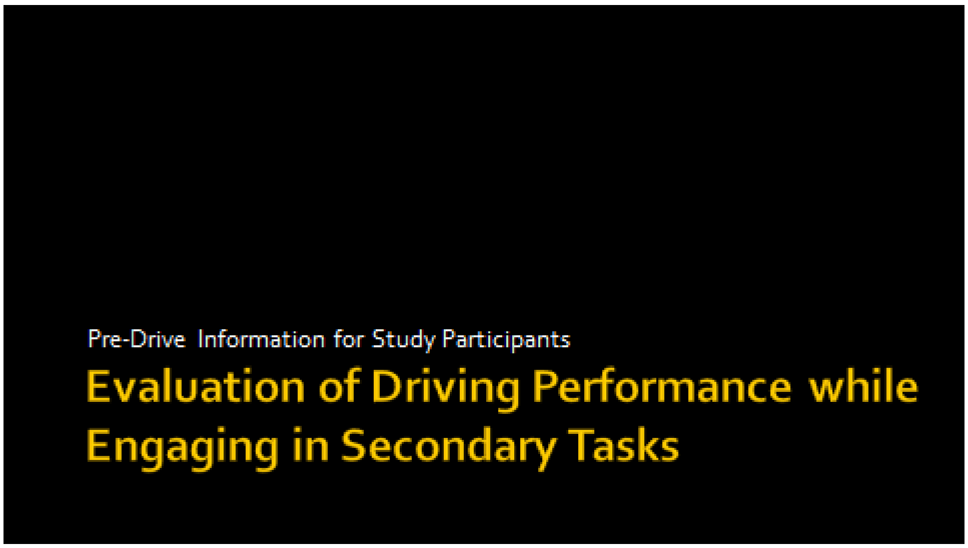
During your drive today, you will be asked to maintain a headway of 110 feet. A display is mounted on top of the dash to provide you with your headway distance.

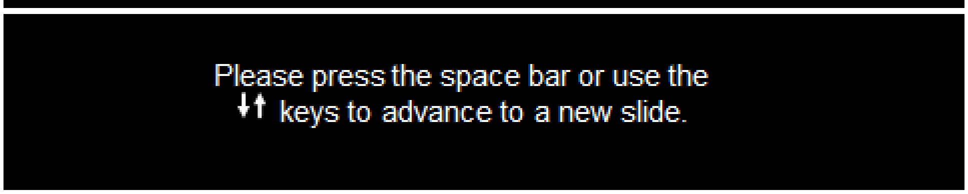
Additional compensation is available if you successfully stay within 15 feet of this target (95 to 125 feet). If you can stay in that range, you will receive $2.12 per straight segment following the practice.

Each straight-away is separate and does not influence the amount of money you earn on the others.

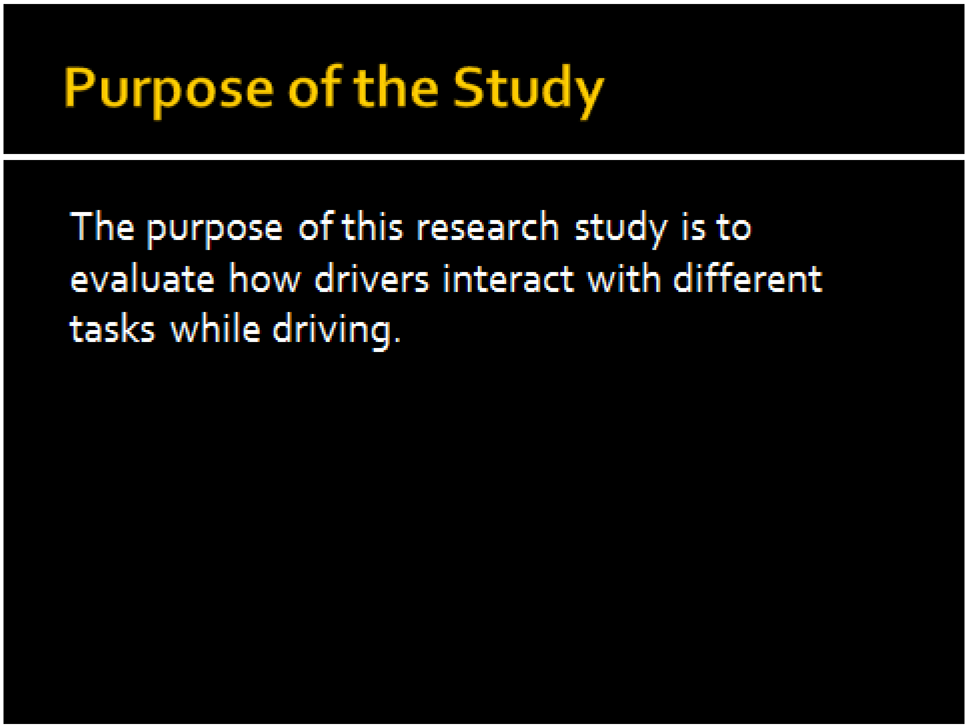
Conclusion Slide Here

17.5 Secondary Task and Incentive Considerations Study- No Incentive





Instruction Slide Here



Common Slides Here

The Drive

The drive starts with your car parked on a suburban road. When told to begin, press on the brake, shift into drive, and begin to drive.

The beginning portion of your drive today is designed to help you get used to the simulator. During this time you should become familiar with driving at the posted speed limit, the feel of the simulator, and some of the new technologies.

You will leave the suburban town and drive into a rural area between towns. This rural road is a two lane street. The speed limit is 55 mph.

Distraction Tasks

You will be asked to perform four distraction tasks while driving.

1. Task 1: Number Recall
2. Task 2: Bug Catching
3. Task 3: Message Reading
4. Task 4: Menu Search Selection

These tasks are described in detail on the following slides.

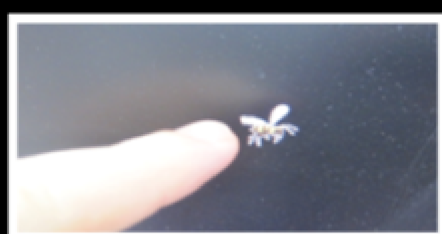
Task #1 – Number Recall

You will hear "Number Recall" indicating the start of the task. Five random single digit numbers are presented one at a time on a computer screen.

The computer screen is located to the left of the passenger headrest.

After all five numbers have been presented to you, your task is to recall the five numbers aloud in the correct order.

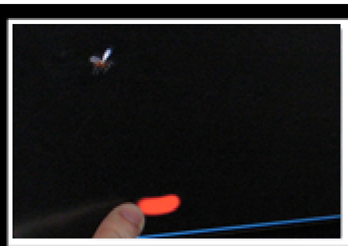
Task2: Bug Catching Task

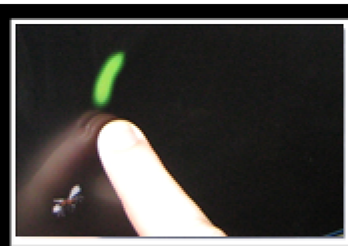


At several points in your drive you will be asked to follow a bug that is flying in the backseat of the vehicle.

This virtual bug will appear on a touch screen located behind the passenger seat.

Task2: Bug Catching Task





You will see a RED glow around your finger if you are not doing a good job following the path of the bug.

You will see a GREEN glow around your finger if you are doing a good job following the path of the bug.

Your goal in this task is to maintain a green glow until you follow the bug.

Task #3 – Message Reading

This task will be presented on a touch screen located in the passenger seat. When you hear "read message," you should begin the task. You should read aloud as much of the text as possible in the time available.

Task #4 – Menu Search Selection

This task will be presented on a touch screen located in the passenger seat. You will see four two-word phrases on the touch screen. Your task will be to match a word and its location. An example will be presented on the next slide.

Menu Selection Example

This task will begin when you hear "Discover Project". You need to find the line that has either of these words in the correct position.

Protest	Discover
Project	Diaper
Discount	Paper
Disco	Project

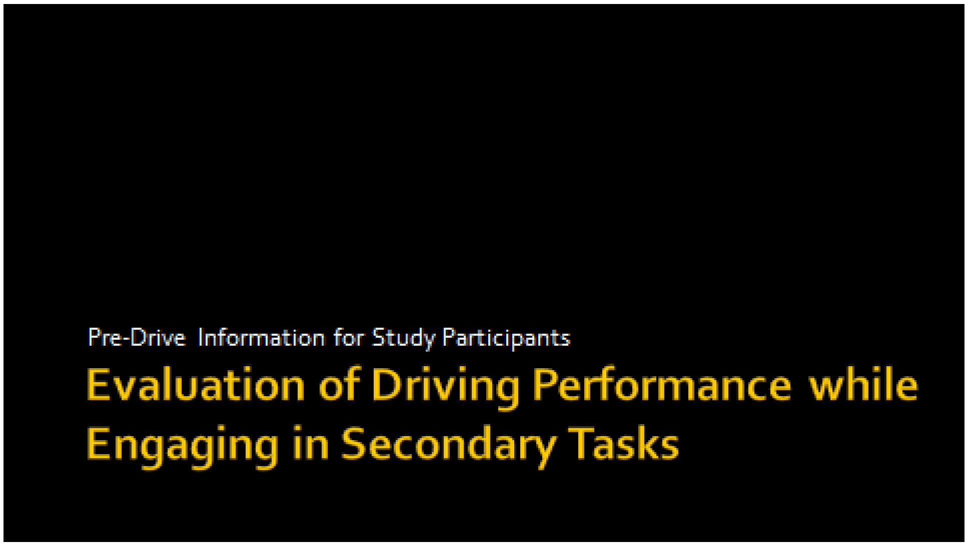
Headway Maintenance

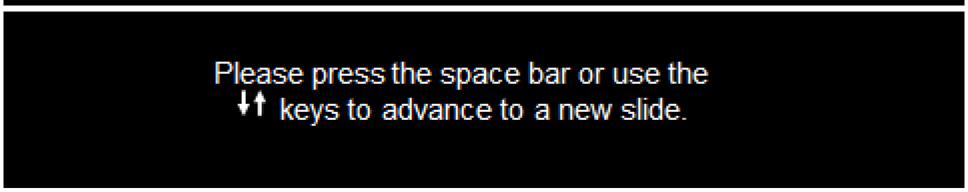
Headway maintenance is your ability to maintain a specified distance from your vehicle to the vehicle in front of you.

During your drive today, you will be asked to maintain a headway of 185 from vehicles ahead of you. You are asked to stay within 15 feet of this target (170 to 200 feet). A display is mounted on top of the dash to provide you with your headway distance.

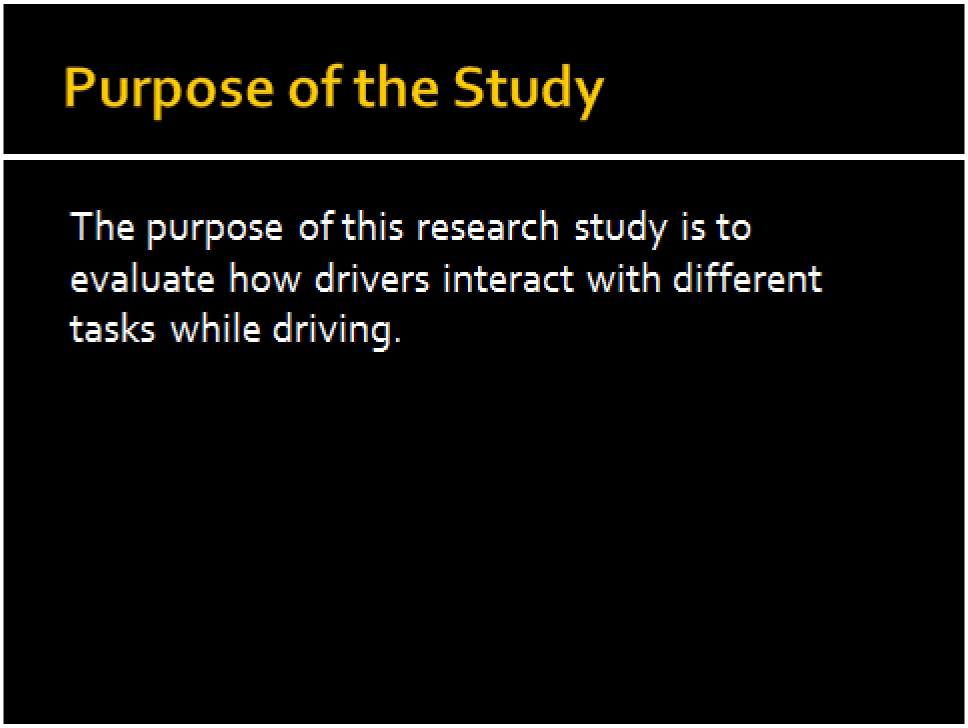
Conclusion Slide Here

17.6 Secondary Task and Incentive Considerations Study-High Base





Instruction Slide Here



Common Slides Here

The Drive

The drive starts with your car parked on a suburban road. When told to begin, press on the brake, shift into drive, and begin to drive.

The beginning portion of your drive today is designed to help you get used to the simulator. During this time you should become familiar with driving at the posted speed limit, the feel of the simulator, and some of the new technologies.

You will leave the suburban town and drive into a rural area between towns. This rural road is a two lane street. The speed limit is 55 mph.

Distraction Tasks

You will be asked to perform four distraction tasks while driving.

1. Task 1: Number Recall
2. Task 2: Bug Catching
3. Task 3: Message Reading
4. Task 4: Menu Search Selection

These tasks are described in detail on the following slides.

Task #1 – Number Recall

You will hear "Number Recall" indicating the start of the task. Five random single digit numbers are presented one at a time on a computer screen.

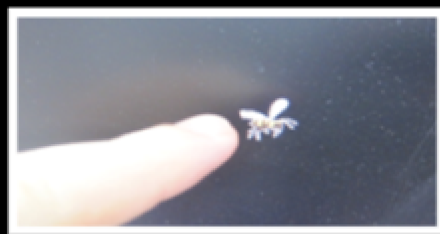
The computer screen is located to the left of the passenger headrest.

After all five numbers have been presented to you, your task is to recall the five numbers aloud in the correct order.

Incentive

- Five tasks across the drive
- You will receive up to $0.61 for each task
- You will receive $0.12 for each number correct
- You will be deducted $0.07 for numbers out of order on a task

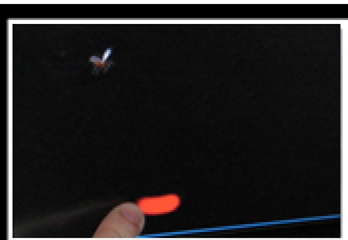
Task2: Bug Catching Task



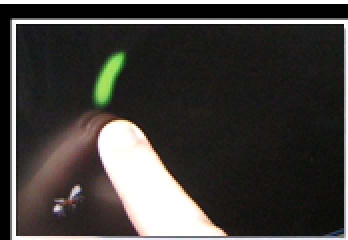
At several points in your drive you will be asked to follow a bug that is flying in the backseat of the vehicle.

This virtual bug will appear on a touch screen located behind the passenger seat.

Task2: Bug Catching Task

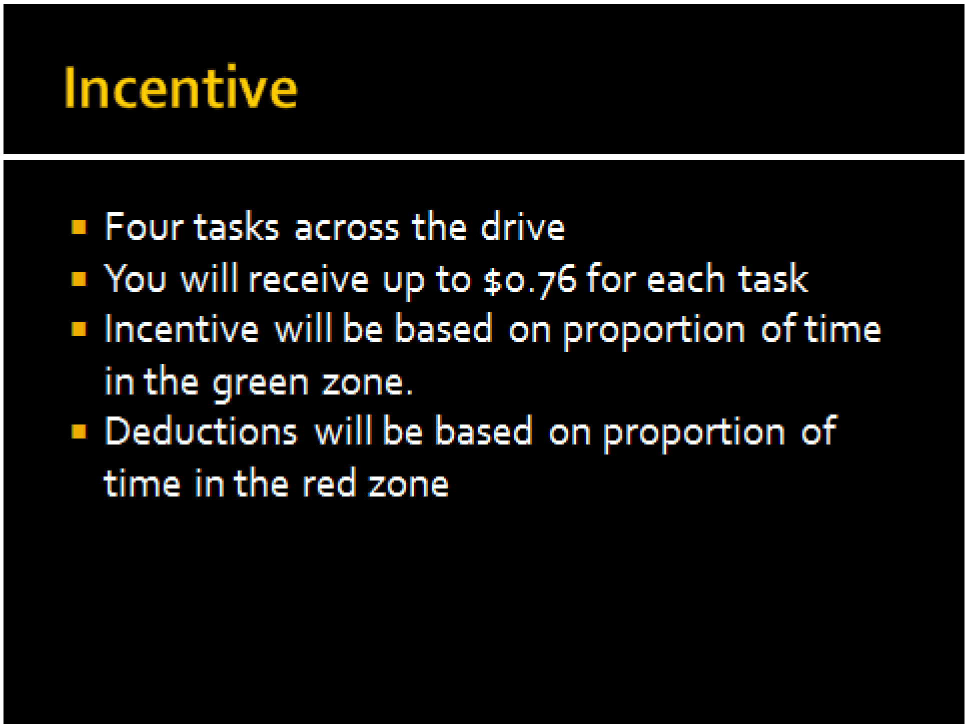


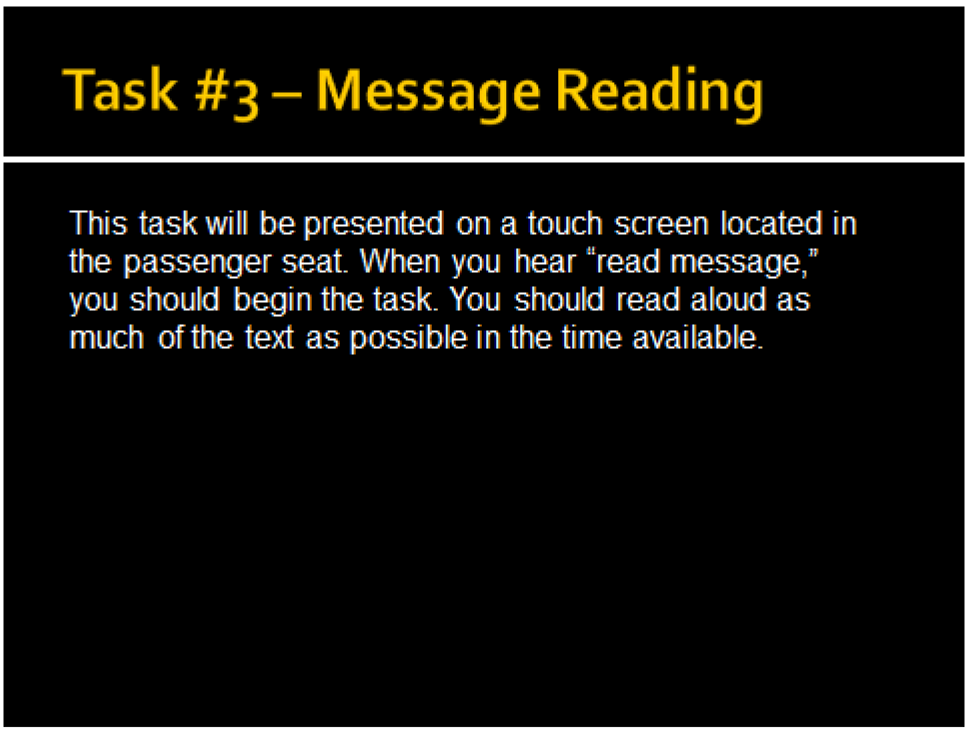
You will see a RED glow around your finger if you are not doing a good job following the path of the bug.



You will see a GREEN glow around your finger if you are doing a good job following the path of the bug.

Your goal in this task is to maintain a green glow until you follow the bug.


Incentive
Four tasks across the drive
You will receive up to $0.76 for each task
Incentive will be based on proportion of time in the green zone.
Deductions will be based on proportion of time in the red zone

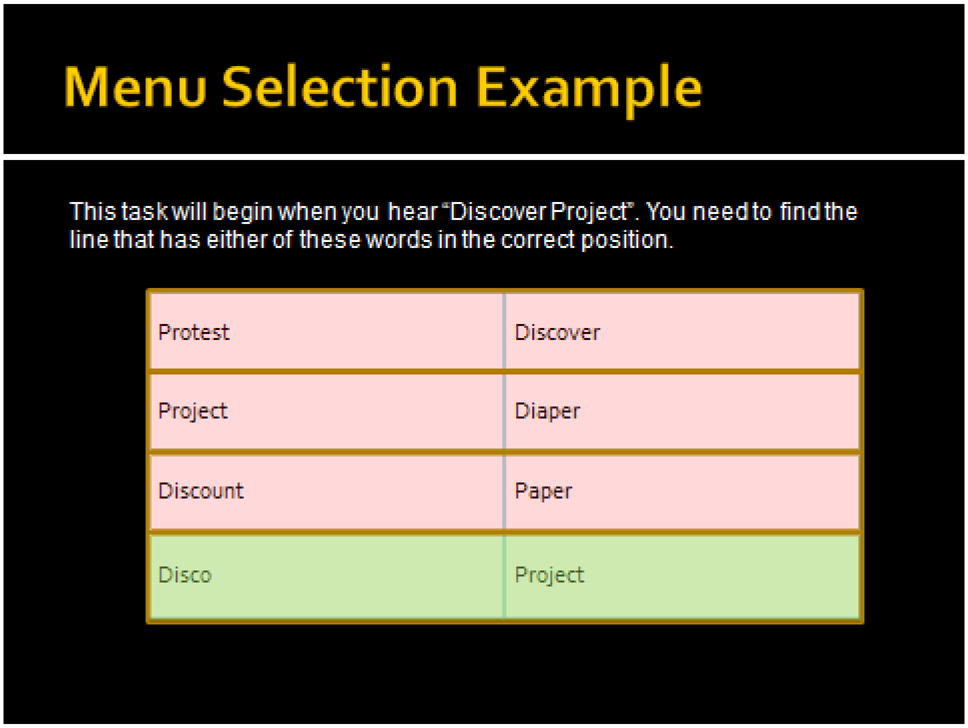

Task #3 – Message Reading
This task will be presented on a touch screen located in the passenger seat. When you hear “read message,” you should begin the task. You should read aloud as much of the text as possible in the time available.

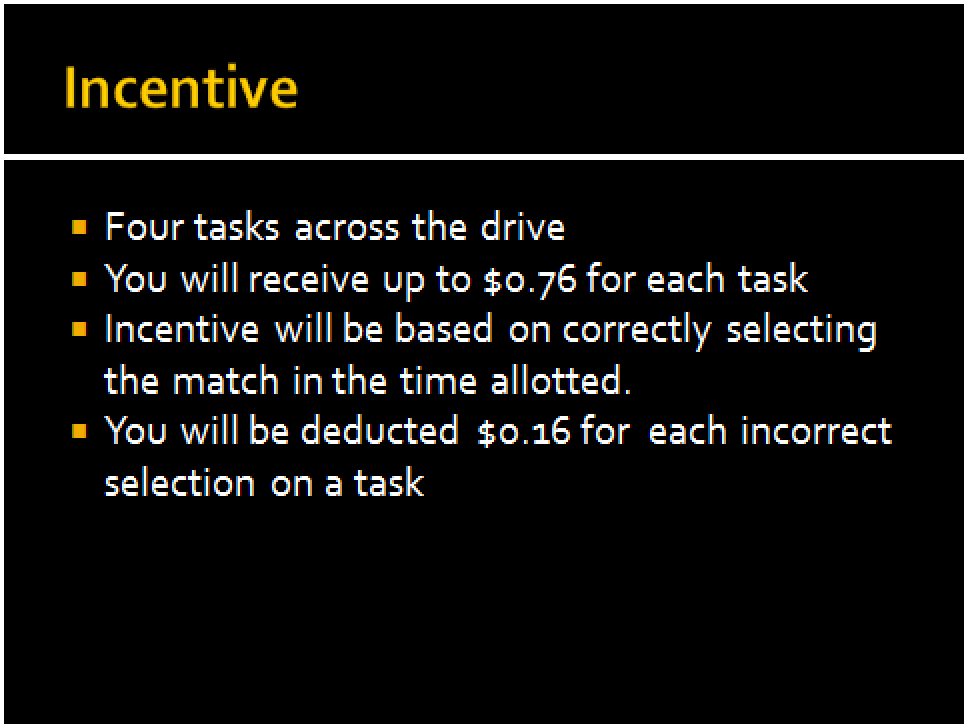
Incentive

- Four tasks across the drive
- You will receive up to $0.76 for each task
- Incentive will be based on correctly selecting the match in the time allotted.
- You will be deducted $0.16 for each incorrect selection on a task

Task #4 – Menu Search Selection

This task will be presented on a touch screen located in the passenger seat. You will see four two-word phrases on the touch screen. Your task will be to match a word and its location. An example will be presented on the next slide.


Menu Selection Example
This task will begin when you hear "Discover Project". You need to find the line that has either of these words in the correct position.
Protest
Discover
Project
Diaper
Discount
Paper
Disco
Project


Incentive
Four tasks across the drive
You will receive up to $0.76 for each task
Incentive will be based on correctly selecting the match in the time allotted.
You will be deducted $0.16 for each incorrect selection on a task

Headway Maintenance

Headway maintenance is your ability to maintain a specified distance from your vehicle to the vehicle in front of you.

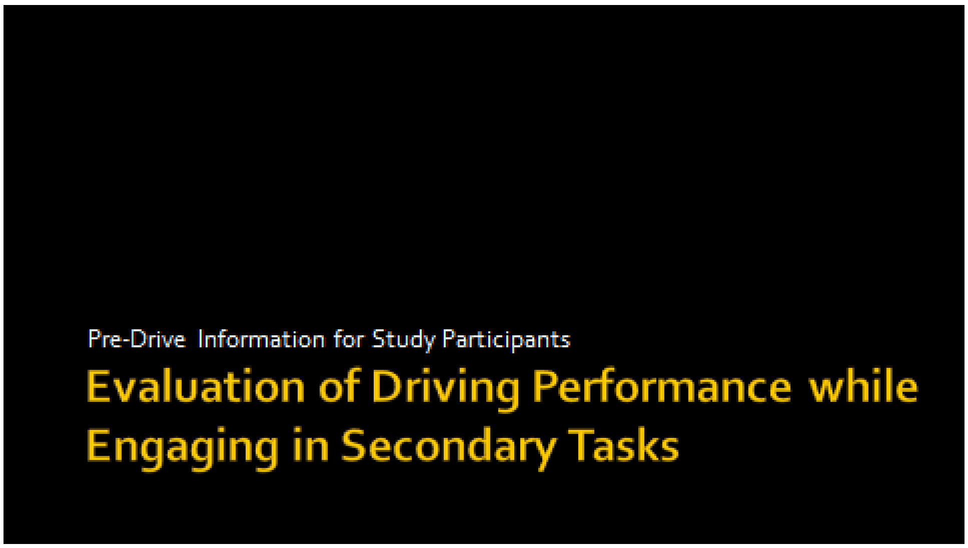
During your drive today, you will be asked to maintain a headway of 185 feet from vehicles ahead of you. A display is mounted on top of the dash to provide you with your headway distance.

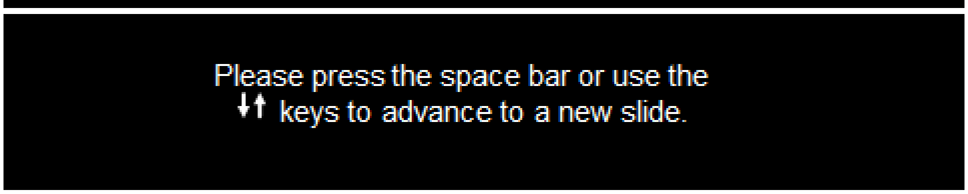
Incentive

- Additional compensation is available if you successfully stay within 15 feet of this target (170 to 200 feet).
- If you can stay in that range, you will receive $5.38 for the drive. This is cumulative over the whole drive

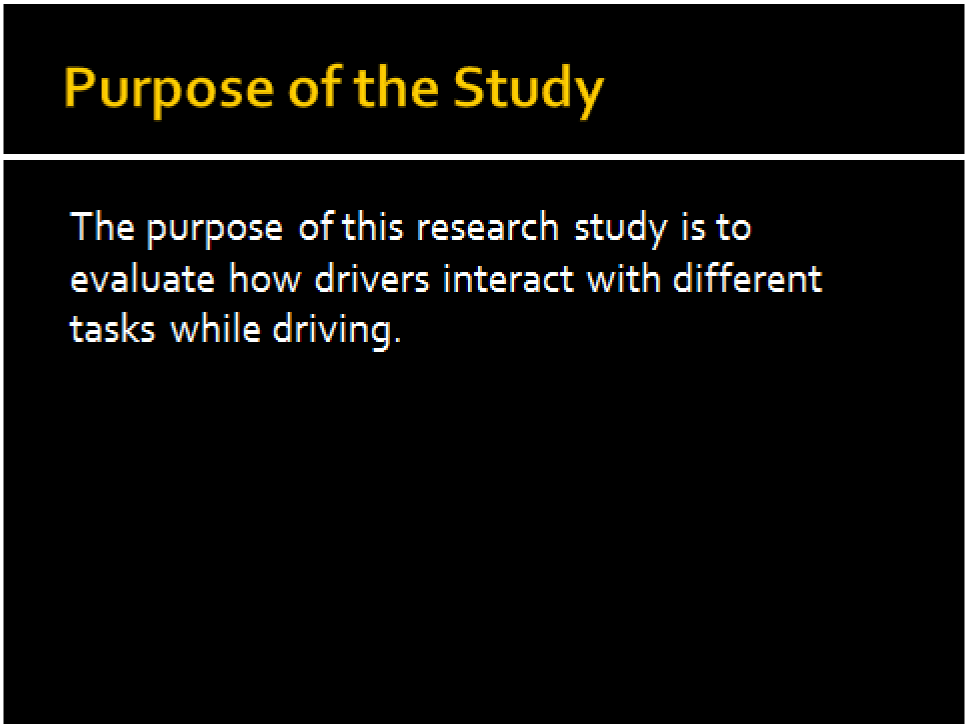
Conclusion Slide Here

17.7 Secondary Task and Incentive Considerations Study-Low Base





Instruction Slide Here



Common Slides Here

The Drive

The drive starts with your car parked on a suburban road. When told to begin, press on the brake, shift into drive, and begin to drive.

The beginning portion of your drive today is designed to help you get used to the simulator. During this time you should become familiar with driving at the posted speed limit, the feel of the simulator, and some of the new technologies.

You will leave the suburban town and drive into a rural area between towns. This rural road is a two lane street. The speed limit is 55 mph.

Distraction Tasks

You will be asked to perform four distraction tasks while driving.

1. Task 1: Number Recall
2. Task 2: Bug Catching
3. Task 3: Message Reading
4. Task 4: Menu Search Selection

These tasks are described in detail on the following slides.

Task #1 – Number Recall

You will hear "Number Recall" indicating the start of the task. Five random single digit numbers are presented one at a time on a computer screen.

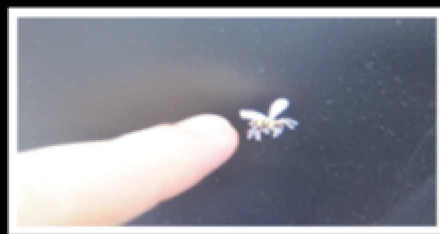
The computer screen is located to the left of the passenger headrest.

After all five numbers have been presented to you, your task is to recall the five numbers aloud in the correct order.

Incentive

- Five tasks across the drive
- You will receive up to $0.95 for each task
- You will receive $0.19 for each number correct
- You will be deducted $0.07 for numbers out of order on a task

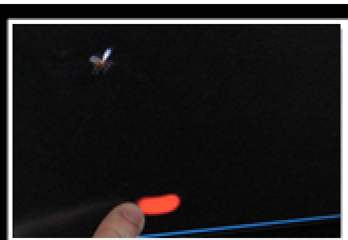
Task2: Bug Catching Task



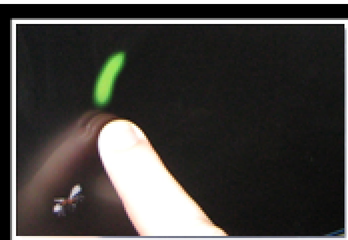
At several points in your drive you will be asked to follow a bug that is flying in the backseat of the vehicle.

This virtual bug will appear on a touch screen located behind the passenger seat.

Task2: Bug Catching Task



You will see a RED glow around your finger if you are not doing a good job following the path of the bug.



You will see a GREEN glow around your finger if you are doing a good job following the path of the bug.

Your goal in this task is to maintain a green glow until you follow the bug.

Incentive

- Four tasks across the drive
- You will receive up to $1.19 for each task
- Incentive will be based on proportion of time in the green zone.
- Deductions will be based on proportion of time in the red zone

Task #3 – Message Reading

This task will be presented on a touch screen located in the passenger seat. When you hear "read message," you should begin the task. You should read aloud as much of the text as possible in the time available.

Incentive

- Four tasks across the drive
- You will receive up to $1.19 for each task
- Incentive will be based on percent of words read during the allotted time.
- You will be deducted $0.25 for each incorrect word on a task.

Task #4 – Menu Search Selection

This task will be presented on a touch screen located in the passenger seat. You will see four two-word phrases on the touch screen. Your task will be to match a word and its location. An example will be presented on the next slide

Menu Selection Example

This task will begin when you hear "Discover Project". You need to find the line that has either of these words in the correct position.

Protest	Discover
Project	Diaper
Discount	Paper
Disco	Project

Incentive

- Four tasks across the drive
- You will receive up to $1.19 for each task
- Incentive will be based on correctly selecting the match in the time allotted.
- You will be deducted $0.25 for each incorrect selection on a task

Headway Maintenance

Headway maintenance is your ability to maintain a specified distance from your vehicle to the vehicle in front of you.

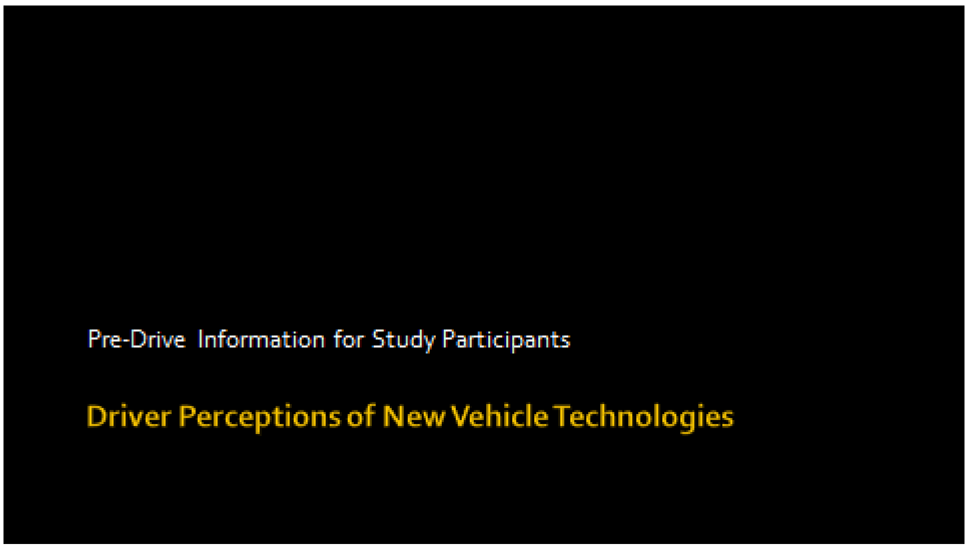
During your drive today, you will be asked to maintain a headway of 185 feet from vehicles ahead of you. A display is mounted on top of the dash to provide you with your headway distance.

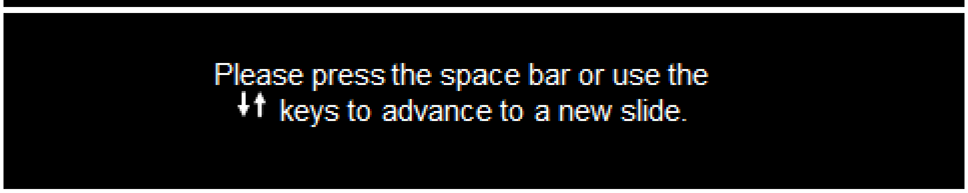
Incentive

- Additional compensation is available if you successfully stay within 15 feet of this target (170 to 200 feet).
- If you can stay in that range, you will receive $8.46 for the drive. This is cumulative over the whole drive

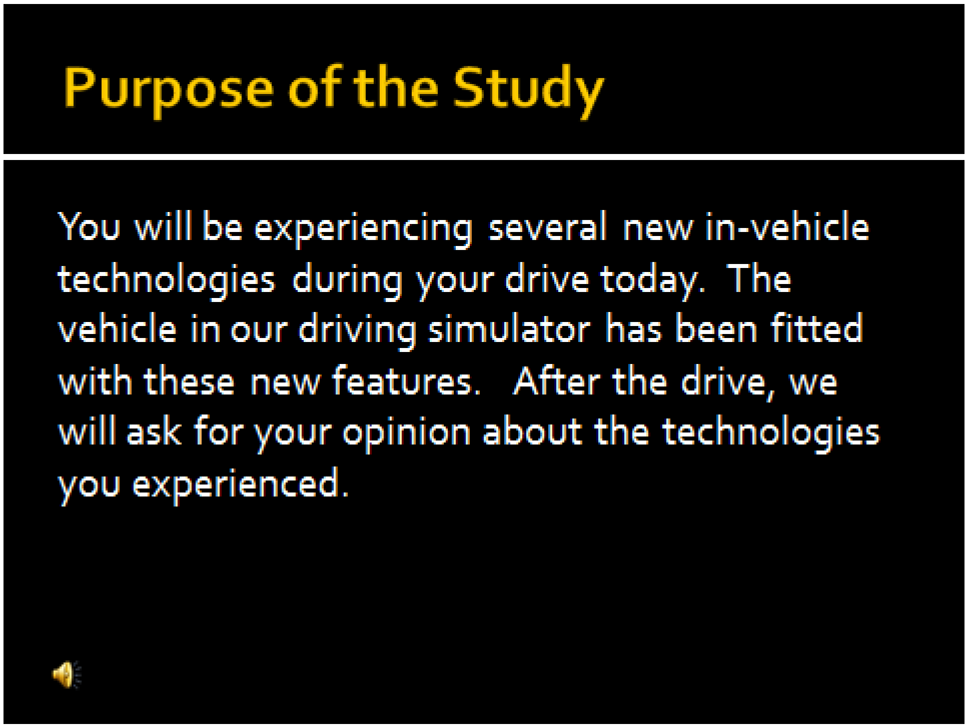
Conclusion Slide Here

17.8 System Training and Exposure Study





Instruction Slide Here



Common Slides Here

Reviewing the New Technologies and Distraction Tasks

After you have made all necessary adjustments and are comfortable in the vehicle, a researcher will review what your drive will be like, show you the new technologies, and practice the distraction tasks with you.

The Drive

The drive starts with your car parked on a suburban road. When told to begin, press on the brake, shift into drive, and begin to drive.

The beginning portion of your drive today is designed to help you get used to the simulator. During this time you should become familiar with driving at the posted speed limit, the feel of the simulator, and some of the new technologies.

You will leave the suburban town and drive into a rural area between towns. This rural road is a two lane street. The speed limit is 55 mph.

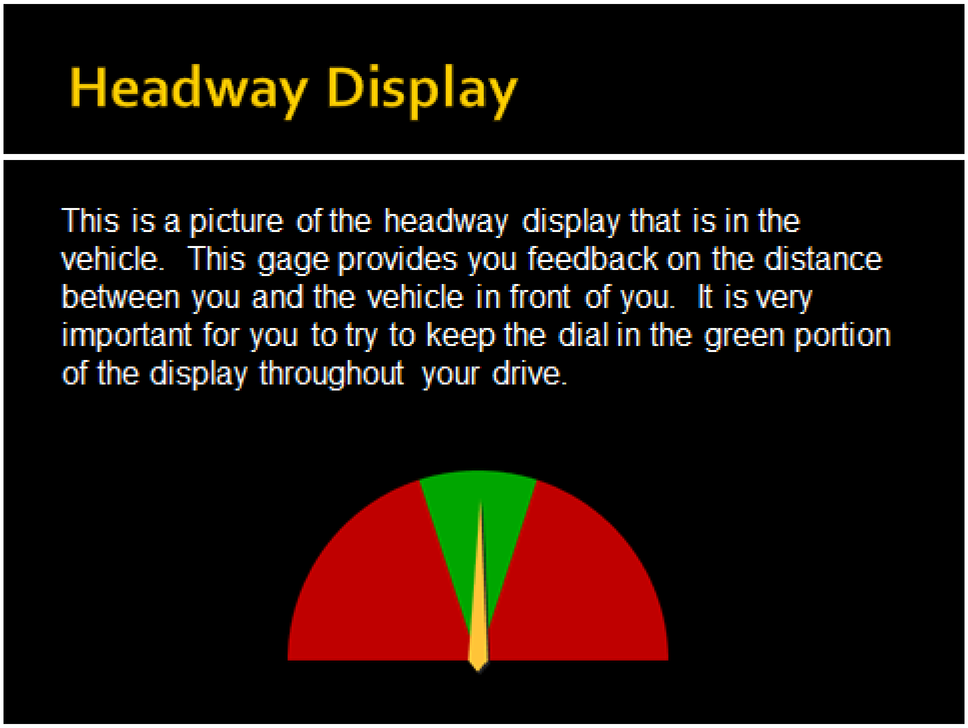
New Technologies

You will be experiencing several new in-vehicle technologies during your drive today. After the drive, we will ask for your opinion about the technologies you experienced. The next few slides will give you information about these new technologies.

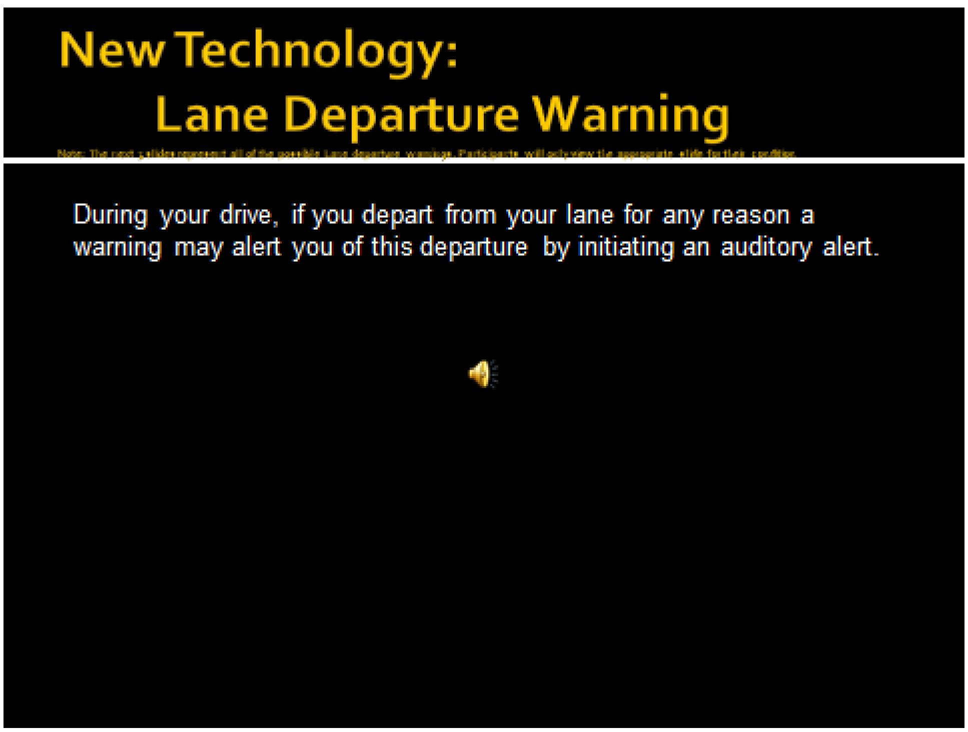
- Auditory-Only Navigation System
- Headway Display
- Lane Departure Warning System (NOTE: may or may not be present)
- Forward Collision Warning System (NOTE: may or may not be present)
- Speed Warning Alert System

New Technology:
Auditory-Only Navigation System

As you approach intersections during your drive, you may or may not hear an auditory navigation system inform you of which direction you should take in order to arrive at your desired destination. There is no visual navigation screen included, this is an auditory only navigation system. To hear a sample of the auditory alert click on the icon below.

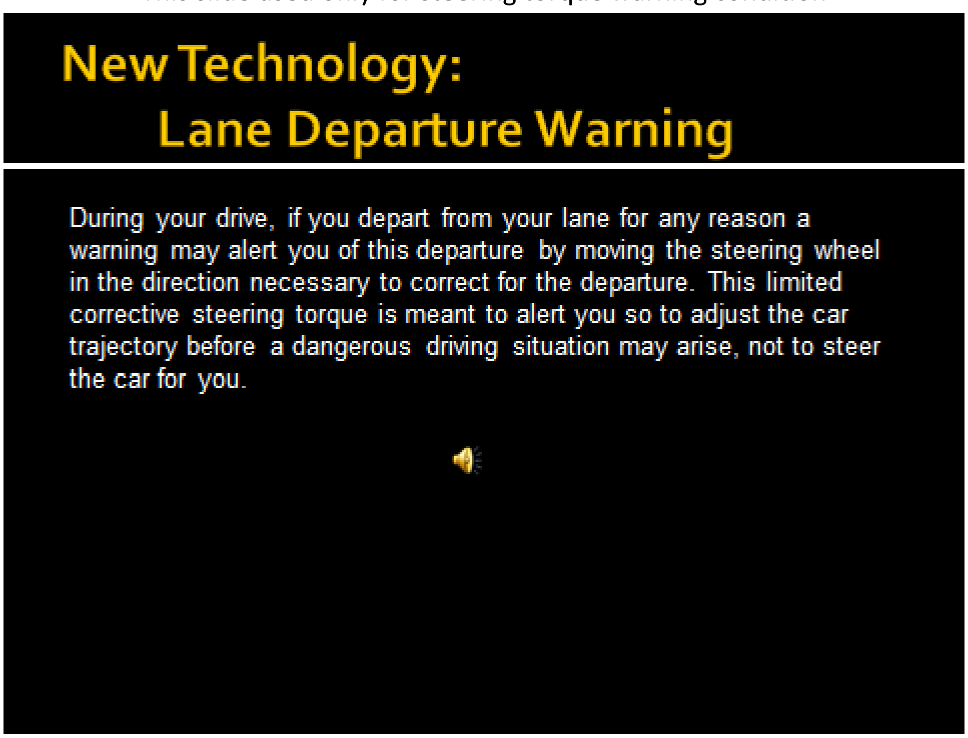


This slide used only for auditory warning condition.



This slide used only for vibrating steering wheel warning condition

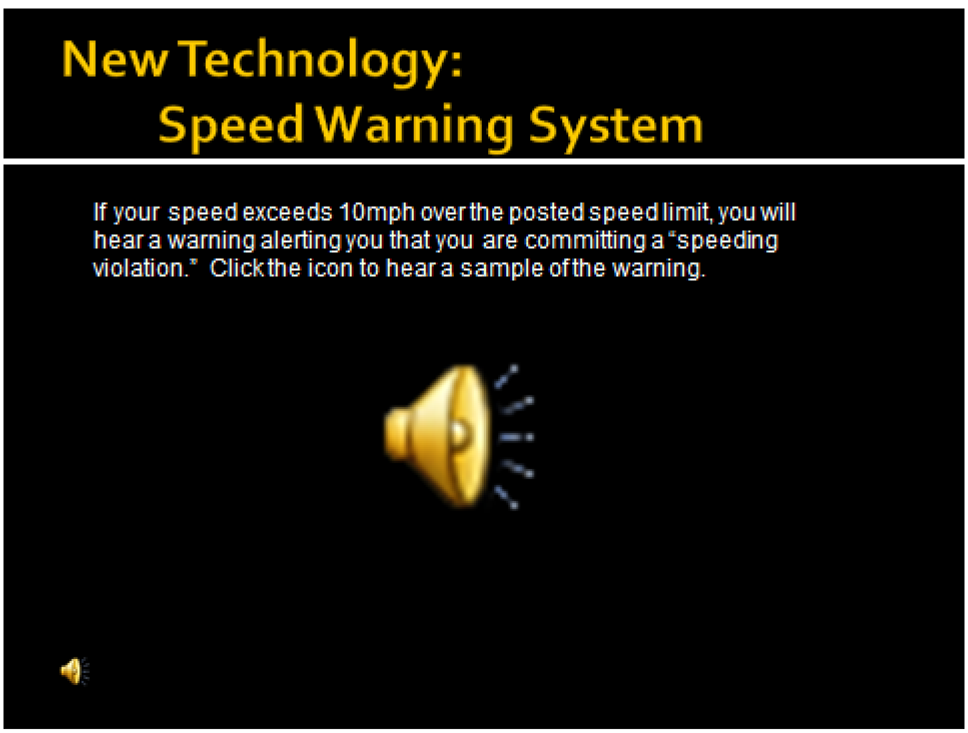
This slide used only for steering torque warning condition



This slide used only for brake pulse warning condition

This slide used only for seat belt warning condition

This slide used only for auditory warning condition



Distraction Tasks

In order to ensure that the new technologies are experienced in a way that is realistic, we will ask you to perform a distraction task while driving.

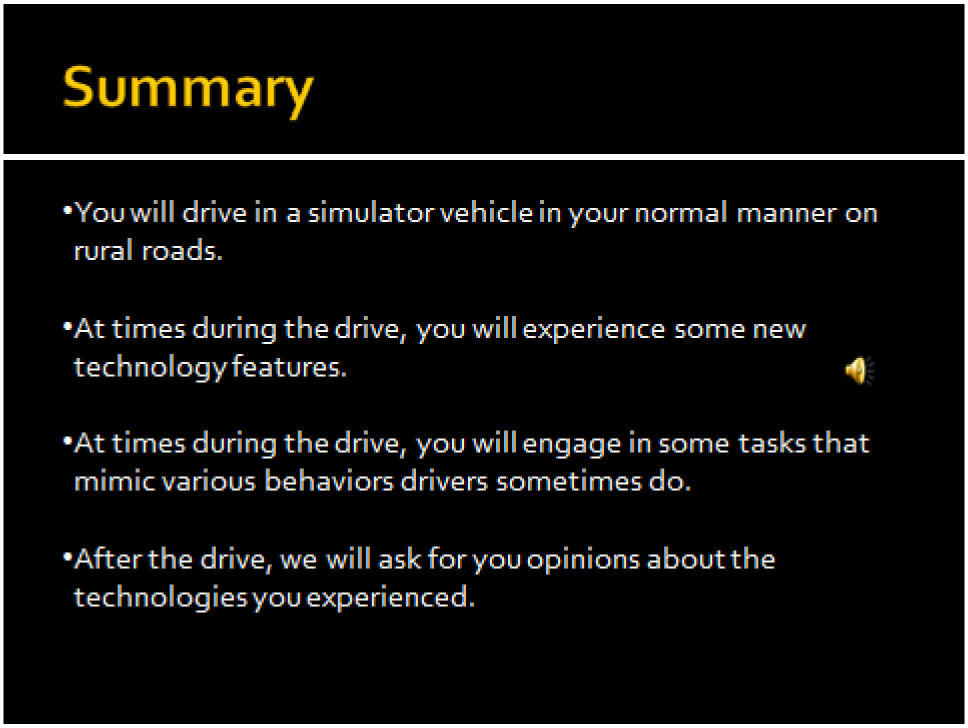
This task is described in detail on the following slide.

Number Recall Task

You will hear “Begin task now” indicating the start of the task. Five random single digit numbers are presented one at a time on a computer screen.

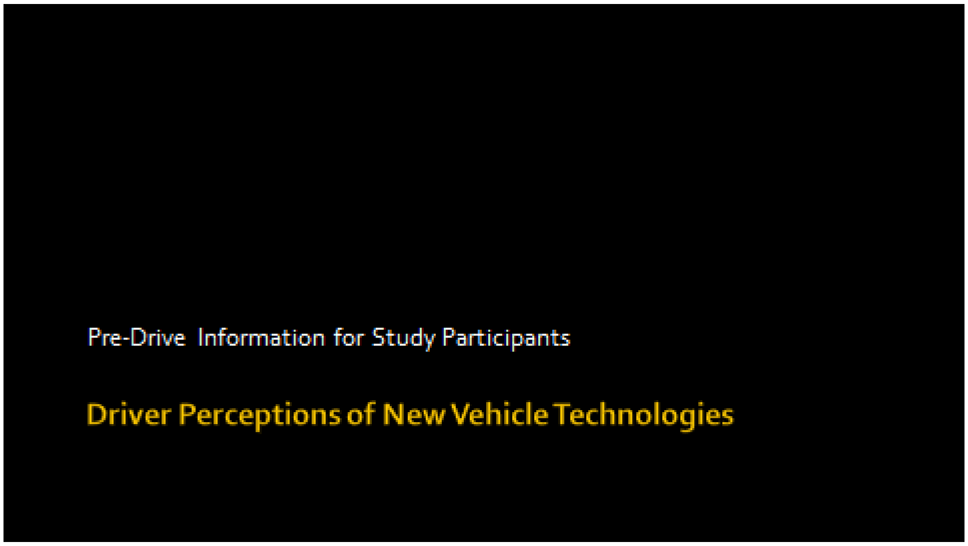
The computer screen is located on the back passenger headrest.

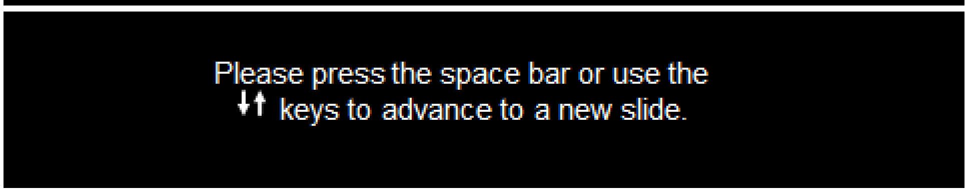
After all five numbers have been presented to you, your task is to recall the five numbers aloud in the correct order.



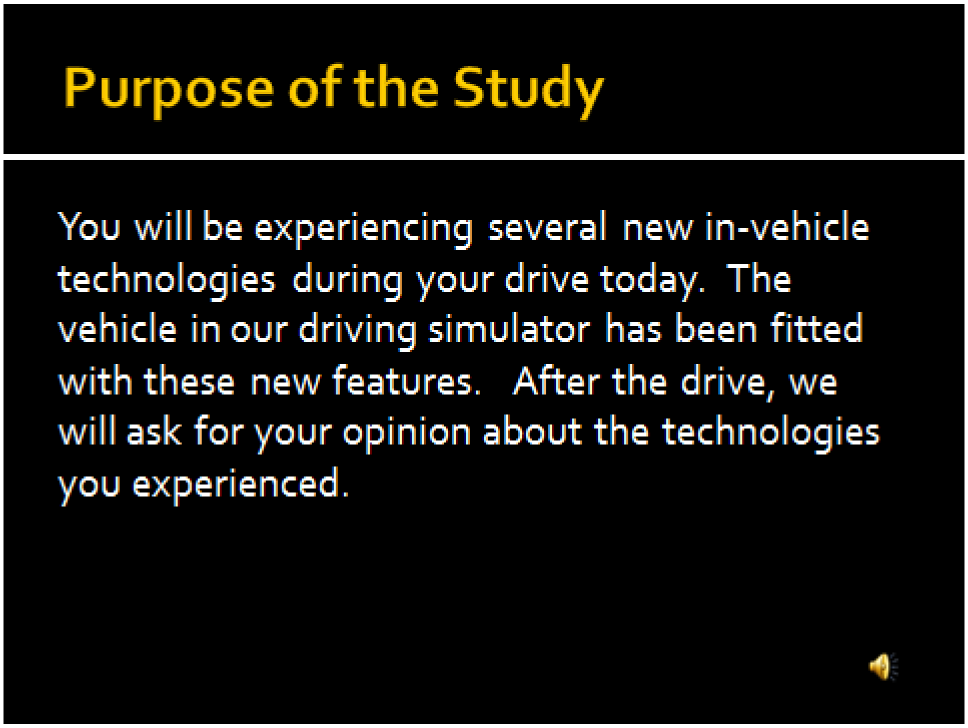
Conclusion Slide Here

17.9 Alert Timing and Protocol Sensitivity to Systems and Motion Feedback Considerations Studies





Instruction Slide Here



Common Slides Here

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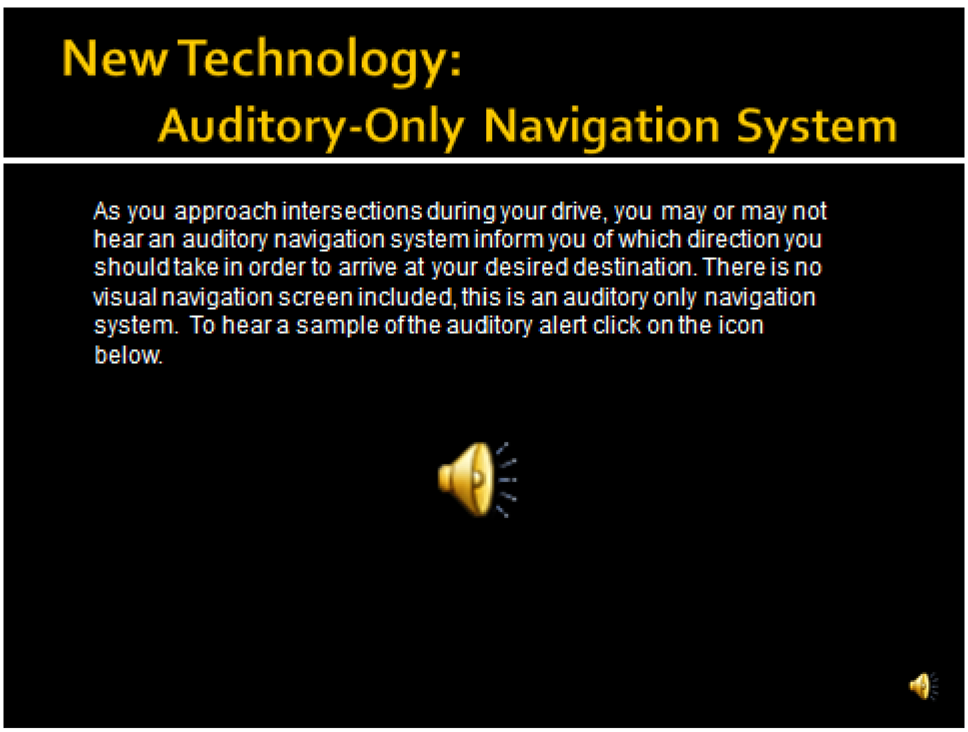
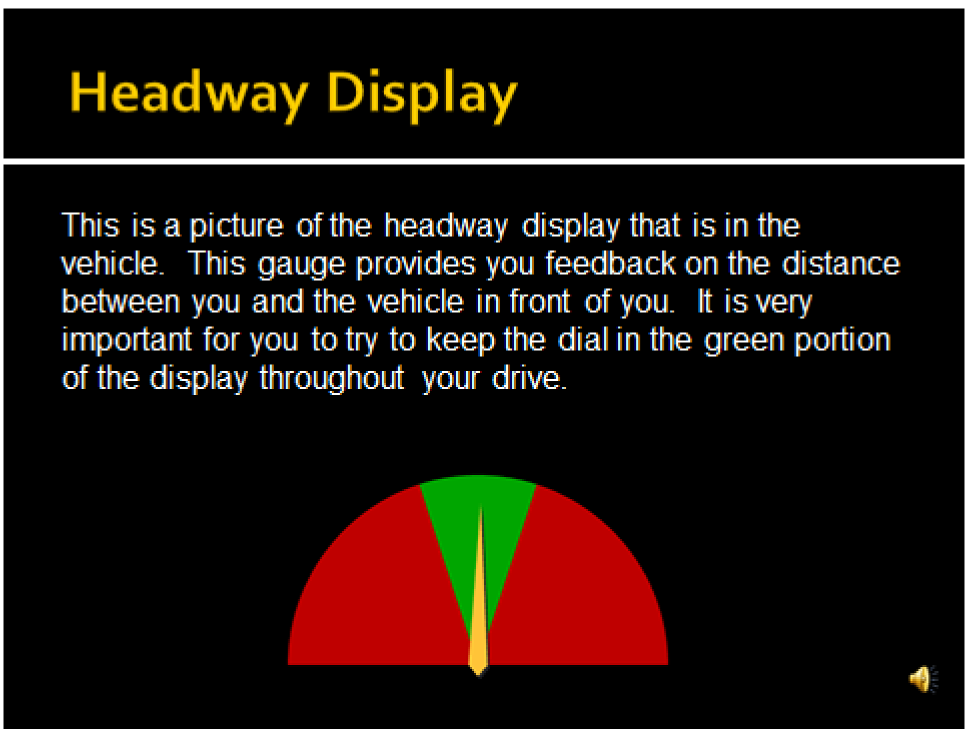
The beginning portion of your drive today is designed to help you get used to the simulator. During this time you should become familiar with driving at the posted speed limit, the feel of the simulator, and some of the new technologies.

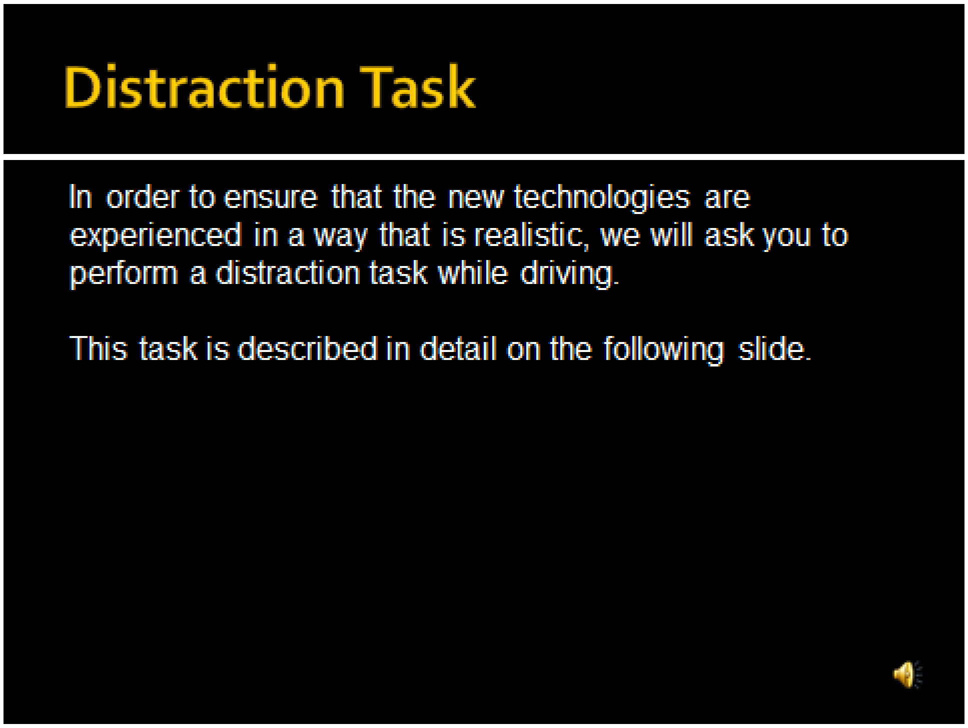
You will leave the suburban town and drive into a rural area between towns. This rural road is a two lane street. The speed limit is 55 mph.

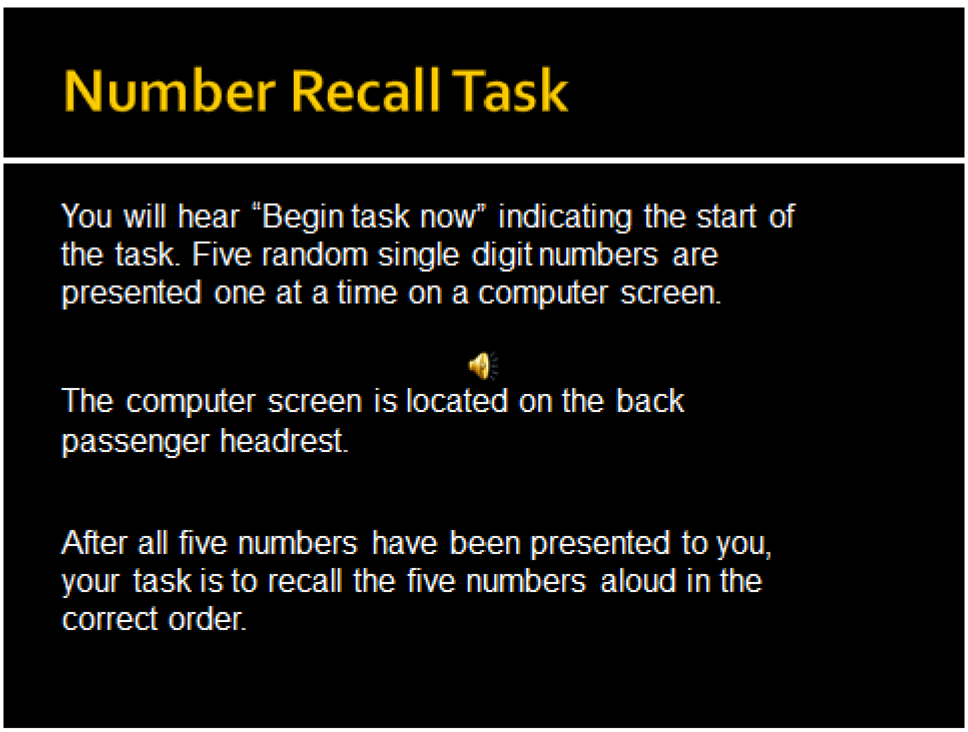

New Technologies
You will be experiencing several new in-vehicle technologies during your drive today. After the drive, we will ask for your opinion about the technologies you experienced. The next few slides will give you information about these new technologies.
• Auditory-Only Navigation System
• Speed Warning Alert System
• Headway Display

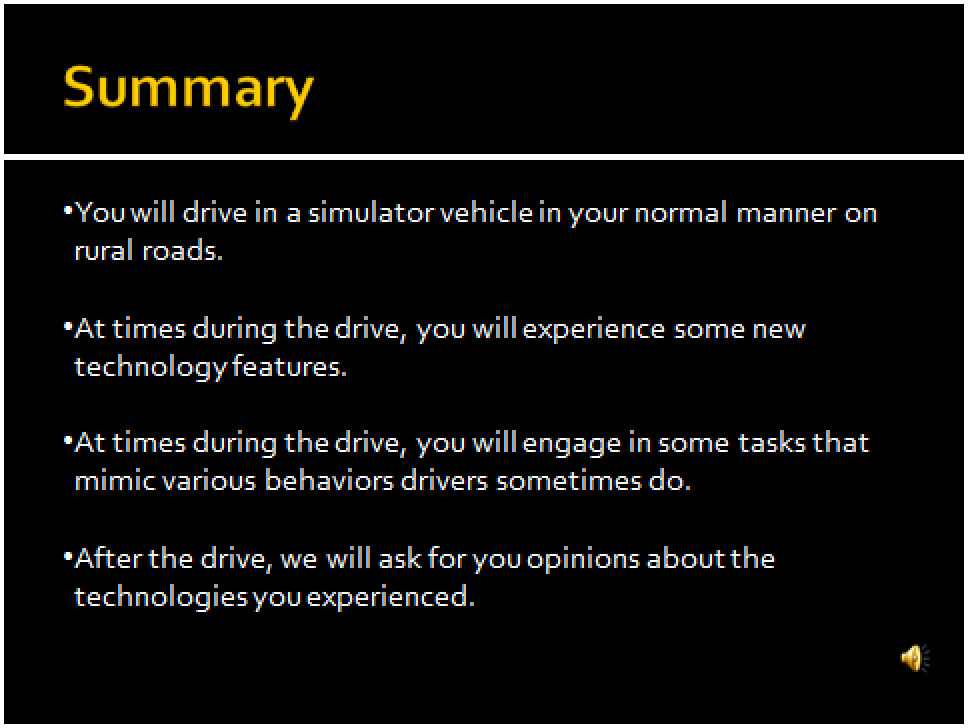

New Technology:
Auditory-Only Navigation System
As you approach intersections during your drive, you may or may not hear an auditory navigation system inform you of which direction you should take in order to arrive at your desired destination. There is no visual navigation screen included, this is an auditory only navigation system. To hear a sample of the auditory alert click on the icon below.


New Technology:
Speed Warning System
If your speed exceeds 10mph over the posted speed limit, you will hear a warning alerting you that you are committing a "speeding violation." Click the icon to hear a sample of the warning.


Headway Display
This is a picture of the headway display that is in the vehicle. This gauge provides you feedback on the distance between you and the vehicle in front of you. It is very important for you to try to keep the dial in the green portion of the display throughout your drive.

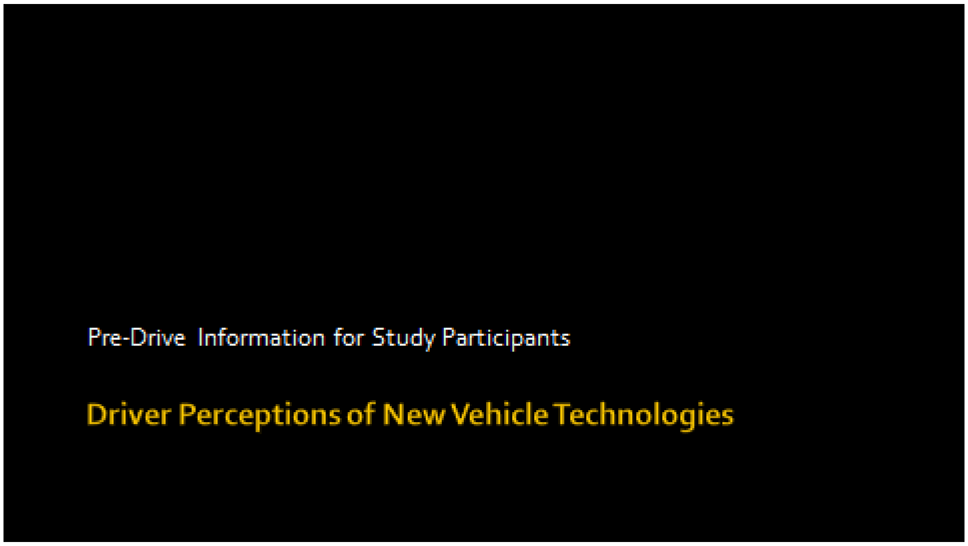

Distraction Task
In order to ensure that the new technologies are experienced in a way that is realistic, we will ask you to perform a distraction task while driving.
This task is described in detail on the following slide.

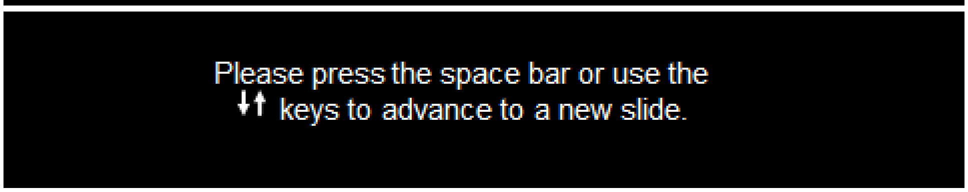

Number Recall Task
You will hear "Begin task now" indicating the start of the task. Five random single digit numbers are presented one at a time on a computer screen.
The computer screen is located on the back passenger headrest.
After all five numbers have been presented to you, your task is to recall the five numbers aloud in the correct order.



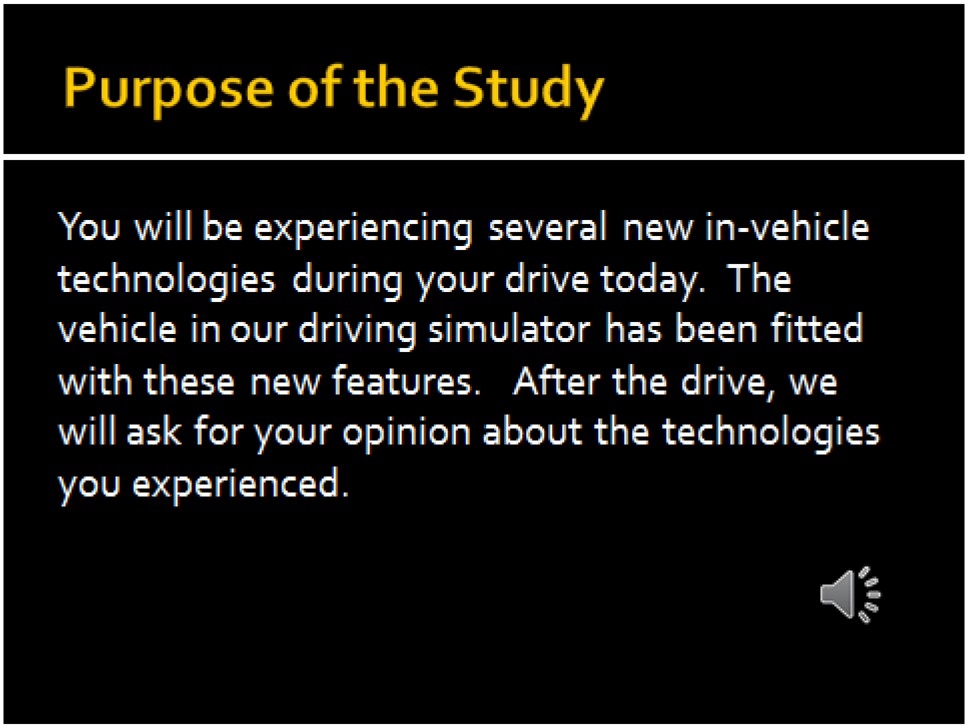
Conclusion Slide Here

17.10 Crash Warning Evaluation in a Connected Vehicles Environment Study





Instruction Slide Here



Common Slides Here

Reviewing the New Technologies

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The Drive

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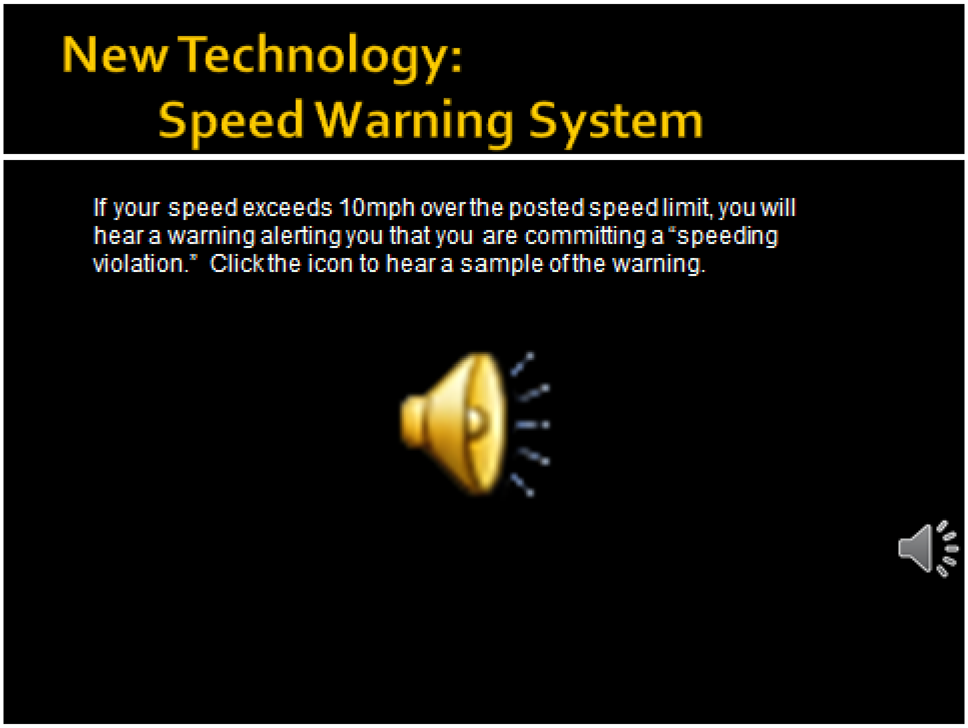
New Technologies

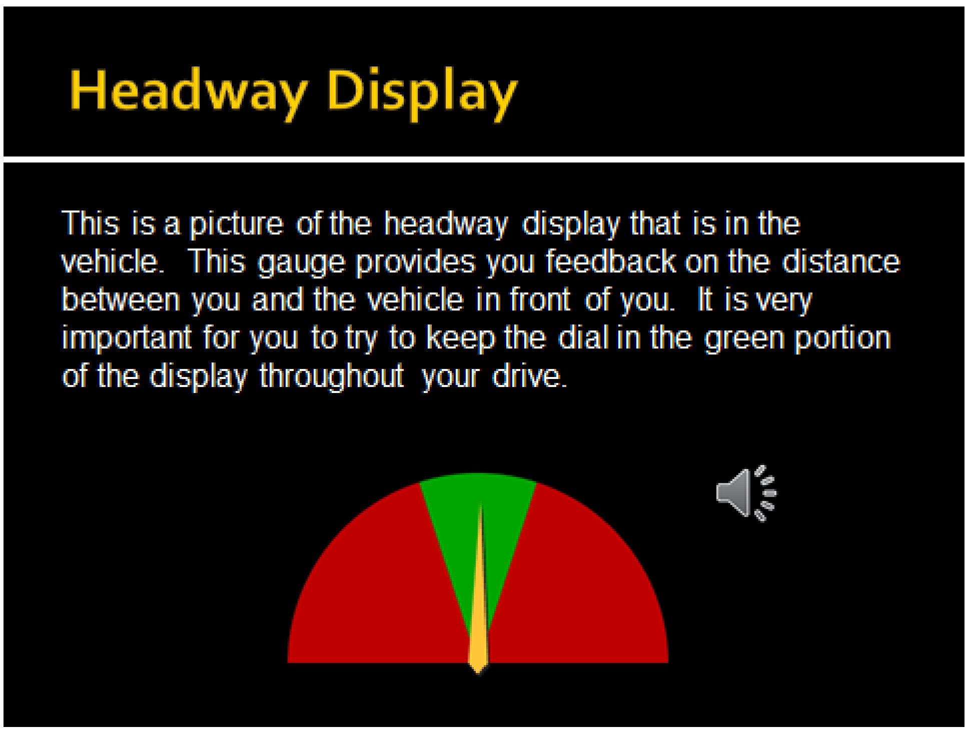
You will be experiencing several new in-vehicle technologies during your drive today. After the drive, we will ask for your opinion about the technologies you experienced. The next few slides will give you information about these new technologies.

- Auditory-Only Navigation System
- Speed Warning Alert System
- Headway Display
- Information Task
- Text Messages

New Technology: Auditory-Only Navigation System

As you approach intersections during your drive, you may or may not hear an auditory navigation system inform you of which direction you should take in order to arrive at your desired destination. There is no visual navigation screen included, this is an auditory only navigation system. To hear a sample of the auditory alert click on the icon below.


New Technology:
Speed Warning System
If your speed exceeds 10mph over the posted speed limit, you will hear a warning alerting you that you are committing a "speeding violation." Click the icon to hear a sample of the warning.


Headway Display
This is a picture of the headway display that is in the vehicle. This gauge provides you feedback on the distance between you and the vehicle in front of you. It is very important for you to try to keep the dial in the green portion of the display throughout your drive.

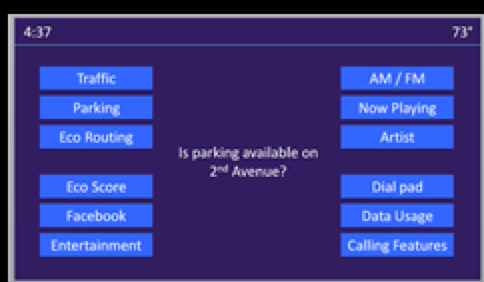
Information Task

In order to ensure that the new technologies are experienced in a way that is realistic, we will ask you to perform a distraction task while driving.

This task is described in detail on the following slides.

Information Task

You will hear "Begin task now" indicating the start of the task. Each time you hear this, a screen like the one shown here will come on.



The screen is located near the heat and air conditioning controls.

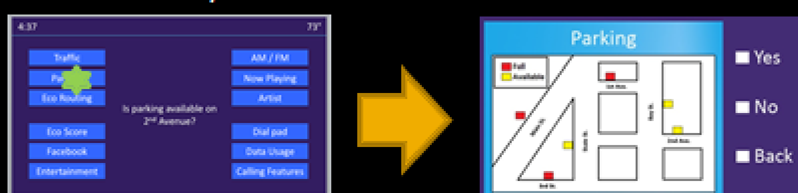
Information Task

The first screen you will see is the home screen. In the center of the home screen you will see a Yes/No question.

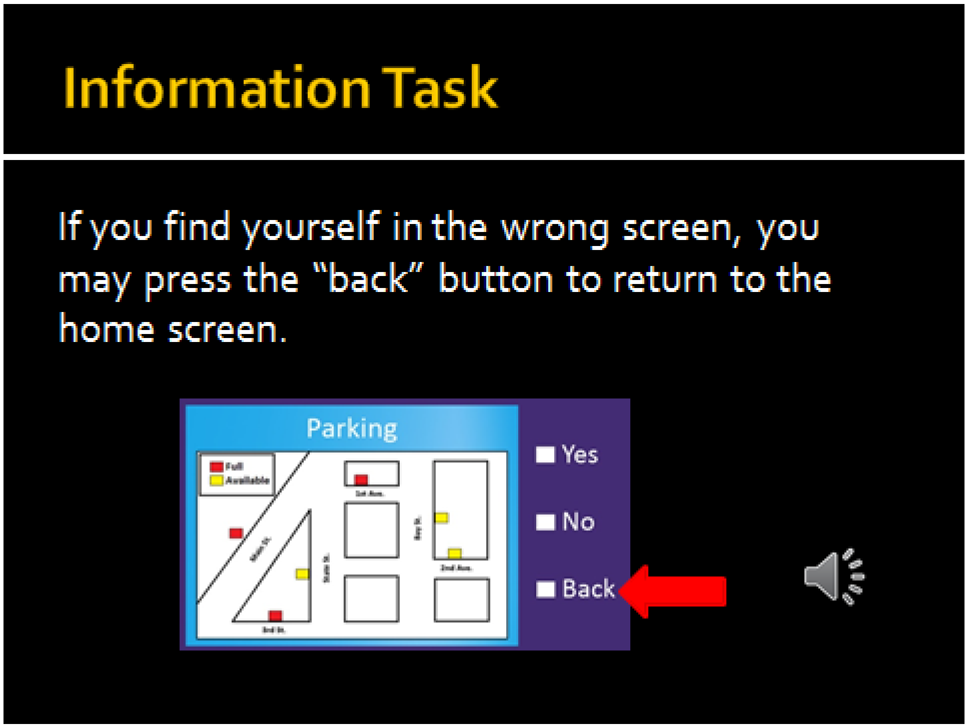
Your task is to seek out the appropriate information to address the question.

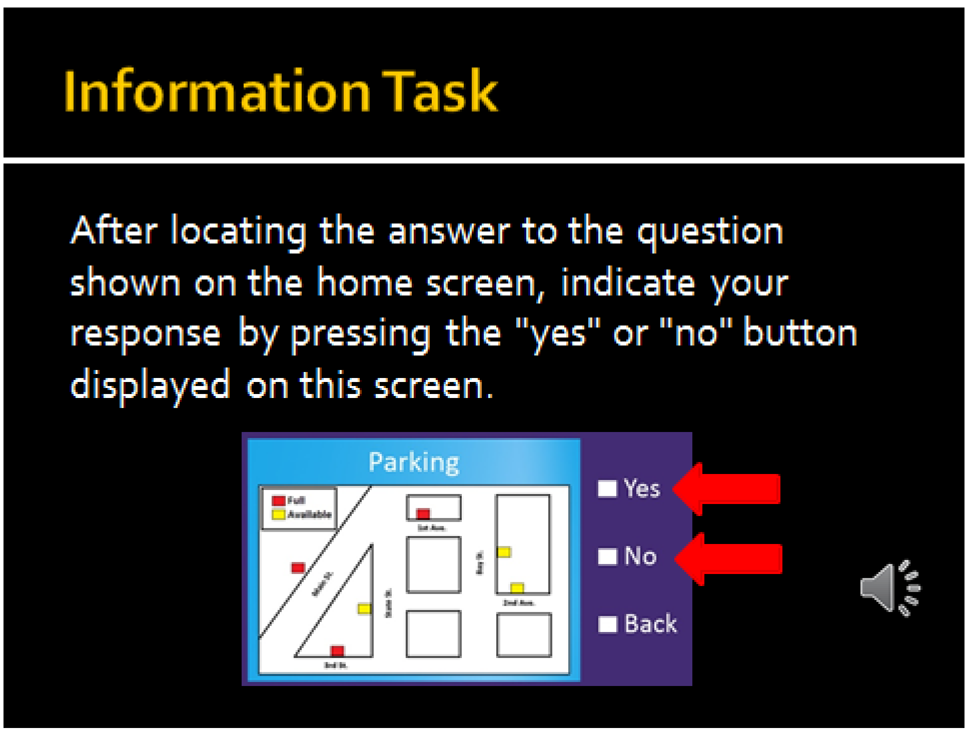
Information Task

When you press any one of the buttons on the home screen,



a second screen will appear, which may contain the information needed to correctly respond to the question posed on the home screen.


Information Task
If you find yourself in the wrong screen, you may press the "back" button to return to the home screen.
Parking
Full
Available
Yes
No
Back

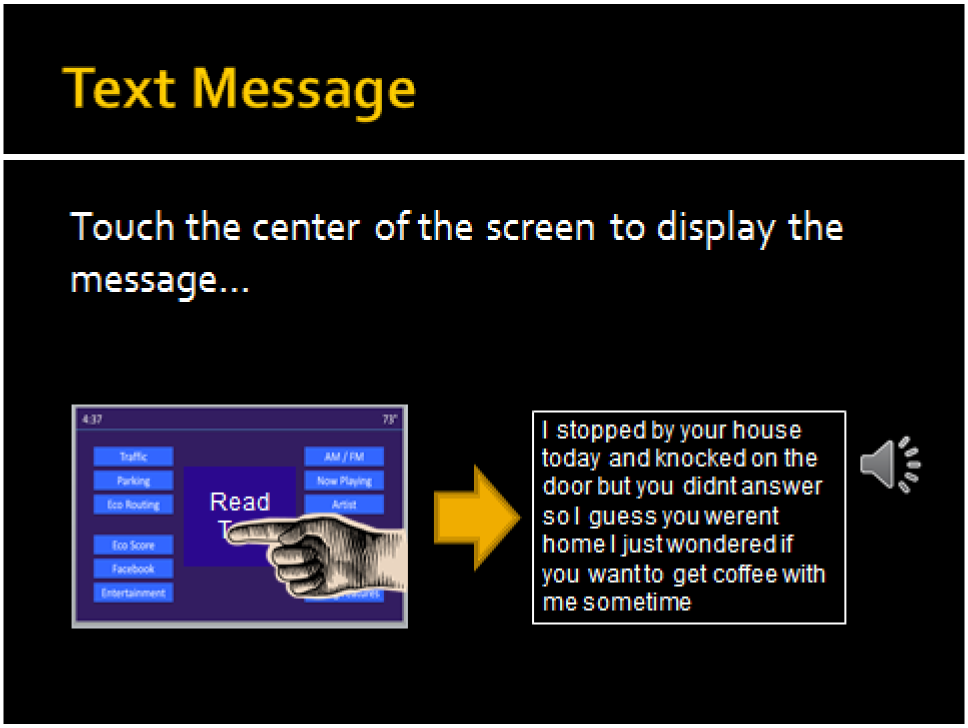

Information Task
After locating the answer to the question shown on the home screen, indicate your response by pressing the "yes" or "no" button displayed on this screen.
Parking
Full
Available
Yes
No
Back

Information Task

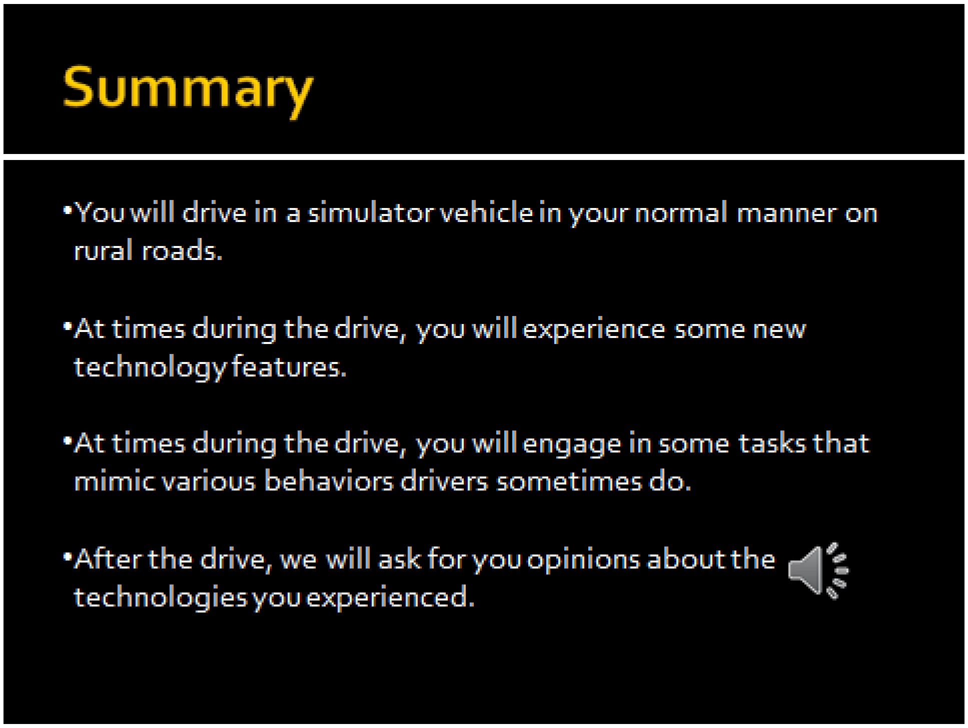
Once you press "yes" or "no", the home screen will again be shown with a new question. Please complete as many searches as you can while the screen is on.

Text Message

From time to time you will also receive text messages. A notification on the home screen will appear:


Text Message
Touch the center of the screen to display the message...
4:37
73°
Traffic
Parking
Eco Routing
Eco Score
Facebook
Entertainment
AM / FM
Now Playing
Artist
Read
I stopped by your house today and knocked on the door but you didnt answer so I guess you werent home I just wondered if you want to get coffee with me sometime


Text Message
Then read the message aloud.
I stopped by your house today and knocked on the door but you didnt answer so I guess you werent home I just wondered if you want to get coffee with me sometime



Conclusion Slide Here

18 Appendix G: Wellness Survey

WELLNESS QUESTIONIRE

Directions: Circle one option for each symptom to indicate whether that symptom applies to you right now

1. General Discomfort ....None..............Slight..............Moderate.........Severe
2. Fatigue ....None..............Slight..............Moderate.........Severe
3. Headache ....None..............Slight..............Moderate.........Severe
4. Eye Strain ....None..............Slight..............Moderate.........Severe
5. Difficulty Focusing ....None..............Slight..............Moderate.........Severe
6. Salivation Increased ....None..............Slight..............Moderate.........Severe
7. Sweating ....None..............Slight..............Moderate.........Severe
8. Nausea ....None..............Slight..............Moderate.........Severe
9. Difficulty Concentrating ....None..............Slight..............Moderate.........Severe
10. *"Fullness of the Head" ....None..............Slight..............Moderate.........Severe
11. Blurred Vision ....None..............Slight..............Moderate.........Severe
12. Dizziness with Eyes Open ....None..............Slight..............Moderate.........Severe
13. Dizziness with Eyes Closed .....None..............Slight..............Moderate.........Severe
14. **Vertigo ....None..............Slight..............Moderate.........Severe
15. ***Stomach Awareness ....None..............Slight..............Moderate.........Severe
16. Burping..................................None..............Slight..............Moderate.........Severe
17. Vomiting.................................None..............Slight..............Moderate.........Severe
18. Other ________________ .....None..............Slight..............Moderate.........Severe

* Fullness of the head is an awareness of pressure in the head.

**Vertigo is experienced as loss of orientation with respect to vertical upright.

***Stomach awareness is a feeling of discomfort which is just short of nausea.

19 Appendix H: Realism Survey

REALISM QUESTIONIRE

For each of the following items, circle the number that best indicates how closely the simulator resembles an actual car in terms of appearance, sound, and response. If an item is not applicable, circle NA.

	General Driving	Not at all Realistic						Completely Realistic	
1	Response of the seat adjustment levers	0	1	2	3	4	5	6	NA
2	Response of the mirror adjustment levers	0	1	2	3	4	5	6	NA
3	Response of the door locks and handles	0	1	2	3	4	5	6	NA
4	Response of the fans	0	1	2	3	4	5	6	NA
5	Response of the gear shift	0	1	2	3	4	5	6	NA
6	Response of the brake pedal	0	1	2	3	4	5	6	NA
7	Response of accelerator pedal	0	1	2	3	4	5	6	NA
8	Response of the speedometer	0	1	2	3	4	5	6	NA
9	Response of the steering wheel while driving straight	0	1	2	3	4	5	6	NA
10	Response of the steering wheel while driving on curves	0	1	2	3	4	5	6	NA
11	Feel when accelerating	0	1	2	3	4	5	6	NA
12	Feel when braking	0	1	2	3	4	5	6	NA
13	Ability to read road and warning signs	0	1	2	3	4	5	6	NA
14	Appearance of car interior	0	1	2	3	4	5	6	NA
15	Appearance of signs	0	1	2	3	4	5	6	NA
16	Appearance of roads and road markings	0	1	2	3	4	5	6	NA
17	Appearance of rural scenery	0	1	2	3	4	5	6	NA
18	Appearance of intersections	0	1	2	3	4	5	6	NA
19	Appearance of other vehicles	0	1	2	3	4	5	6	NA
20	Appearance of rear-view mirror image	0	1	2	3	4	5	6	NA
21	Sound of the car	0	1	2	3	4	5	6	NA
22	Sound of other vehicles	0	1	2	3	4	5	6	NA
23	Overall feel of the car when driving	0	1	2	3	4	5	6	NA
24	Overall similarity to real driving	0	1	2	3	4	5	6	NA
25	Overall Appearance of driving scenes	0	1	2	3	4	5	6	NA

20 Appendix I: Situational Awareness Rating Technique

Situational Awareness

The following questions ask about your study drive. Please read each question carefully. If something is unclear ask the research assistant for help. Your participation is voluntary, and you have the right to omit questions you choose not to answer.

Instability of situation During your drive, how likely was the situation to change suddenly?	No unexpected events, simulation went as expected 1	2	3	4	5	6	Unexpected events, things you react to 7
Variability of Situation During the drive, how many variables which required your attention were changing at once?	Very few things changing at one point in time 1	2	3	4	5	6	A lot of things changing at once 7
Complexity of situation How complicated were the situations in the drive?	Easy route 1	2	3	4	5	6	Difficult to navigate 7
Arousal What was the level of mental stimulation during the drive?	Bored during the scenario 1	2	3	4	5	6	Scenario was engaging 7
Spare Mental Capacity How much mental capacity did you have to spare during the drive?	Could not comfortably perform other tasks 1	2	3	4	5	6	Could perform other tasks 7
Concentration How much could you concentrate your attention to important tasks during the drive?	Distracted by non-essential tasks 1	2	3	4	5	6	Able to focus on the important tasks 7
Division of Attention Were you able to divide your attention between several relevant sources during the drive?	Focused on one source of information 1	2	3	4	5	6	Able to scan between relevant information sources 7
Information Quality How good (useful) was the information you obtained in the drive?	Information is poorly depicted, useless, or difficult to understand 1	2	3	4	5	6	Information is easy to comprehend and very useful 7
Information Quantity How much <u>useful</u> information was provided from the available sources in the drive?	Insufficient amounts of necessary information to perform the task 1	2	3	4	5	6	A lot of useful information to complete the task 7
Familiarity How familiar were you with the different elements and events in the drive?	Uncomfortable, no familiarity 1	2	3	4	5	6	Comfortable, very familiar 7

21 Appendix J: Acceptance Surveys

21.1 LDW Survey

Lane Departure Warning Post Drive Acceptance Questionnaire

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

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

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

1. To what extent did you trust the lane departure warning system?

   ❒ Not at all

   ❒ Slightly

   ❒ Moderately

   ❒ Very Much

   ❒ Extremely

What factors led to this degree of trust?

____

____

____

2. To what extent did you rely on the lane departure warning system?

❒ Not at all

❒ Slightly

❒ Moderately

❒ Very Much

❒ Extremely

What factors led to this degree of reliance?

____

____

____

3. How would you rate your level of comfort when the lane departure warning sounded/caused vibrations in the steering wheel/caused the steering wheel to move?

❒ Not at all comfortable

❒ Slightly comfortable

❒ Moderately comfortable

❒ Very comfortable

❒ Extremely comfortable

What affected your level of comfort?

____

____

____

4. How reliable was the lane departure warning system?

❒ Not at all reliable

❒ Slightly reliable

❒ Moderately reliable

❒ Very reliable

❒ Extremely reliable

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

____

____

____

5. What was your level of confidence in the lane departure warning system?

❒ Not at all confident

❒ Slightly confident

❒ Moderately confident

❒ Very confident

❒ Extremely confident

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

____

____

____

6. Would you want a lane departure warning system in your next vehicle?

❒ Yes

❒ No

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

____

____

____

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

$___________________________

17. What was your degree of ***self confidence*** to handle lane departures?

❒ Not at all confident

❒ Slightly confident

❒ Moderately confident

❒ Very confident

❒ Extremely confident

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

____

____

____

____

21.2 LDW Survey – No Warning

Lane Departure Warning Post Drive Acceptance Questionnaire
(No Warning)

The following question asks about your study drive and about your opinions related to the Lane Departures you encountered and your trust in automation. Please read each question carefully. If something is unclear ask the research assistant for help. Your participation is voluntary, and you have the right to omit questions you choose not to answer.

1. What was your degree of ***self confidence*** to handle lane departures?

    ❒ Not at all confident

    ❒ Slightly confident

    ❒ Moderately confident

    ❒ Very confident

    ❒ Extremely confident

21.3 FCW Survey

Forward Collision Warning Post Drive Acceptance Questionnaire

The following questions address ONLY the ALERT issued by the **Forward Collision Warning System**. This is the only system you will be asked to evaluate. The alert activated when there was a potential collision with a vehicle in front of you. Please read each question carefully and circle 1 - 7 for each question. If something is unclear ask the research assistant for help. Your participation is voluntary, and you have the right to omit questions you choose not to answer.

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

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

1. To what extent did you trust the forward collision warning system?

❒ Not at all

❒ Slightly

❒ Moderately

❒ Very Much

❒ Extremely

What factors led to this degree of trust?

____

____

____

2. To what extent did you rely on the forward collision warning system?

❒ Not at all

❒ Slightly

❒ Moderately

❒ Very Much

❒ Extremely

What factors led to this degree of reliance?

____

____

____

3. How would you rate your level of comfort with the forward collision warning system alert sound and
visual warning/causing the vehicle to brake? (*note: only one of these will be shown to the participant depending on their condition)

- ❒ Not at all comfortable
- ❒ Slightly comfortable
- ❒ Moderately comfortable
- ❒ Very comfortable
- ❒ Extremely comfortable

What affected your level of comfort?

____

____

____

4. How reliable was the forward collision warning system?

- ❒ Not at all reliable
- ❒ Slightly reliable
- ❒ Moderately reliable
- ❒ Very reliable
- ❒ Extremely reliable

What about the forward collision warning system's operation influenced how you rated its reliability?

____

____

____

5. What was your level of confidence in the forward collision warning system?

❒ Not at all confident

❒ Slightly confident

❒ Moderately confident

❒ Very confident

❒ Extremely confident

What about the forward collision warning system influenced how you rated your confidence in its operation?

____

____

____

6. Would you want a forward collision warning system in your next vehicle?

❒ Yes

❒ No

Why would/wouldn't you want a forward collision warning system in your next vehicle?

____

____

____

16. How much would you be willing to pay for a forward collision warning system?

$_________________________

18. What was your degree of ***self confidence*** to handle vehicles slowing in front of you?

❒ Not at all confident

❒ Slightly confident

❒ Moderately confident

❒ Very confident

❒ Extremely confident

Suggestions for improving the alert of the forward collision warning system:

____

____

____

____

21.1 FCW Survey – No Warning

Forward Collision Post Drive Acceptance Questionnaire
(No Warning)

The following question asks about your study drive and about your opinions related to the potential collisions with a vehicle in front of you. Please read each question carefully. If something is unclear ask the research assistant for help. Your participation is voluntary, and you have the right to omit questions you choose not to answer.

1. What was your degree of ***self confidence*** to handle potential collisions with another vehicle in front of you?

    ❒ Not at all confident

    ❒ Slightly confident

    ❒ Moderately confident

    ❒ Very confident

    ❒ Extremely confident

22 Appendix K: Debriefing Statement

22.1 Test Track Comparison Study

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

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

Not only did we tell you that we were interested in how drivers maintain headway with a vehicle, we were also interested in how an incentive and engagement in tasks effects the response to an imminent crash warning.

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

It is very important that you do not discuss this study with anyone else until the study is complete. Our efforts will be greatly compromised if participants come into the study knowing its true purpose and how their reactions are being examined. To this end, we would ask that you not discuss any of the details of the study until June 15, 2012.

22.2 Secondary Task and Incentive Considerations Study

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

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

Not only did we tell you that we were interested in how drivers interact with different tasks while driving, we were also interested in how an incentive and engagement in tasks effects the response to an imminent crash warning.

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

It is very important that you do not discuss this study with anyone else until the study is complete. Our efforts will be greatly compromised if participants come into the study knowing its true purpose and how their reactions are being examined. To this end, we would ask that you not discuss any of the details of the study until June 15, 2012.

22.3 Other Studies

Debriefing Statement

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

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

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

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

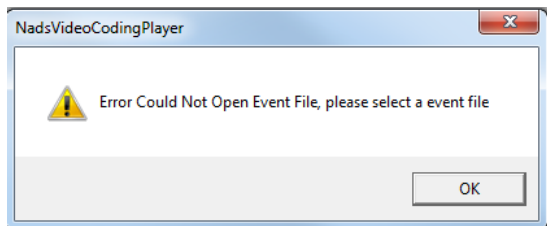
It is very important that you do not discuss this study with anyone else until the study is complete. Our efforts will be greatly compromised if participants come into the study knowing its true purpose and how their reactions are being examined. To this end, we would ask that you not discuss any of the details of the study until January 1st, 2013.

23 Appendix L: Video Coding Procedures

23.1 Video Coding Procedure- CWIM2012- Main 1

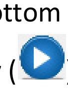
1. Log onto a computer that has the NADS video coding player already downloaded (note: it must be in a shared file to use it, if it is not already shared find Steve). Open the video Software
2. Open "Computer" file and select video drive (U:)
3. Open the desired subject video by dragging the .mpg file into the coding player. If your computer is not set up to access vidserve2 the following link under "video coding software instructions" in the NADS intranet will help you establish this connection: https://www.nads-sc.uiowa.edu/intranet/mapvidserve.php.

   a. If the file is unable to open you will get the error message pictured below. You will need to load a file from the DAQ database (explained in step 3). If you do not have this problem, skip directly to step 4.



4. Click "OK" on the error message, an opener with the associated DAQ files are listed. Select the text document that begins with "events_#.txt". This will open the video. If your computer is not set up to access the DAQ files the following link under "video coding software instructions" in the NADS intranet will help you establish this connection: https://www.nads-sc.uiowa.edu/intranet/mapvidserve.php.

5. Click on the desired event to code on the right side panel- this will take you directly to the event.

   a. Control the speed of the video playback for coding: the slider on the bottom of the player controls playback speed while the buttons lateral to the play () button control frame-by-frame motion

6. Open the Excel document into which you will be coding your data.

7. In the excel document, fill in the subject number and event number. These event numberss will appear on the right hand side of the video player. The event numbers and subject numbers are also located on the log stream (yellow and green highlight, respectively):

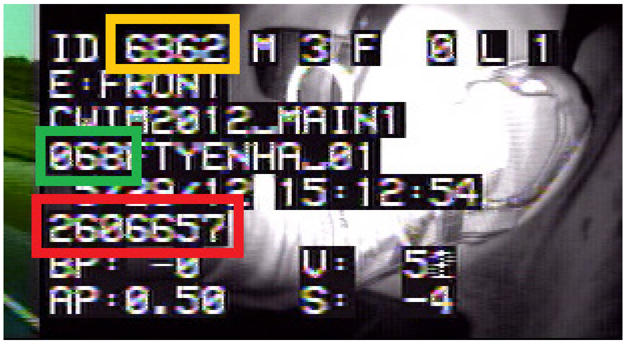
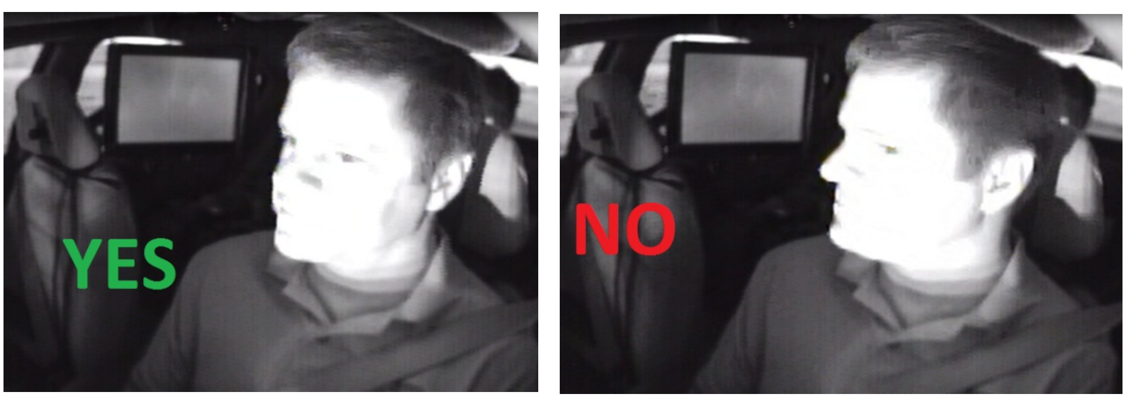


Image of the Logstream: Yellow highlight is the event number, green highlight is the subject number, and red highlight is the frame number.

8. Use the frame number (highlighted in red above) to identify the start, end, and attempted end of visual commitments. If the logstream frame number is unreadable or not present, use the value in the bottom left of the video: 

. However, this is **NOT** preferable. You should first rewind the video and see if you can get a more clear view of the frame number.

   a. Visual commitment **STARTS** when the participant looks to their right shoulder for the number recall and the **<u>inside corner</u>** of the participant's right eye is no longer visible. The movement must be continuous toward screen, if the participant looks back to the road before completing the full motion to the screen and before the inside corner is still visible, visual commitment was never initiated. When the audio prompt plays and the participant begins to look if the inside corner does disappear but the participant looks back before the numbers start a visual commitment has occurred. Here is an example of the start of visual commitment:



   b. The **END** of visual commitment occurs when the **<u>outside of the participant's right eye is fully visible</u>**. Instances where the outside corner does not become visible and the participant returns vision to the number recall screen are highlighted in 'part c.'

c. The "Looked back with no Visual Commitment" column is reserved for attempted glances. That is, during the middle of the task the participant tries to 'sneak' a glance and the outside corner of the eye **never** becomes visible, therefore the criteria of "End of Visual Commitment" is not met. In the excel file, mark "0 (zero), 1, 2, 3, 4, etc. indicating how many glances were attempted- no frame number is needed.

9. The column labeled "Code 1= used corners of eyes, 2= used iris to approximate" is used to record your coding method. In the event that you the corners of the eyes are not completely visible, due to such things as glasses or video quality, it is acceptable to use the Iris of the eye to approximate the start and end of visual commitments. The start of visual commitment would occur when the participants right Iris is moved toward the number recall screen in a continuous motion. The end of visual commitment would be when the participants right Iris is once again focused on the road.

10. Record the determined frame numbers in the excel document (except for attempted glances). Make sure to record the exact frame number that the event happened, not a frame forward or back!!

11. If data is missing first make sure there are not multiple video files resulting from restarts (if there are make sure you get the correct DAQ as well!). Every time you open a new video file you will need to close and re-open the NADSVideCodingPlaer. If data continues to be missing verify with this with the data coordinator and put a period (.) in any boxes for data.

24 Appendix M: Incentive Feedback

Message 1: Good Headway & Good secondary task

"For that task, you were able to maintain an acceptable headway, and successfully identified the numbers and sequence of the secondary task. So, for that trial, you earned $2.12 for the primary task, and $X for the secondary task."

Message 2: Good Headway & bad secondary task

"For that task, you were able to maintain an acceptable headway, but unsuccessfully identified the numbers and sequence of the secondary task. So, for that trial, you earned $2.12 for the primary task, and $X for the secondary task."

Message 3: Bad Headway, good secondary task

"For that task, you were unable to maintain an acceptable headway, but successfully identified the numbers and sequence of the secondary task. So, for that trial, you earned $X for the primary task, but $X for the secondary task."

Message 4: Bad headway, bad secondary task

"For that task, you were unable to maintain an acceptable headway, and unsuccessfully identified the numbers and sequence of the secondary task. So, for that trial, you earned $X for the primary task, and $X for the secondary task."

25 Appendix N: Display Position Setup

Protocol for Display Setup

Consistency of the display setup is critical for comparing data across subjects. These procedures are designed to allow for consistent configuration of the displays. The researcher escorting the participant to the simulator to secure the door will complete these tasks.

1. Insure appropriate location of the rear touch screen.
    a. After the participant has adjusted their seat, the passenger seat should be adjusted to have the front of the display aligned with the back of the participant's eyes.
    b. Verify by looking at L-bracket held behind drivers eyes.

2. Insure proper configuration of the front touch screen.
    a. Attach the mirror to the monitor.
    b. Adjust display position such that the driver can touch the display with their finger and the top of the display is below the bottom edge of the support over the radio.
    c. Adjust the tilt of the display in this position so that the participant can see their eyes in the mirror.
    d. Secure the display
    e. Remove mirror

3. Insure proper configuration of the large touch screen behind passenger seat.
    a. Keeping the display as close to the back of the passenger seat as possible, adjust the display so that the driver can touch all four corners using when they turn their shoulder.
    b. Verify that the participant can see all four corners of the display.
    c. Secure the display

26 Appendix O: Task Training

Prep Room Practice Protocol

The aim of this protocol is to insure that each participant has an understanding of how each of the secondary tasks works and will be able to perform them appropriately in the simulator.

Researcher: "*You will now have a chance to practice the four tasks that were described in the training presentation before going to the simulator. We would like you to become familiar with how the task works before experiencing them in the driving environment.*"

Position participant, in a non-spinning chair, such that the touch screen is to his/her right at just past 90 degrees.

"*The first task will be the bug task. When I say '________', place your finger on the red X and then follow the bug when it appears.*"

Repeat until up to five times until participant can keep the feedback in the green and yellow color (no red). Record the number of attempts.

"*The second task will be the number recall task. When I say 'Number Recall', turn and look at the display. After all five numbers have been shown, repeat them aloud.*"

Repeat until up to five times until participant keeps their attention continuously on the display until the fifth number is presented and gets all five numbers correct. Record the number of attempts.

Position participant, in a non-spinning chair, such that the small screen is to his/her right at approximately 20 degrees at a downward angle of approximately 45 degree.

"*The third task will be the menu task. When I say 'menu task', move your hand toward the display and select the word combination that has either 'discover' as the first word, or 'project' as the second word.*"

Repeat until up to five times until participant can complete correctly in the available time without an error. Record the number of attempts.

"*The fourth task will be the message reading task. When I say '___________', look at the display and read aloud the sentence once it appears.*"

Repeat until up to five times until participant can read at least 80% of the sentence without error. Record the number of attempts.

Driver-Vehicle Interfaces for Advanced Crash Warning Systems: Research on Evaluation Methods and Warning Signals

Appendix B

Warning and Message Perception Under Ambient Noise Conditions

Acknowledgement

The authors acknowledge the contributions of Richard Huey, Robert Lassins, Daniel Kellman, Luis Romero, and Diane Snow in the implementation and conduct of the research.

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1 Introduction

This report describes the methods and findings of research on the effects of various vehicle interior ambient noise conditions on driver perception of warnings and messages. This task is part of a larger National Highway Traffic Safety Administration (NHTSA) project titled *Crash Warning Interface Metrics (CWIM), Phase 3*. The CWIM project deals broadly with the effectiveness of the driver interface for in-vehicle crash warnings. As part of this project, the work reported here addresses how acoustic interface effectiveness may be affected by various noise conditions that may realistically occur under different driving conditions.

In order to be reasonably effective, in-vehicle crash warnings must be reliably and rapidly detected by the driver and properly interpreted. They must convey the proper degree of urgency so that driver response is quick and appropriate. They should be distinguishable from less urgent alerts and messages, so that distraction, annoyance, and false alarm mistrust effects are minimized. Considerable research has addressed these issues, both within the CWIM project and broadly in the literature. However, the vast majority of this work has been conducted under relatively benign in-vehicle ambient noise conditions. Whether on-road or driving simulator methods are used, the conditions have typically been moderate speeds on good quality road surfaces with major potential sources of interior noise excluded. Warnings, however, need to remain effective under the likely range of noise conditions that may be anticipated in vehicles. Very little information exists on perception of meaning and urgency in noise even if the sound is detected.

Determining the appropriate sound intensity at which to present acoustic signals is not straightforward and not all signals of the same intensity will be perceived as well under various noise conditions. Recommendations for acoustic warning signal characteristics from a variety of sources have been summarized in Campbell et al. (in preparation). Sound level recommendations from various sources cited by Campbell et al. include 20-30 dB above masked threshold; 10-15 dB above masked threshold; at least 15 dB above ambient noise level for cautionary signals and at least 20 dB above ambient noise level for alerting signals; and more. Various of the aforementioned sources also indicated maximum sound levels that should not be exceeded (e.g., 90 dBA). Under many actual driving cases with noisy backgrounds, meeting a minimum criterion above masked threshold or ambient noise level would result in exceeding the recommended maximum threshold. Furthermore, as Campbell et al. note, it may be desirable to have some classes of warnings or alerts presented at a lower intensity than others, which further limits flexibility. Of course, ambient noise levels in vehicles can vary substantially under different driving conditions, so unless the intensity of a signal is variable and intelligently adapted in real time to the current ambient noise condition, some "baseline" ambient noise level and spectrum must be assumed. Campbell et al.'s own guidance based on their review is that auditory signals should be in the range of 10-30 dB above masked threshold (with a recommended minimum of at least 15 dB) or at least 15 dB above ambient noise. The signal should not exceed 90 dB.

Despite such existing recommendations, actual practice among OEMs often results in sound levels that are lower than recommended, at least under some driving conditions. For example, Lin and Green (2013) measured sound levels for a variety of driver assist functions in ten models of 2013 cars. These included the functions of blind spot warning, lane departure warning, and park assist. Most warning sounds were in the 65-70 dBA range, although Volvo models had somewhat higher levels. Actual industry practice may be driven by various factors, including consumer acceptance if signals are perceived as overly loud and annoying.

In the present study, the objective was to measure various aspects of driver perception of warnings and alerts under a range of ambient noise driving conditions on actual roads. The characteristics and sound level of in-cab ambient noise may vary due to the vehicle's physical characteristics, the road surface, surrounding traffic, travel speed, and interior noise sources. As an initial study of this topic, only a limited set of ambient noise conditions could be included. Likewise, there are a great many types of auditory displays that might be evaluated, including various sounds as well as voice messages. Only a limited set of auditory displays could be included. The goal, then, was to provide an initial assessment of the nature and magnitude of the effects of ambient noise conditions on key aspects of driver perception of warnings. The intent was to encompass a range of noise conditions and auditory signal types. More refined investigations of listening conditions, signal characteristics, and driver reactions may be warranted based on these initial results.

It should be noted that in addition to this study of driver perception of warnings under ambient noise conditions, the project also included a parallel effort to produce a library of recordings of ambient vehicle noise under a range of driving conditions. The audio library and accompanying documentation are provided as a separate deliverable.

2 Method

2.1 Study design

The experiment was a three-factor design, with one between-groups factor (vehicle type) and two within-groups factors (interior noise condition, acoustic signal). Three different vehicles were used in the experiment in order to provide a representative range of vehicle types: (1) a small car, (2) a larger sedan, and (3) an SUV. Each participant drove only one of these vehicles. During the drive, data were collected under three different interior noise conditions: (1) windows up, music off; (2)

windows down, music off; and (3) windows up, music on. The order in which each noise condition block was presented to participants was counterbalanced within each vehicle condition.

A set of 15 different acoustic signals was presented under each noise condition. These included three unique voice messages and eight unique non-voice sounds. All eleven of the unique sounds and voices were presented at a sound pressure level (SPL) of approximately 65 dBA as measured near the driver's right ear. One of the voice messages and three of the non-voice sounds were also presented at 75 dBA, with the resultant total of 15 signals. The lower 65 dBA level is representative of a number of acoustic alerts as measured in actual current practice (e.g., Lin and Green, 2013). The higher 75 dBA level is more consistent with human factors guidance (e.g., Campbell et al., in preparation), assuming a moderate level of ambient vehicle cab noise.

Five different dependent measures were recorded to evaluate driver response. These included: (1) a measure of reaction time for the participant to detect the occurrence of a signal; (2) a rating of signal noticeability; (3) a rating of signal urgency; (4) a rating of speech intelligibility (for voice messages only); and (5) perceived meaning of the signal (chosen from a set of four alternatives).

Further details on the vehicles, driving conditions, auditory signals, and dependent measures are in sections that follow.

2.2 Participants

Participants included 34 drivers aged 22 to 49, with 13 males and 21 females. No participants reported having hearing decrements or using hearing assistive devices. All drove regularly, held valid U.S. driver's licenses and passed a screener of their motor vehicle records. Anyone with a history of serious moving violations or suspensions was excluded from the study. No participants dropped out or were removed from the study.

Participants were recruited through the Volunteers section of Craigslist and through a news item posted on Westat's intranet homepage. Westat employees were not eligible, but could refer friends or family. Participants received $75 for completing the session. Prospective participants completed a screener questionnaire. The screener questions concerned age, gender, license status, and familiarity with various types of vehicles. It also included a set of questions related to hearing impairment. A recruitment ad and the telephone screener are shown in Appendix A and Appendix B, respectively.

2.3 Instrumentation and displays

2.3.1 Vehicles

Three different classes of passenger vehicles were used in order to provide a range of vehicle types. These types were small car, sedan, and SUV. The specific vehicles used were selected from among the most popular (highest sales) models in that class and with good rental availability. The specific vehicles were:

- Small car: 2013 Hyundai Accent GLS
- Sedan: 2013 Toyota Camry LE
- SUV: 2013 GMC Terrain SLT

2.3.2 Roadway

Data collection took place on a limited access toll highway (Maryland Route 200) running East to West in Montgomery County, with a 60 mph speed limit. Participants traversed this route between Shady Grove Road and Briggs Chaney Road in both directions until data collection was complete. This span of roadway was about 13 miles in length (one way). This is a relatively new highway with smooth and uniform asphalt over most of its length. It is also generally free-flowing, without congestion. These attributes permitted good control over ambient road noise and speed conditions. The roadway has three travel lanes in each direction. Participants were instructed to travel in the right lane except when needing to pass slower vehicles.

2.3.3 Noise conditions

All drives were conducted during clear weather on dry roads, with a target speed of 60 mph. The fan on the climate control system was on but set to a low setting. During the Baseline condition, all windows were closed and music was off. During the Windows Down condition, the front windows on both sides of the vehicle were fully opened. During the Music On condition, the song “Café Amore” by Spyro Gyra played in a continuous loop. The song could be categorized as instrumental smooth jazz. It was selected because it had been used in previous research (Brodsky, 2002) and has a medium tempo and relatively constant loudness through the duration of the track. The song has a dynamic range of 14 dB, where dynamic range is defined as the difference between a song’s maximum sound pressure level (SPL) and its average SPL.

The volume of the music was adjusted by the participant to the volume they would typically use for their own music while driving alone in their own car. However, the experimenter required participants to set the volume at a level equating to at least 60 dB(A), as measured in an otherwise silent vehicle. The minimum SPL was established to ensure that the music could potentially affect participants' detection and ratings of messages. A maximum SPL of 85 dB(A) was also established, but no participants attempted to exceed this level. Music SPL was measured in the vehicle by recording the SPL of a volume-matched pink noise track at the same level as the music set by participants. The bass, treble, balance, and fade settings for each test vehicle's sound system were preset to neutral "0" values.

Ambient noise level was measured continuously during data collection, with the microphone mounted approximately 12 inches to the right of the participant's right ear. This was done to define a typical ambient noise level and range under each condition, as well as being able to identify outlier ambient noise levels during any particular trial. The typical ambient sound levels during the measurement sessions, in each condition for each vehicle, are shown in Table 1.

Table 1. Typical ambient sound levels (dBA) in each condition

Vehicle	Noise Condition	Typical dBA
Small car	Baseline	65.56
	Windows down	76.11
	Music	
Mid-size sedan	Baseline	63.89
	Windows down	73.39
	Music	
SUV	Baseline	64.44
	Windows down	74.56
	Music	

2.3.4 Auditory signals and stimulus presentation

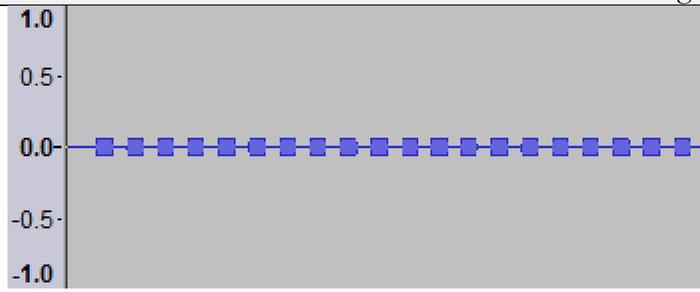
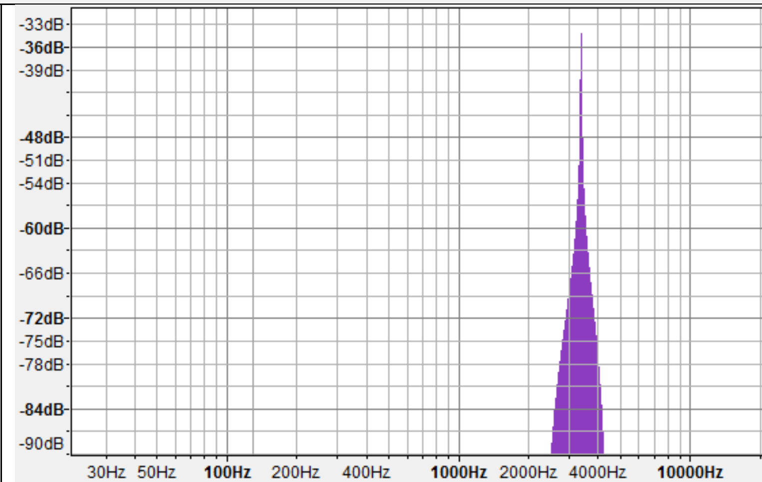
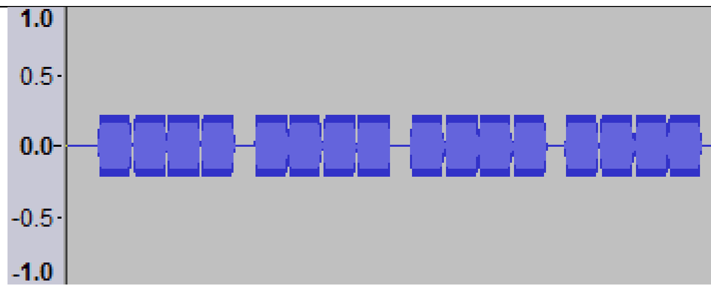
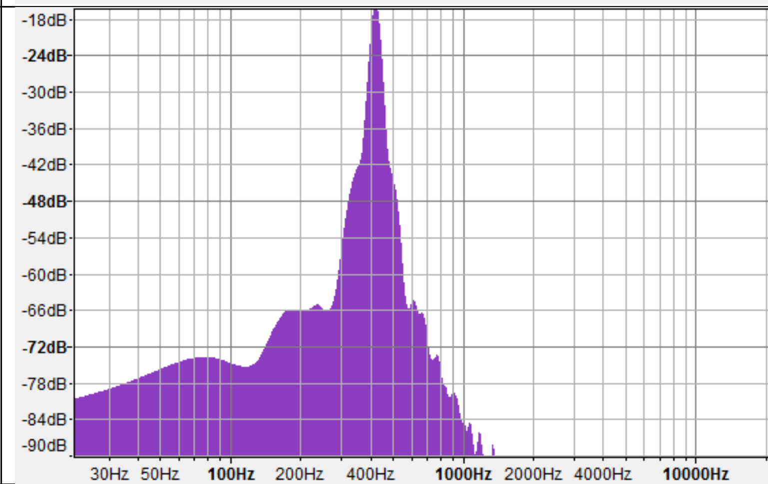
Fifteen auditory signals were compared in the experiment. In addition, several other signals were used for training or as novel signals to help prevent the participant from recognizing that the same set of sounds was being used under each ambient noise condition. There were 11 unique alerts presented at approximately 65 dBA. Four of these sounds were also presented at approximately 75 dBA. All sounds were initially volume-adjusted to these levels, but were then adjusted for perceptual equivalence of loudness, as determined by a panel of six individually tested raters.

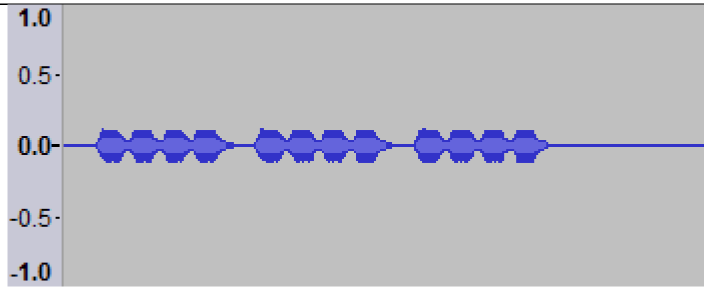
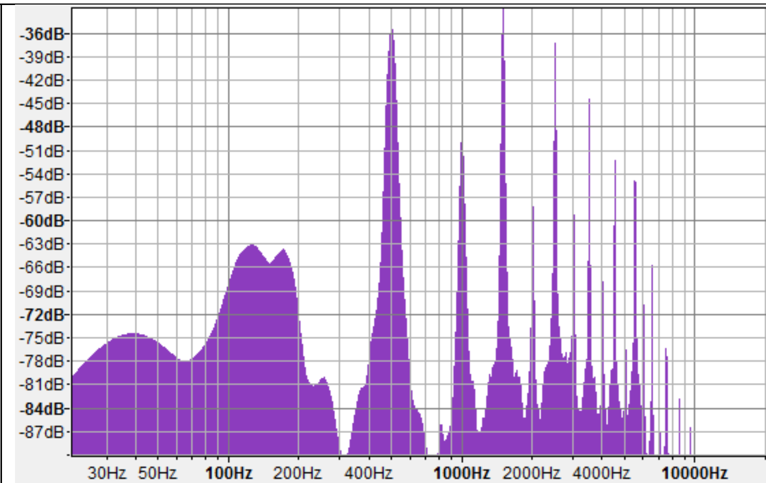
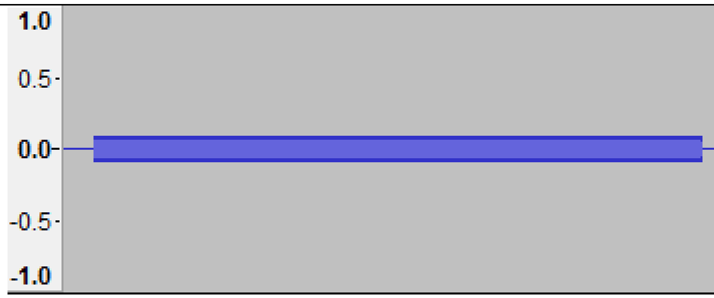
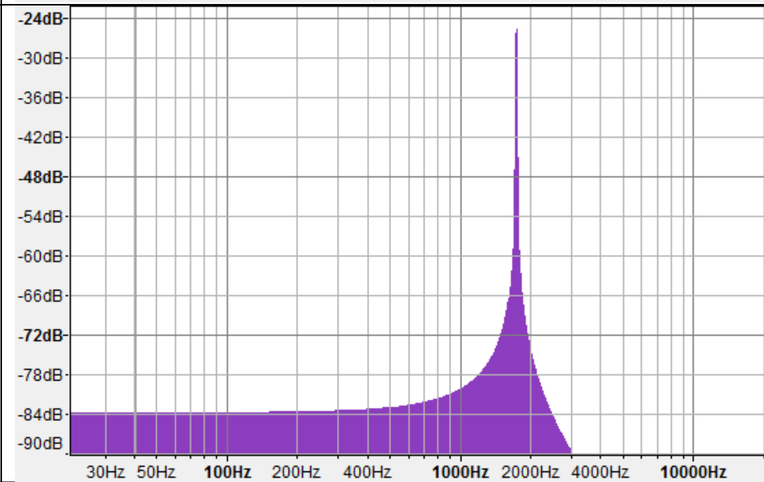
The alerts used in this experiment were adapted from examples of current in-vehicle warnings and alerts of various types, other sounds found in various sources, and synthetic speech messages created using an online text-to-speech generator.[1] The experiment was not intended as a test of any particular acoustic signal but rather to examine the effects of ambient noise across a diverse range of signals. As a set, these signals intentionally spanned a range of temporal and acoustic characteristics. Each signal was of a nominal length of 2 seconds. It is important to note that the signals that were sourced from current in-vehicle systems were presented using a different speaker in a different vehicle interior, and are not necessarily presented at the same SPL as the original alerts. Therefore, the results of this experiment do not necessarily reflect upon the messages as used in their native vehicle environments. The alerts used in this experiment are briefly described below. Note that alerts 1-8 are sounds presented at 65 dBA, alerts 9-11 are voice messages at the 65 dBA level, and alerts 12-15 are the subset of alerts presented at the 75 dBA level. Table 2 lists the 11 unique sounds and provides an amplitude waveform and a frequency spectrograph for each one.

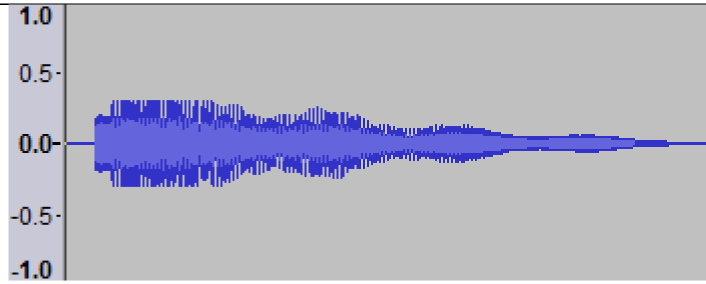
1. FCW 1: One burst of 20 fast beeps with a relatively high frequency profile.
2. FCW 2: Four bursts of four fast beeps with a relatively low frequency profile.
3. Blind spot warning: Three bursts of four fast beeps, each with a smoothed onset and decay and a sustained low intensity sound between beeps.
4. Pedestrian warning: A constant beep with a duration of 2 seconds.
5. Seat belt alert 1: A single chime that decays to silence in the span of about two seconds, with intensity varying in a wavelike pattern.
6. Seat belt alert 2: Two chimes, each of which decays to silence in the span of about one second
7. Park assist 1: One burst of eight beeps.
8. Park assist 2: Two bursts of three beeps.
9. Female voice – not urgent: Female voice says "Attention."
10. Female voice – urgent: Female voice says "Warning, warning."
11. Male voice – urgent: Male voice says "Warning, warning."
12. FCW 1 (high): Same as FCW 1, but presented at 75 dB
13. Blind spot warning (high): Same as Blind spot warning, but presented at 75 dB
14. Park assist 1(high): Same as Park assist 1, but presented at 75 dB
15. Female voice – urgent (high): Same as Female voice – urgent, but presented at 75 dB

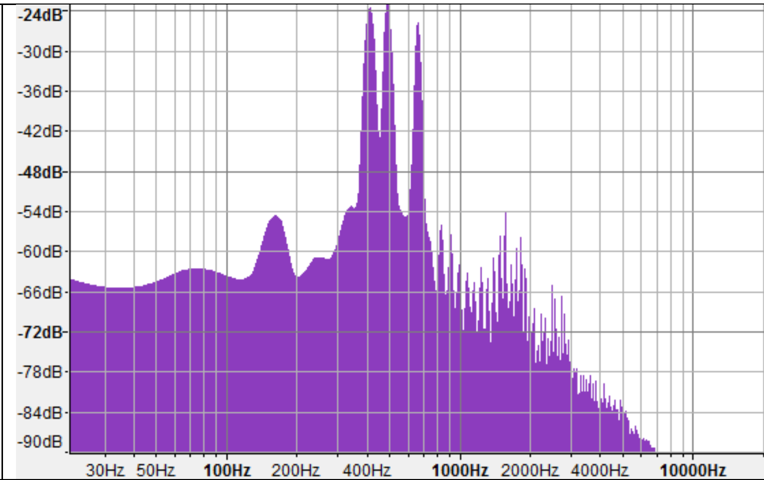
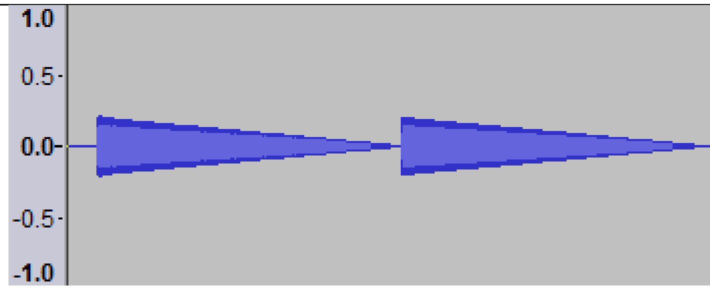
[1] http://www.oddcast.com/home/demos/tts/tts_example.php

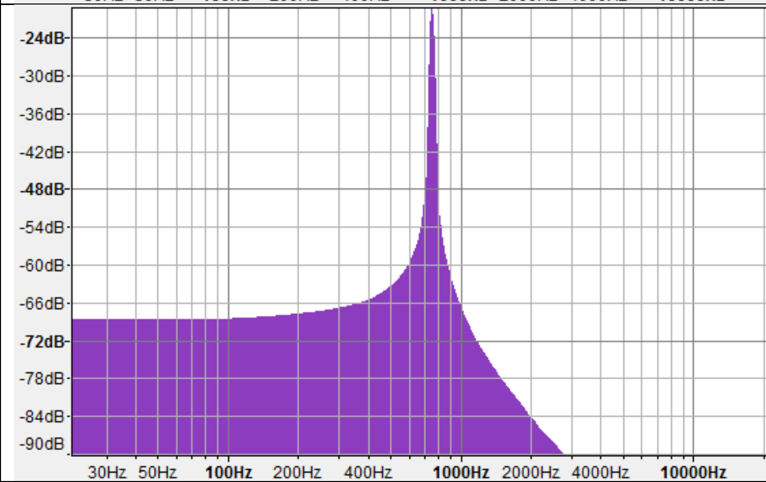
Table 2. Descriptions of auditory tones and voice signals

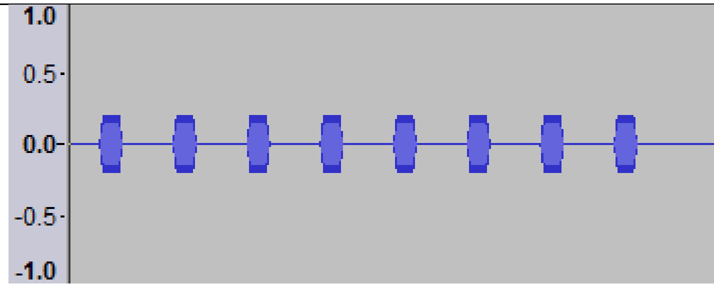
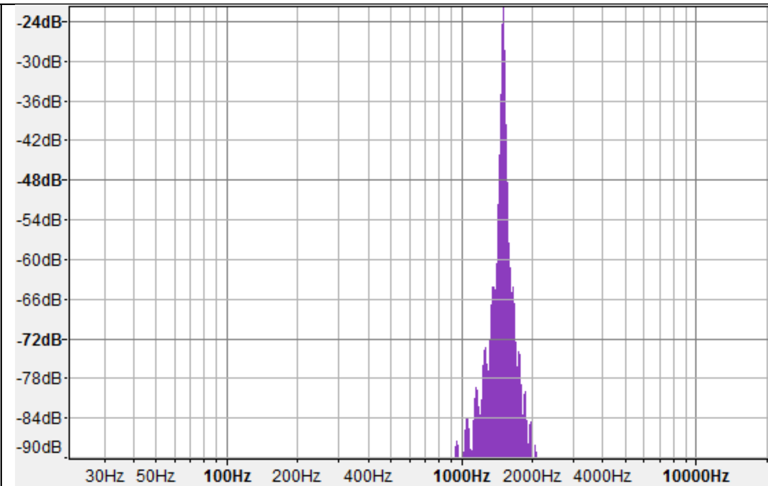
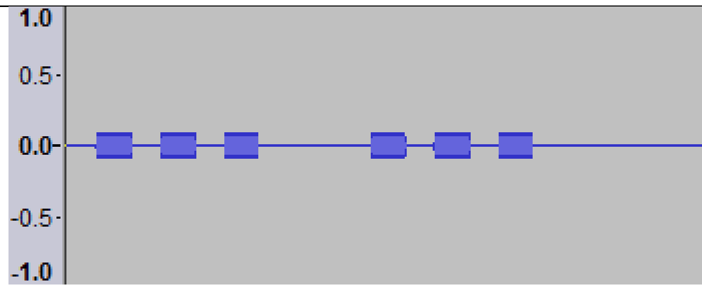
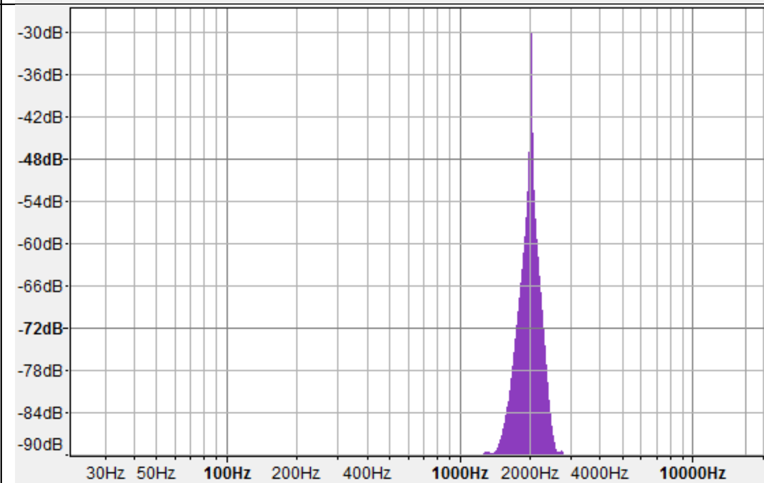
No.	Name	Amplitude waveform (2 s duration)	Frequency and intensity spectrograph (logarithmic)
Tone Signals			
1	FCW 1	 One burst of 20 fast beeps with a relatively high frequency profile.	
2	FCW 2	 Four bursts of four fast beeps with a relatively low frequency profile.	

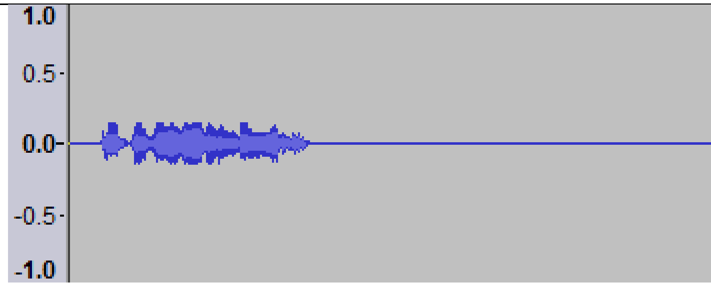
3	Blind spot warning	 Three bursts of four fast beeps, each with a smoothed onset and decay and a sustained low intensity sound between beeps.	
4	Pedestrian warning	 A constant beep with a duration of 2 seconds.	

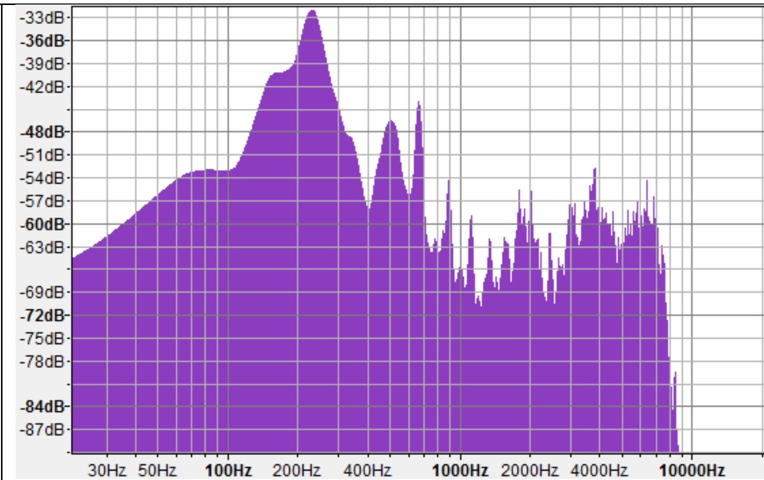
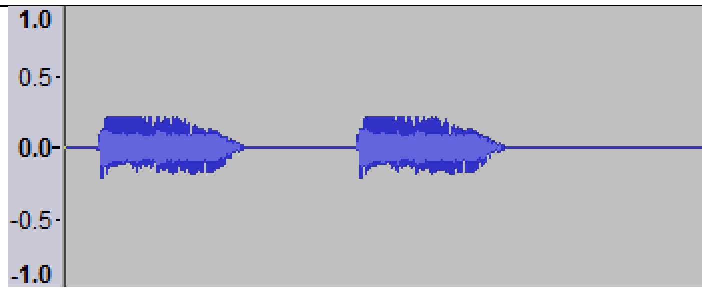
<table>
<tr><td>5</td><td>Seat belt alert 1</td><td>

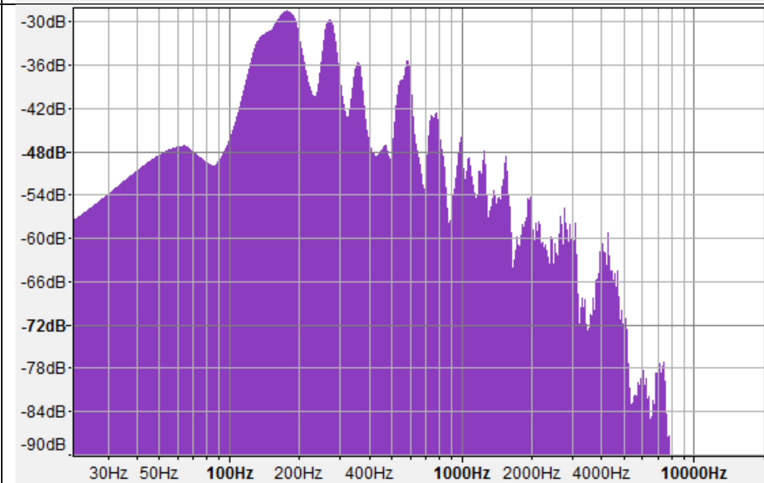
A single chime that decays to silence in the span of about two seconds, with intensity varying in a wavelike pattern.</td><td>
</td></tr>
<tr><td>6</td><td>Seat belt alert 2</td><td>

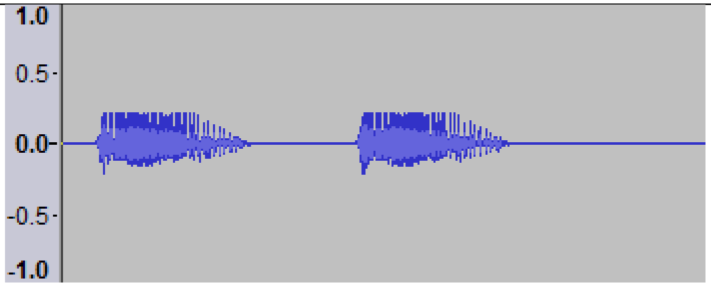
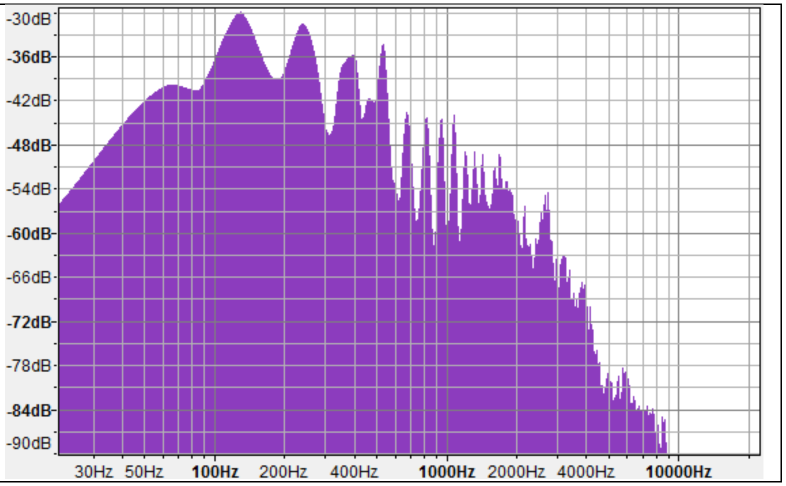
Two chimes, each of which decays to silence in the span of about one second.</td><td>
</td></tr>
</table>

<table>
<tr><td>7</td><td>Park assist 1</td><td>
One burst of eight beeps.</td><td></td></tr>
<tr><td>8</td><td>Park assist 2</td><td>
Two burst of three beeps.</td><td></td></tr>
<tr><td colspan="4">Voice signals</td></tr>
</table>

<table>
<tr>
<td>9</td>
<td>Female voice – not urgent</td>
<td>

Female voice says “Attention.”</td>
<td>
</td>
</tr>
<tr>
<td>10</td>
<td>Female voice – urgent</td>
<td>

Female voice says “Warning, warning.”</td>
<td>
</td>
</tr>
</table>

11	Male voice – urgent	 Male voice says "Warning, warning."	

During the experimental drives, the auditory signals were presented by an X-Mini II XAM4 capsule speaker mounted on top of the dashboard immediately behind the steering wheel (see Figure 1). A pink noise calibration signal was used to adjust the volume so that for each vehicle the nominal baseline signal intensity was 65 dBA at the driver's position.

Figure 1. Capsule speaker used for stimulus presentation

Within each noise condition block, the experimental control software generated a random presentation order for the 15 auditory signals. The software provided a random time gap that ranged from 10 to 50 seconds and averaged 30 seconds from the completion of the previous sound's ratings to the presentation of the next sound. Once the random time had passed, the software indicated to the experimenter that the next signal could be activated. The actual triggering of the trial was done by the experimenter, who first determined that there were no usual acoustic circumstances (e.g., a large truck passing or a patch of noisier roadway surface). When triggered, a trial began with a 5-second pre-signal period to document the ambient noise level. The signal was then automatically triggered at the end of the 5 seconds. When the participant detected the signal they pressed a microswitch button, worn on their finger or thumb, to provide a reaction time. The microswitch was attached to a Velcro strap that allowed the participant to locate the switch in a comfortable but easy-to-reach position, in a manner that was unlikely to result in unintentional switch activations. The precise location on the index finger or thumb was determined by the participant.

The data collection system recorded the reaction time and then cued the experimenter to verbally present a series of rating and choice questions. The questions were:

- "How noticeable was that that sound?" (1=not very; 7=extremely)
- "How urgent was that sound?" (1=not very; 7=extremely)
- "How intelligible was that sound"? (this question only asked for voice messages) (1=not very; 7=extremely)
- "Which of the following most closely matches the meaning conveyed to you by this sound?"
    - Urgent crash warning
    - Safety information
    - Information not related to safety
    - Incoming personal communication

The participant provided verbal responses which were manually entered by the experimenter. Thus for each trial, the following data were collected: ambient noise level in the period immediately preceding the auditory signal; detection reaction time; ratings/choices for noticeability, urgency, intelligibility (voice messages only), and perceived meaning. The definitions of key terms are shown in Table 3.

Table 3. Definition of rating factors and choice options

Term	Definition
Noticeability	The sound is easily noticeable among other sounds and noises in the vehicle
Urgency	The sound conveys a sense of importance, motivating you to make an immediate response
Intelligibility	The spoken words can be easily understood
Perceived Meaning	Choose the one that most closely matches the meaning conveyed to you by this sound
Urgent crash warning	… means that there is a situation in which you must react immediately to avoid a crash. For example, imagine you are about to hit a pedestrian or about to run off the road.
Safety information	… means that there is a safety issue that you need to pay attention to, but you are not in immediate danger of a crash. For example, imagine that you are approaching a work zone where two lanes are closed or there are reports of icy roads ahead.
Information not related to safety	… means exactly what it says – you are receiving information, but the information is not safety-related. This could include various types of information, such as traffic congestion several miles ahead, prices at nearby gas stations, or a navigation system telling you to make the next turn.
Incoming personal communication	… means that you are receiving an incoming call, text message, email, or other direct communication.

2.4 Procedure

Upon arrival, the participant's driver's license was checked to confirm identity and status and the participant read and signed an informed consent form. They were then seated in the test vehicle and the seat position and mirrors were adjusted. The experimenter was positioned in the rear right seat.

The complete set of instructions to the participants is attached in Appendix C. The general purpose and procedure were first explained to the participant as an overview. Safety priorities were made clear and participants were asked to silence their cell phones so not to add any extra unintended sounds that might disrupt the study. This was followed by a period of vehicle familiarization, during which the participant drove the vehicle around the parking lot. Following this, the participant practiced opening and closing the electrically-operated vehicle front windows and adjusting the music on a CD in the vehicle stereo system. The microswitch was then attached to the participant's finger or thumb and adjusted so that they could quickly and easily activate the switch without removing a hand from the steering wheel or altering their typical hand positions while driving. The experimenter confirmed that the switch mounting position was unlikely to result in unintended switch activations.

Next, the participant was introduced to the responses they were to make when they heard an auditory signal. An example sound (distinct from any in the set of test signals) was presented with the vehicle stationary. The experimenter had the participant operate the microswitch to provide the detection reaction time. The experimenter then walked the participant through the set of ratings and choice questions. The participant was provided with a definition of each of the factors to be rated and for each choice option for the meaning of the signal. The ratings for the three attributes of noticeability, urgency, and intelligibility were all made on a scale of 1 (not very) to 7 (extremely).

Following this example, the participant was presented with a second practice trial. This time the signal was a voice message, distinct from other voice messages in the set of test signals. The participant clicked the microswitch after detecting the message and then made ratings about each attribute. During this trial, the experimenter introduced the intelligibility question, which was not asked for the previous practice question. Following this training, the experimenter directed the participant onto the test roadway (Maryland Highway 200) and the data collection portion of the session began. The participant was instructed to try to maintain a target speed of 60 mph and to travel in the right lane except when needing to pass slower moving vehicles.

Data collection occurred in three blocks, each block under a different ambient noise condition. The sequence of the three noise conditions was counterbalanced within each vehicle condition. The first block included only the core set of 15 auditory signals (see Table 2). The second and third blocks each began with two novel auditory signals (one voice, one non-voice). Different novel sounds were used for the second and third blocks. This was done to help preclude the participant from assuming that the same set of signals occurs for each block. The novel signals were then followed by the 15 signals of the primary set in a random order.

During the drive, the experimenter was seated in the right rear seat and had a laptop computer for experimental control and data entry. The computer program indicated the sequence of blocks and the sequence of trials within blocks. The program indicated to the experimenter when they were authorized to initiate the next trial. The experimenter triggered that trial once they confirmed that the roadway situation was appropriate (e.g., proper speed, no unusual surrounding vehicles, proper road surface). Triggering a trial first initiated a 5-second interval, which served as a basis for post hoc confirmation of appropriate ambient noise levels. At the end of 5 seconds, the auditory signal was activated. When the participant pressed the microswitch the response time was automatically recorded and the sequence of rating and meaning questions appeared on the experimenter's screen. The experimenter then read each question to the participant, who gave a verbal response. The experimenter then entered the response on the computer. Once the data for all questions were entered, the controlling software began timing the interval for the next trial. If the participant did not activate the microswitch within 8 seconds of activation of the auditory signal, the trial was recorded as a failure to detect the sound. In the case of this event, the experimenter was presented with an option from the computer, asking them if the sound had been heard by the participant. If the experimenter clicked "no", the software began the timing for the next trial. If the participant verbalized that they heard the sound but forgot or mis-clicked the microswitch, the experimenter clicked "yes" and proceeded to ask the participant questions about the sounds. (Events of this type were rare.) Participants were not given any feedback if they failed to hear a sound, so if they did not verbalize that they heard the sound on their own, the rating questions were not asked.

When the "Music On" block of trials was scheduled to begin, the experimenter had the participant turn on the CD player and adjust the sound level of the music to the volume they would choose for listening to their own music when driving alone in their own vehicle. This adjustment was made while traveling at the target speed of 60 mph. Once the participant had set the music at their chosen level, the experimenter instructed them to skip to the next track, which was a pink noise track calibrated to the level of the music. A 10-second recording was made near the driver's head position to document the SPL inside the vehicle with the pink noise playing. The experimenter also documented the digital volume knob setting selected by the participant. After sound level measurement, the participant skipped back to the music track and the stimuli were presented as they were in the other two noise conditions. If the participant had the music volume set loud, the experimenter asked them to turn the music off while answering the ratings questions. Note that the level of the music selected by participants had no effect on the level of the acoustic alerts presented during this block.

The entire session took approximately 90 to 120 minutes, with the data collection portion taking approximately 60-80 minutes.

3 Results

Ambient noise conditions had a substantial effect on all dependent measures in this experiment. Three factor (alerting signal, ambient noise background, and vehicle type) analyses of variance were conducted for the measures of rated noticeability, rated urgency, and response time. The conclusions of these three ANOVAs were identical and are presented in Tables 4, 5, and 6. In each case, there was a statistically significant effect of alerting signal, noise condition, and the signal-by-noise interaction. There was no main effect of vehicle type and no interaction of vehicle type with ambient noise condition. There was a statistically significant interaction of alerting signal with vehicle type, although the effects were not pronounced. Some such interaction may be expected due to the complex and varied geometry of the vehicle cabin space and the nature of the reflective and absorbing materials in the car. Such differences in the acoustic space could idiosyncratically affect some particular sound. There was no statistically significant three-way interaction.

Table 4. Summary of ANOVA for noticeability

Effect	DF	F Value	Prob > F
Ambient Noise	2	228.38	<.0001
Alerting Signal	14	94.24	<.0001
Vehicle	2	1.74	0.1918
Ambient Noise X Alerting Signal	28	6.35	<.0001
Ambient Noise X Vehicle	4	1.27	0.2786
Alerting Signal X Vehicle	28	2.83	<.0001
Ambient Noise x Signal X Vehicle	52	0.70	0.9501

Table 5. Summary of ANOVA for urgency

Effect	DF	F Value	Prob > F
Ambient Noise	2	59.90	<.0001
Alerting Signal	14	60.73	<.0001
Vehicle	2	2.58	0.0908
Ambient Noise X Alerting Signal	28	3.98	<.0001
Ambient Noise X Vehicle	4	0.73	0.5714
Alerting Signal X Vehicle	28	2.35	<.0001
Ambient Noise x Signal X Vehicle	52	0.75	0.9010

Table 6. Summary of ANOVA for response time

Effect	DF	F Value	Prob > F
Ambient Noise	2	16.67	<.0001
Alerting Signal	14	13.66	<.0001
Vehicle	2	0.38	0.6843
Ambient Noise X Alerting Signal	28	2.99	<.0001
Ambient Noise X Vehicle	4	1.90	0.1083
Alerting Signal X Vehicle	28	2.05	0.0011
Ambient Noise x Signal X Vehicle	52	0.96	0.5643

Figures 2, 3, and 4 illustrate the effects of alerting signal, ambient noise, and their interaction. Figure 2 shows the group mean ratings of noticeability for each of the 15 sounds for each of the three ambient noise conditions. The overall main effect of noise condition is evident, with alerts being rated highest under baseline noise and lowest under the windows-down condition. However the differences between these three conditions varied among the 15 sounds. The main effect of alerting signal is evident in the substantial difference in rating from one signal to another. One the 7-point rating scale, some alerts were rated near 7, even under high noise conditions. Others were rated about only 2 for noticeability under windows-down noise.

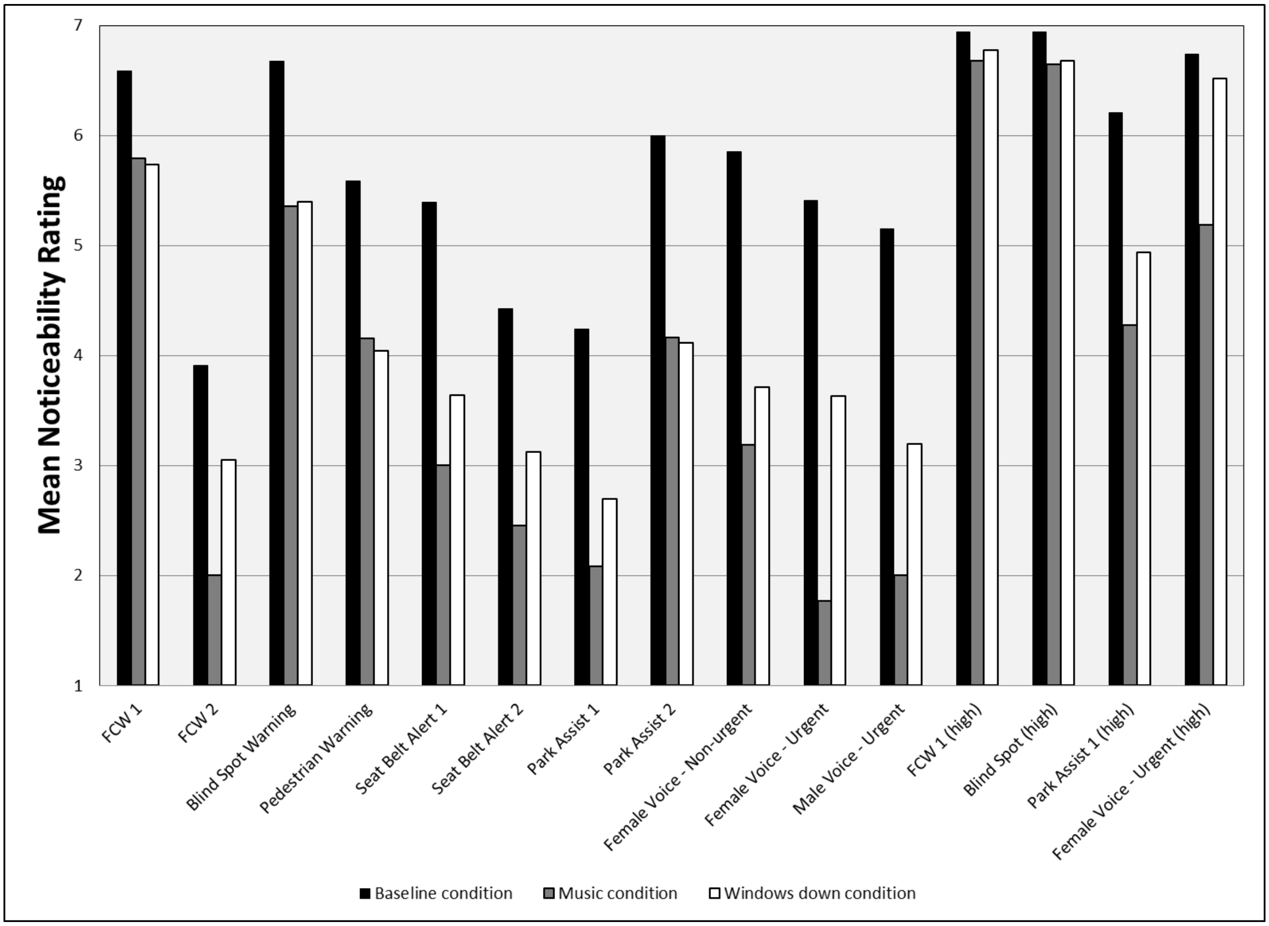


Figure 2. Mean noticeability rating for each combination of signal and ambient noise condition

Figure 3 shows a similar pattern for the group mean ratings of urgency. It may be noted that sounds presented at the 75 dBA level tended to preserve their urgency even under the high ambient noise conditions. Degradation of perceived urgency by ambient noise varied considerably among the 65 dBA sounds. As Figures 2 and 3 illustrate, even among sounds equated for approximately equal loudness under relatively quiet listening conditions, there are substantial differences in noticeability and urgency under moderate noise conditions (baseline noise) and even greater differences under higher noise conditions.

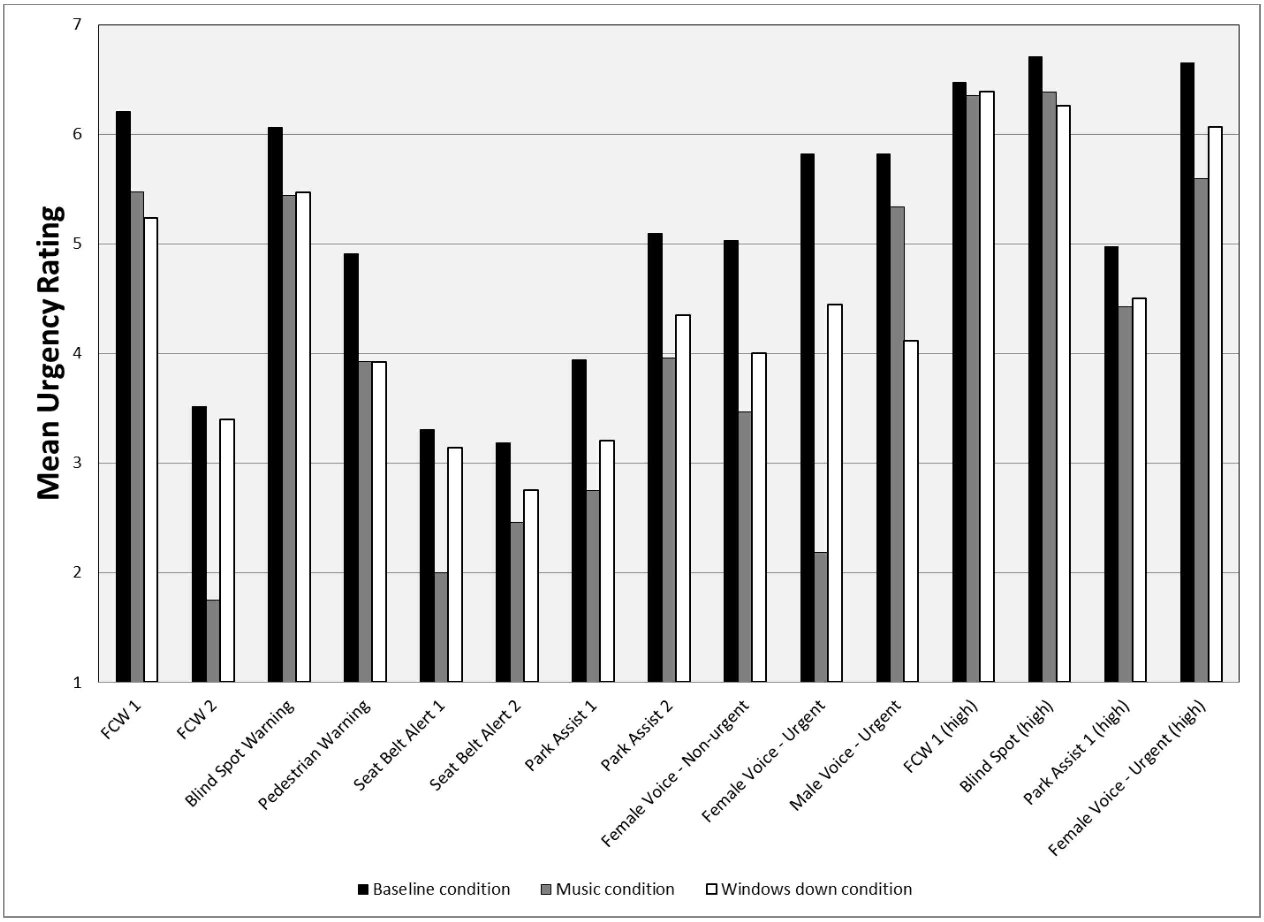


Figure 3. Mean urgency rating for each combination of signal and ambient noise condition

Figure 4 shows the mean response time data. Differences among alerting sounds are again evident. The differences among the ambient noise conditions are not as consistent, but response times tend to be somewhat faster in the baseline condition.

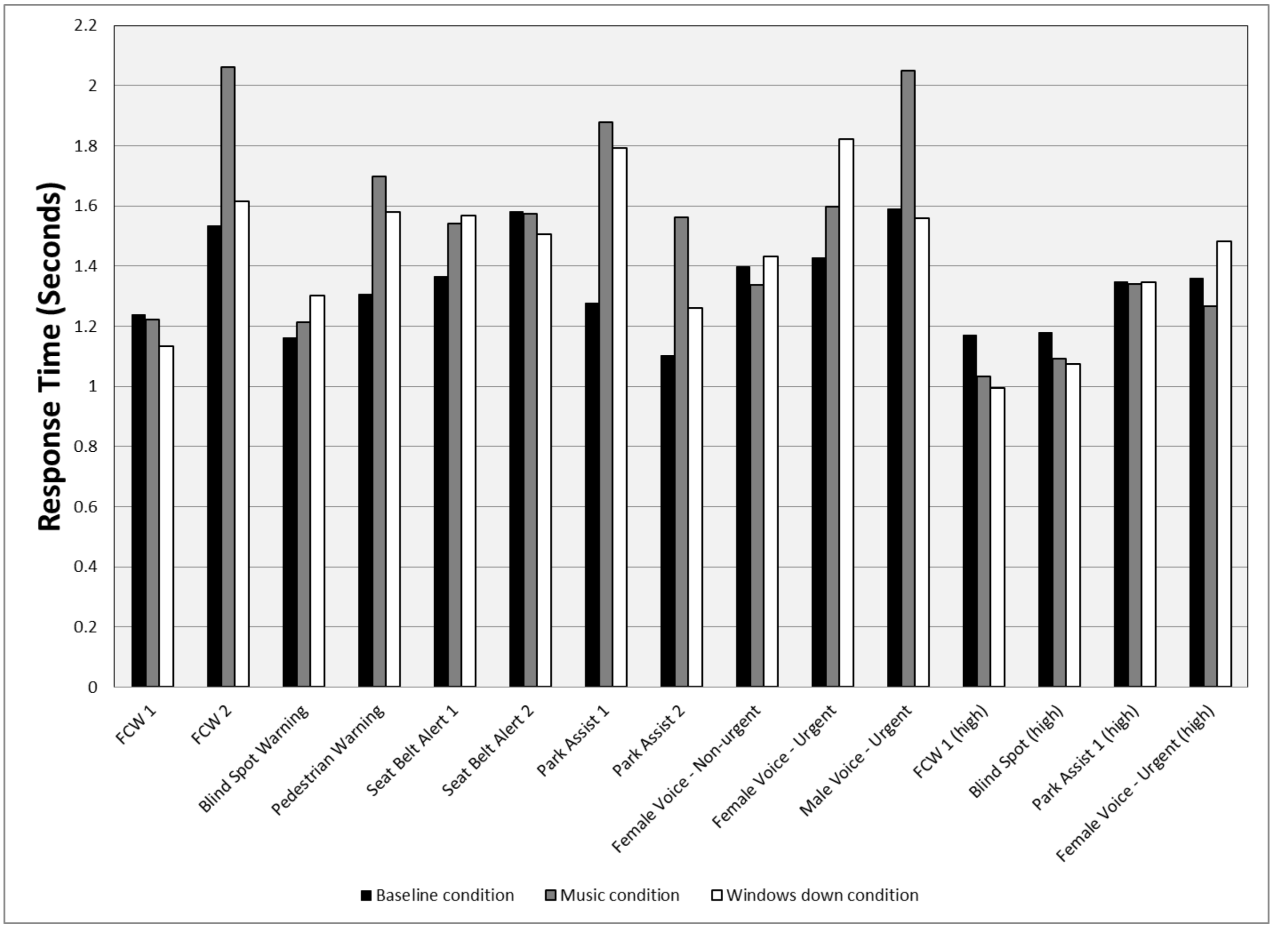


Figure 4. Mean response time for each combination of signal and ambient noise condition

In order to assess the effects of sound level, post hoc tests were conducted to compare each of the four alerts presented at 75 dBA with the identical alert presented at 65 dBA. For the measures of perceived noticeability and perceived urgency, in each case the rating for the 75 dbA sound was statistically significantly higher than for the 65 dBA sound (at $p<.0001$ in all cases). For the response time measure, responding was significantly faster to the 75 dBA sound for park assist 1 ($p<.0001$) and female voice - urgent ($p<.0005$). Sound level did not significantly speed response time for FCW 1 or blind spot warning.

The analyses and figures above represent the findings on participant responses to alerting signals, given that they were able to detect the signal. Under moderate (baseline) noise, participants rarely failed to hear an alert. Under higher noise conditions, missed signals were more frequent. Across all 15 alerting sounds, only about 1% were missed under the baseline condition, 15% under the music condition, and 36% under the windows-down condition. Under the windows-down condition, some alerts were missed in a majority of cases. Figure 5 shows the percent of times each alerting signal was detected, under each of the three ambient noise conditions. As with the ratings and response time measures, it is evident that even though the 65 dBA alerts were equated to be of similar loudness under relatively quiet listening conditions, they differed substantially in detectability once noise levels rose above the baseline condition. Music had a detrimental effect for most of the alerts, with 10-50% misses. A few 65 dBA alerts continued to be well detected even in the windows down condition. However, others were missed around 90% of the time with the windows down. The four alerts presented at 75 dBA were all well detected, even under the higher noise conditions.

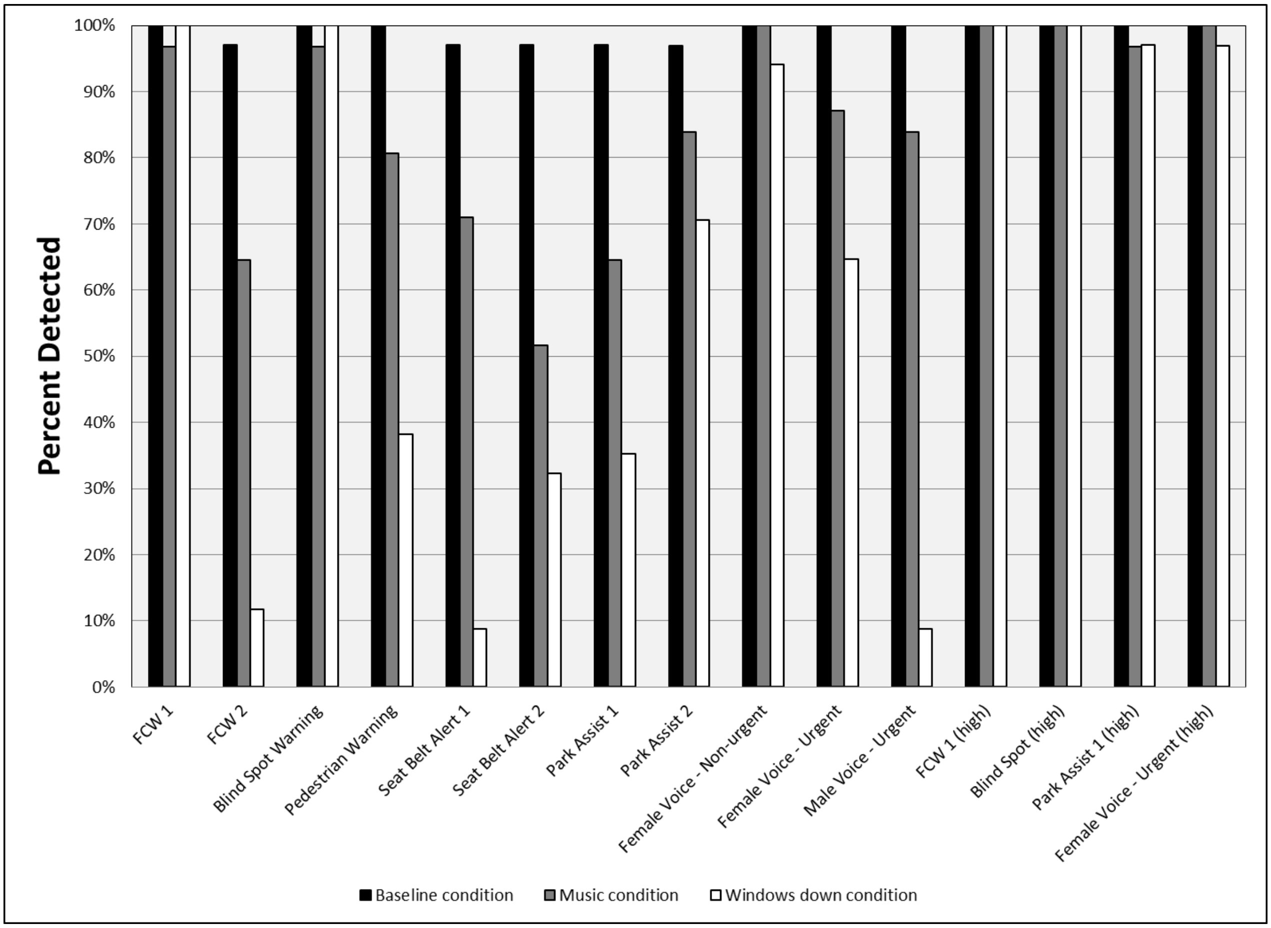


Figure 5. Percentage of participants who detected alerts under each ambient noise condition

In considering the effects of music on the detection of the alerting signals, it should be kept in mind that the participant set the volume of the music to the volume they would typically use for their own music while driving alone in their own car. Thus the actual volume varied from participant to participant. The sound intensity (measured near the driver's ear position while traveling at 60 miles per hour) ranged from 66 to 81 dBA, with a mean of 71.4 dBA and a standard deviation of 3.7 dBA. This setting may actually be rather conservative as an estimate of how loud some drivers may adjust their music, since the "Café Amore" track is "smooth jazz" and people may adjust their preferred music, in other genres, to louder volumes in actual practice. In order to determine whether the volume at which a particular participant adjusted the music influenced the magnitude of observed noise effects, a difference score was computed between the baseline condition and the music condition, for the measures of rated urgency, response time, and percent of alerts detected. There was no meaningful correlation of music loudness with the difference score for urgency ratings (R=-0.18) or response times (R=0.22). There was a moderate correlation (R=0.70) of music loudness with the difference score for detection rate of the alerting signals. While there was not a highly consistent relationship, 5 of the 6 participants with the largest difference scores for signal detection were among the top third of the group in terms of music volume.

The ambient noise condition influenced the category of meaning that a listener assigned to a particular alert. Participants had the option of classifying a given alert as "urgent crash warning," "safety information," "information not related to safety," and "incoming personal communication." As expected, the various alerts differed in terms of how they were interpreted, with some predominantly viewed as urgent crash warnings and others predominantly view as unrelated to safety at all. Multinomial logistic regression was used to analyze the perceived meaning classifications. Multinomial logistic regression is used to predict the probability of category membership on a dependent variable based on multiple independent variables. This approach is an extension of binary logistic regression that allows for k>2 categories of a dependent variable. Maximum likelihood estimation is used to evaluate the probability of category membership. It is an attractive approach due not assuming normality, linearity, or homoscedasticity. In addition, it assumes non-perfect separation of the outcome variables by the predictor variables. The current model analysis was performed in SAS and used a cumulative logit model with Fisher's scoring as an optimization technique. Differences of least square means are reported with Sidak adjusted p-values. The Wald Chi-Square statistics are presented in Table 7.

Table 7. Summary of analysis for perceived meaning

Effect	**DF**	**Wald Chi-Square**	**Prob > Chi Sq**
Ambient Noise	2	11.23	0.0036
Alerting Signal	14	318.29	<.0001
Ambient Noise X Alerting Signal	28	42.38	0.0399
Subject	33	161.07	<.0001

As Table 7 indicates, there were significant effects of ambient noise, alerting signal, and their interaction. Table 8 presents the actual distribution of choices among meaning categories for each alert under each noise condition. The effects of ambient noise were complex and depended upon the particular alert, as the significant interaction term suggests.

Table 8. Distribution of meaning categories for alerts under each ambient noise condition

Alert	Ambient Noise Condition	Meaning Category (%)			
		Urgent Crash Warning	Safety Information	Non-Safety Information	Personal Communication
1 FCW 1	Baseline	18	56	12	15
	Music	17	33	23	27
	Windows Down	26	44	9	21
2 FCW 2	Baseline	3	21	36	39
	Music	0	30	35	35
	Windows Down	0	0	25	75
3 Blind spot warning	Baseline	26	50	12	12
	Music	17	53	7	23
	Windows Down	9	56	21	15
4 Pedestrian warning	Baseline	12	41	35	12
	Music	16	28	44	12
	Windows Down	0	31	54	15
5 Seat belt alert 1	Baseline	0	12	27	61
	Music	0	5	50	45
	Windows Down	0	33	67	0
6 Seat belt alert 2	Baseline	0	24	48	27
	Music	0	31	56	13
	Windows Down	0	36	13	18
7 Park assist 1	Baseline	3	27	42	27
	Music	0	25	40	35
	Windows Down	0	25	50	25
8 Park assist 2	Baseline	6	41	31	22
	Music	4	38	31	27
	Windows Down	0	25	42	33
9 Female voice - non urgent	Baseline	0	65	29	6
	Music	10	42	39	10
	Windows Down	3	44	34	19
10 Female voice - urgent	Baseline	44	50	6	0
	Music	37	37	15	11
	Windows Down	9	36	36	18
11 Male voice - urgent	Baseline	41	53	0	6
	Music	35	42	19	4
	Windows Down	67	0	0	33
12 FCW 1 (high)	Baseline	47	24	18	12
	Music	55	16	3	26
	Windows Down	35	47	3	15
13 Blind spot (high)	Baseline	65	29	0	6
	Music	61	16	6	16

Alert	Ambient Noise Condition	Meaning Category (%)			
		Urgent Crash Warning	Safety Information	Non-Safety Information	Personal Communication
	Windows Down	47	32	12	9
14 Park assist 1 (high)	Baseline	3	44	38	15
	Music	3	37	40	20
	Windows Down	9	33	45	12
15 Female voice – urgent (high)	Baseline	82	15	3	0
	Music	58	42	0	0
	Windows Down	38	47	9	6

To illustrate the effects of ambient noise on perceived meaning of the alert, several examples are presented in Figures 6-9. Figure 6 shows the percentage of participants choosing each category of meaning for the blind spot warning presented at the higher (75 dBA) level. Under baseline noise conditions, a majority of participants viewed this sound as an "urgent crash warning," and 94% of participants put it in one of the two safety-related categories ("urgent crash warning" or "safety information"). However, only 61% classified this sound as an "urgent crash warning" under the music ambient noise condition and only 47% under the windows down condition. Figure 7 shows data for the same blind spot warning when presented at 65 dBA. Most participants interpret the sound as safety-related, but only about 26% interpret it as an "urgent crash warning." The percentage reduces under the higher noise conditions, so that only 9% view the sound as an "urgent crash warning" under the windows down condition. Figures 6 and 7 illustrate a trend seen for a number of alerts in which an alert is predominantly perceived as a safety-relevant message under the baseline condition but this aspect weakens under noise. Figure 8 shows another example, this time for the female voice – urgent, at the higher (75dBA) level. The drop in the percentage viewing this as an "urgent crash warning" is particularly dramatic, dropping from 82% in the baseline noise condition to 38% in the windows down condition. This may be because the degree of urgency is conveyed by the content of the speech ("warning"), more so than any sound quality of the voice. Figure 9 shows data for seat belt alert 2. Under baseline noise conditions, relatively few participants (24%) interpreted this sound as being safety-related. Unlike the other examples shown, under higher noise conditions, this percentage did not shrink, but actually increased somewhat (36% in the windows down condition). These examples are intended to illustrate the interaction of ambient noise conditions with specific alerts in terms of what meaning is conveyed. Table 8 may be referred to for all such comparisons.

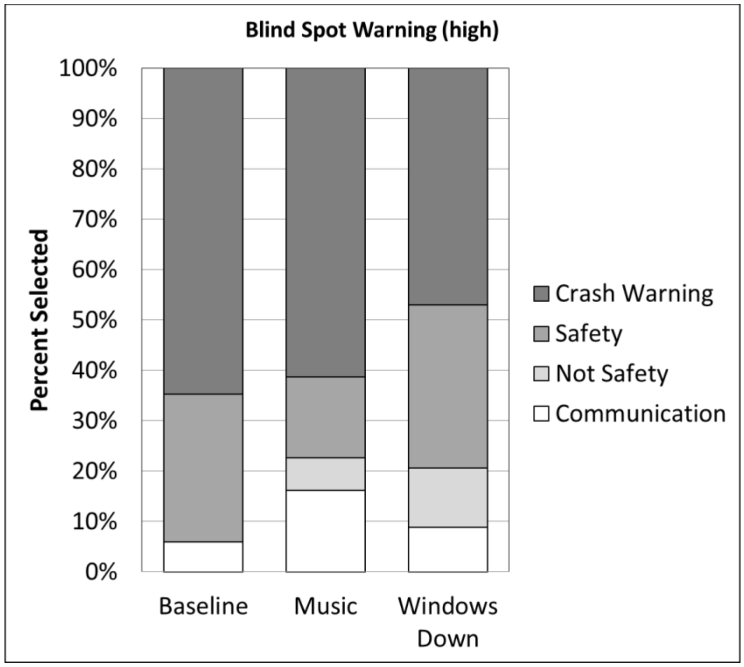


Figure 6. Categorization of signals by ambient noise condition for blind spot warning (high)

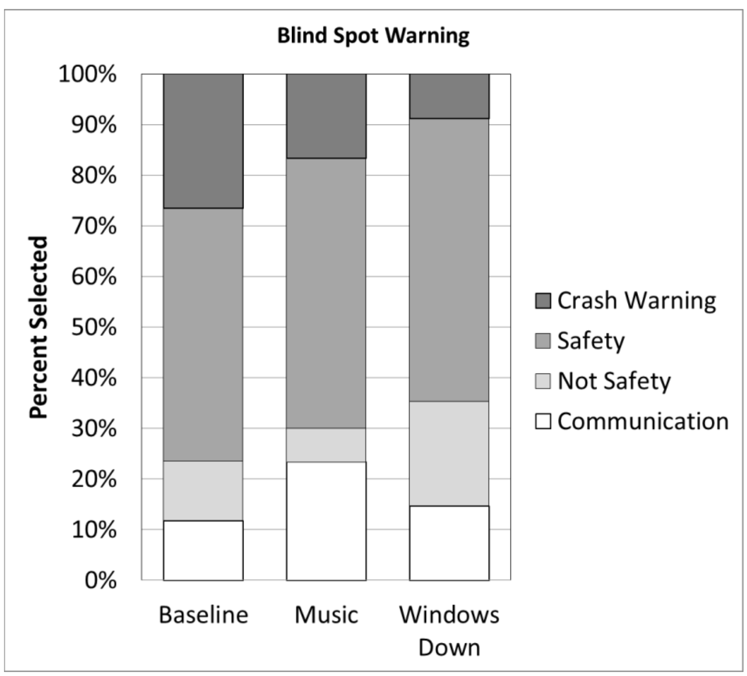


Figure 7. Categorization of signals by ambient noise condition for blind spot warning

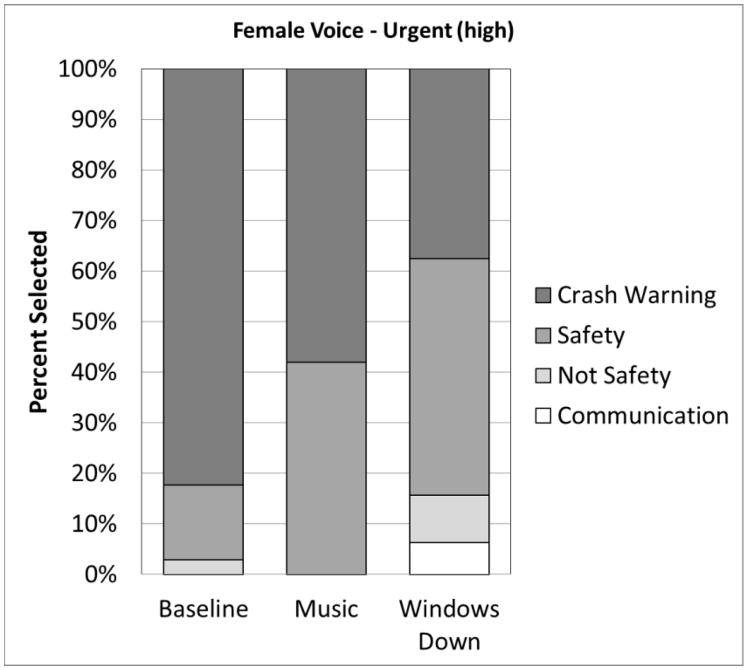


Figure 8. Categorization of signals by ambient noise condition for Female Voice – Urgent (high)

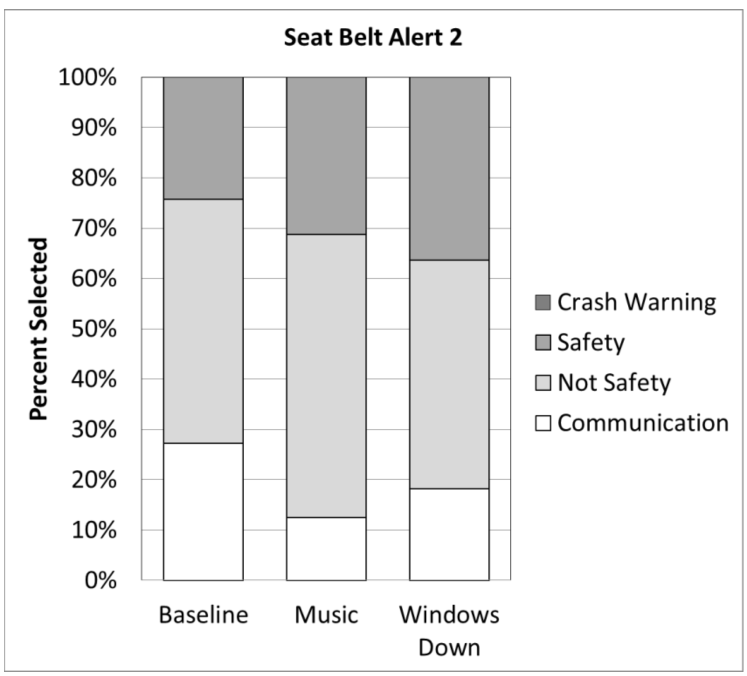


Figure 9. Categorization of signals by ambient noise condition for Seat Belt Alert 2

4 Discussion

This research was motivated by the concern that auditory urgent crash warnings may lose their effectiveness under foreseeable ambient noise conditions in passenger vehicles. Imminent crash alerts that appear effective in moderate ambient noise levels may not be reliably detected in higher noise, or may lose their subjective sense of urgency, may be confused with other categories of messages, or may be responded to more slowly. Little research basis exists to understand the nature and magnitude of these possible effects. It is not known under what naturally occurring ambient noise conditions such effects may be meaningful. It is not known what features of an auditory alert may make it more or less susceptible to noise effects. The existing literature on in-vehicle warnings is primarily based on the presentation of the auditory signals under quite moderate ambient noise conditions. This experiment was intended to provide initial findings on the nature of these effects. Background noise from music, and especially from open windows, interfered with the perception of auditory signals presented at 65 dBA. Interference was not very pronounced for the set of 75 dBA signals, although only four signals were included at this level. The set of sounds and voice messages equated for approximately equal loudness under relatively quiet listening conditions differed substantially in noticeability and urgency even under the baseline condition and even more under the music and open windows conditions. Under noise conditions, 65 dBA signals typically lost much of their perceived urgency, which may compromise their effectiveness for crash warnings. This is even assuming they are heard. Some sounds suffered low detection rates under noise, particularly the windows down ambient condition.

This experiment was designed to provide an initial examination of the extent to which possible ambient noise conditions might interfere with signal detection and meaning. It was not intended to provide any systematic evaluation of signal features or parameters regarding their resistance to noise effects. However, based on the limited sample of sounds and conditions, it appeared that the predominant frequencies that characterize a signal may relate to perceived urgency under noise. Sounds with predominant frequencies below 1000 Hz generally performed worst and those with primary or significant components above 1500 Hz performed best. However, this observation is based on a very limited sample of sounds that also differed in a number of other respects, and so should be considered tentative.

Given the very limited research on the perception of alerting signals under vehicle noise conditions, there is a need for further research. As an initial study on this topic, the experiment demonstrated very sizable effects of ambient noise conditions that might reasonably be expected to naturally occur on occasion. Alerting signals at the 65 dBA level are seen in practice (Lin & Green, 2013) and this intensity was generally quite susceptible to ambient noise interference. Further research on this topic should systematically evaluate the effects of audible signal features and parameters, including sound level, sound frequency characteristics, and temporal patterns. In addition to detection, urgency, and meaning, subsequent research might also include measures of driver annoyance and consumer acceptance. Research is being conducted by NHTSA and others on the characteristics of auditory signals that make them effective as crash warnings and that distinguish them from other sorts of messages. Consideration of background noise effects should be incorporated into such research. A greater range of ambient noise conditions than those included in this experiment should also be assessed. For example, traveling at higher speeds on worn concrete roads will generate a quite different noise condition than traveling at 60 mph on smooth asphalt (as in this experiment). Other potentially significant noise conditions might include loud adjacent large vehicles (e.g., tractor trailer), rain, or road surfaces under repair. Although the present experiment did include a music condition, this only addresses a single piece of music and a broader and more representative range of music, including listening volumes, would be appropriate, given how common this activity is.

Another research need concerns methodology. This experiment was conducted under realistic field conditions, presenting acoustic signals in an actual vehicle while operating at speed on functional roadways. While this provides a strong degree of face validity, on-the-road methods are less efficient than laboratory methods for collecting perceptual data. On-road methods require a period of sufficient training and vehicle familiarization for each participant so that the participant is comfortable and safe while engaged in driving an unfamiliar vehicle. Non-productive time is required to drive to and from test sites and for engaging in maneuvers such as exiting, merging, and turning. On-road methods are also subject to scheduling limitations and problems, broken sessions, or data loss due to weather, road maintenance activity, or traffic conditions. Certain noise conditions may be difficult to obtain for extended listening periods, such as loud passing vehicles or rough pavement conditions. Furthermore, in any on-road experiment there is some degree of variability in conditions from session to session. Therefore it would be valuable to develop an efficient and valid means of collecting perceptual data for ambient noise conditions in a laboratory setting. Such methods must be careful to maintain accurate replication of acoustics and should be validated against comparable data from on-road methods. Once developed, such laboratory methods could make use of high-quality field recordings to allow efficient evaluation of a broad range of noise conditions and alerting signals.

In summary, the present experiment demonstrated that comparing auditory signals under "typical" moderate background noise conditions may fail to discriminate important differences in how well alternative signals might function under more demanding, but still realistic, noise conditions. Ambient noise conditions influence how well signals will be detected, how quickly they are responded to, and how they are interpreted (urgency, meaning). Some of these effects can be quite large. Signal characteristics and noise characteristics interact to influence driver perception of alerts.

Alerts at a level of about 75 dBA maintained their detectability and perceived urgency quite well under the noise conditions included in this experiment, but those at 65 dBA varied considerably from one another. Designers and evaluators of driver interfaces for FCW and other types of in-vehicle alerts and messages will need to consider how a given auditory signal will perform under an appropriate range of possible in-vehicle noise conditions.

References

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Appendix A: Recruitment ad

Title: Participants needed for Driving Safety Study (receive $75 compensation)
Compensation: $75 for a 2-hour session
Location: Rockville

Westat is seeking participants for a federally-funded research study on drivers' ability to detect and recognize sounds and voice messages under different driving conditions.
If you participate in the study, you will take part in a 2-hour session in Rockville. You will drive a vehicle that Westat provides you on highways and local roads. You will hear occasional sounds and messages while you are driving and you will be answer questions about what you hear. The actual driving portion of the session will take about one hour.
Sessions will take place on weekday mornings and afternoons. Occasional weekend sessions may be available.
To be eligible to participate:

- You must have had a valid U.S. driver's license for at least 2 years and no major driving violations in the past few years.
- You must drive a car on a regular basis
- You must be between 21 and 50 years old
- You must have normal hearing; hearing aid users or those with functional hearing loss are not eligible.

If are interested in participating or would like to learn more about this study, please call […].

Appendix B: Recruitment screener

Thank you for your interest in the Ambient Vehicle Noise Driving Study. If you participate in this study, you will drive a vehicle provided by Westat on local roads and on the Inter County Connector while providing feedback about various sounds that will be played in the vehicle. You will drive with the car windows closed, car windows open, and with music playing.

I have a few questions I need to ask to verify your eligibility. Your ability to participate will depend on your eligibility and our need for participants with a variety of characteristics. If you are invited to participate, we will first need to verify your driving records to ensure that you have not had any major driving violations in the past few years.

1. In what year were you born? __________
2. For how many years have you had a valid U.S. driver's license?
3. Has your license ever been suspended or revoked within the past five years __Yes __No
4. What is the year, make, and model of the vehicle you drive most often?

   ____
5. How many days per week do you typically drive? ______
6. How often do you drive a small compact car such as a Ford Fiesta, Toyota Yaris, or Honda Fit? Would you say… [frequently, occasionally, rarely, or never]
7. How often do you drive a full size sedan such as a Chevy Impala, Dodge Charger, Ford Taurus, or Nissan Maxima? Would you say… [frequently, occasionally, rarely, or never]
8. How often do you drive a SUV? Would you say… [frequently, occasionally, rarely, or never]
9. Have you ever been diagnosed with a hearing impairment? __Yes __No
10. Do you have any reason to believe you have a hearing impairment? __Yes __No
11. Do you use a hearing aid? __Yes __No
12. Which statement best describes your hearing (without a hearing aid)? [good, a little trouble, or a lot of trouble]
13. What times can you be available for a 2-hour session in Rockville?
    a. ___weekday mornings
    b. ___weekday afternoons
    c. ___weekend mornings
    d. ___weekend afternoons

14. If eligible: It looks like you are eligible to participate. Before we schedule you for a session, we will need to confirm that you have a valid driver's license and that you have not had any serious driving violations. We will mail you a form that you will sign and return to us that allows Westat's Security Services office to receive your motor vehicle records. This information will be kept confidential and is used only for purposes of qualifying to participate in this study. Are you willing to allow us to obtain that information, after you read and sign the records release consent form? __Yes __No
15. What is your full name? ______________________
16. What is your daytime phone number? ___________________
17. What is your mailing address? ____
18. Is there an email address I can use to contact you about this study? ____________________

Thank you for your interest in this study. We will mail the driving records release form to you shortly. Please sign and return it to us at your earliest convenience. Once we verify your driving records we can schedule you for a session.

Appendix C: Instructions to participants

Intake (in lobby)

- Check driver's license and confirm information vs. driving record check
- Have participant read and sign consent form, offer copy for their records
- Offer use of restroom before starting session

Instruction and Practice

Purpose and Procedure: This is a study about how people hear sounds and messages while they are driving. Some new vehicles can use sounds or voice messages to inform drivers about safety-related issues, the status of their vehicle, traffic conditions, incoming calls, and many other things. One important question is how well drivers can perceive these sounds under realistic driving conditions. Under noisy conditions, it might be harder to hear and understand sounds and messages. In today's study, I am going to ask you to drive on roads in this area including the ICC. The noise conditions are going to vary. Every so often, I will present a sound. Your job will be to let me know as soon as you hear the sound, and then make ratings about what you hear.

Adjustments and calibration: Before we get started, please silence your cell phone. You can also adjust the seat and mirrors to get comfortable in the car. [*wait for participant to make adjustments*] Are you comfortable with your seat and mirror positions? During this session, please do not turn up the air conditioning fan speed – we need to keep the fan low so it doesn't make much noise. However, you can change the temperature control or aim the vents if you get too warm or cold. To the right of your head is a microphone that I will be using to measure sound levels in the car. This mic will also record audio from this session. Before we get started I need to calibrate the sound level in the car. Please sit quietly for a few seconds while I calibrate. [*Click COMP WHITE NOISE button in program and adjust volume level from computer tray until meter steadily reads 65 dB +/- 1 dB*]

Safety precautions. During today's session, safety is the top priority. You will be required to wear your seat belt at all times while driving and obey posted speed limits and other traffic laws. I will be giving you navigation directions while you drive, but please only make driving maneuvers when it is safe to do so. I would prefer you to miss a turn rather than do something risky to make a quick maneuver. Remember that it is *your* responsibility to drive safely.

Vehicle familiarization: First, let's get you familiar with driving this vehicle. We will take a minute to drive around the parking lot. Please pull out of the parking space when it is safe to do so. I'll give you directions around the parking lot. [*Drive one lap around parking lot, return to parking space, put car in Park*]

Now let's make sure you are comfortable with some of the things you will do while driving. Please lower both front windows all the way down using the controls on your door.

Now please turn the car stereo on, and try adjusting the volume up and down. Now skip forward to Track 2, now skip backwards to Track 1 [*instruct as necessary*]. *When done*: OK, please turn off the stereo.

Now let's go over what you will do when you hear a sound or voice message coming from the car. When you hear a message, the first thing you have to do is click this little button [*give finger button to participant*]. That lets us know how quickly you recognized that there was a sound. You will attach it to your finger so you can click it easily without looking at it. *Attach the microswitch and have them operate it; have them adjust it so that they can quickly and comfortably operate the switch but where it will not likely be accidentally activated*] Once you push the button, I will ask you some questions about the sound. You can take your time with these answers. I'll play a practice sound for you, and then we will go through the ratings you will make about that sound. [*play kazoo practice sound*]

The first question I will ask you is "how NOTICEABLE was the sound?" Noticeability means that the sound is easily noticeable among other sounds and noises in the vehicle. You will rate the sound you just heard on a scale from one to seven. A "one" means that the sound is not very noticeable. A "seven" means that the sound is extremely noticeable. How would you rate this sound?

The next question I will ask you is "how URGENT was the sound?" Urgency means that the sound conveys a sense of importance, motivating you to make an immediate response. A "one" means that the sound is not very urgent. A "seven" means that the sound is extremely urgent. How would you rate the urgency of the sound you just heard?

Next, I will read you a list of four possible meanings for this sound. Choose the one the most closely matches the meaning conveyed by this sound. I'll read you the list of possible meanings, then I'll go back and explain what each one means. The options will be:

- <u>Urgent crash warning</u>… means that there is a situation in which you must react immediately to avoid a crash. For example, imagine you are about to hit a pedestrian or about to run off the road.
- <u>Safety information</u>… means that there is a safety issue that you need to pay attention to, but you are not in immediate danger of a crash. For example, imagine that you are approaching a work zone where two lanes are closed or there are reports of icy roads ahead.
- <u>Information not related to safety</u>… means exactly what it says – you are receiving information, but the information is not safety-related. This could include various types of information, such as traffic congestion several miles ahead, prices at nearby gas stations, or a navigation system telling you to make the next turn.
- <u>Incoming personal communication</u>… means that you are receiving an incoming call, text message, email, or other direct communication.

Any questions? Which meaning would you choose for the sound you just heard? [*record answer*] The list of options will be the same for all of the sounds you hear today. I'll read the list to you for each sound you hear. If you can't remember what a category means, let me know and I can try to clarify. Also, please remember that there isn't necessarily a correct or incorrect answer to this question – I want to know what the sound conveys to <u>you</u>.

Now let's try another sound for practice. [*play voice message; go through NOTICEABILITY and URGENCY; read full definitions again and indicate 1-7 scale*] Now the next rating that comes up is INTELLIGIBILITY. You did not make this rating before. That is because it will only come up when the sound is a voice message. "Intelligibility" means that the spoken words can be easily understood. A "one" means that the voice message was not very intelligible. In other words, you could not understand the words clearly. A "seven" means that the message was extremely intelligible. How would you rate this voice message for intelligibility? [*have participant say choice; go through meaning question; read full definitions again*] Do you have any questions about how to do the ratings and choices?

Would you like to make any more adjustments before we go out on real roads? Now let's start driving toward I-270, which will take us to the ICC. I'll give you step by step directions. [*give directions toward I-270*] *Once on I-370*: We're on I-370 now which will eventually become the ICC. While on the ICC, please try to maintain your speed close to the speed limit, which is 60 miles per hour. Be aware that the police frequently pull over speeders on this road. Stay in the right lane unless you need to pass a slower vehicle. If you need to pass, please let me know before you change lanes, use your turn signals, and always look carefully to make sure it is safe to change lanes. When we get close to the end of the ICC, I'll give you directions to exit onto Briggs Chaney Road and get back on in the other direction. Do you have any questions before we start the real experiment?

[wait until you reach the Shady Grove Rd/Metro exit, then begin data collection]

Data Collection

- *Look for upcoming concrete sections/overpasses before triggering*
- *Click button quietly and avoid giving any subtle triggering cues*
- *If participant fails to hear a sound, you can trigger the next one without waiting for the countdown*
- *Try to be silent in back seat at all times*
- *Keep an eye on participant speed*
- *Do not allow cruise control use*
- *Do not allow driver to lean forward to hear better*
- *Watch for signs to exit onto Briggs Chaney Rd (shortly after Route 29); and then Shady Grove Rd.*
- *During final block, choose turnaround spot to minimize drive back to Westat at end of session.*

<u>Prior to Condition 2 (windows down)</u>: For the next set of sounds, you will have the front two windows opened all the way. After each time you click the finger button, I'll ask you to close the windows so we can talk to each other more easily.
<u>Prior to Condition 3 (music on)</u>: For the next set of sounds, you will turn the stereo on and set the volume to the level that you would usually set your own music while driving by yourself. Whether or not you like the music that we have in the car, it is important that you set it to the volume you would choose for your own music and leave it at that volume until we get through this full set of sounds. Having the music on might make it harder to hear some sounds, but that's OK. For this experiment it is <u>much</u> more important that you have the music at your own typical volume than it is for you to be able to hear all of the sounds. Pretend I'm not here when you choose your volume level. Go ahead and turn the stereo on now and set the volume to the level that you would usually set your own music while driving by yourself.* Now please skip forward to track two on the CD player so I can take a sound measurement. Please try not to make any noise until I tell you that the measurement is complete. [*Check for white concrete/tunnels ahead before starting recording. Wait 10 seconds for sound to ramp up, then click to start recording. Write down digital volume level on session info sheet. Max sound level allowed is 90 dB – have participant reduce if necessary.*]
**MINIMUM VOLUME ALLOWED: Accent: 7 … Terrain: 14 … Camry … 21*
Now that I have taken a sound level measurement, it's important that you not change the music volume until we finish this set of sounds. [*If they have the music set loud, say "After each time you click the finger button, I'll ask you to turn off the music so we can talk to each other more easily"*]. Please skip back to Track 1 now and we'll get started.
****[If the participant presses the button when there is no actual signal:]***
If this happens during a non-trial period, ask the participant what sound they heard, then record on paper as accidental or false alarm. If this happens during the 5 s pre-signal period of a trial, ask if they heard something or if it was an accidental button press. Then follow program prompts to redo the trial.

Driver-Vehicle Interfaces for Advanced Crash Warning Systems: Research on Evaluation Methods and Warning Signals

Appendix C

Negative Transfer Study: Additional Methods and Supplemental Report Of Detailed Analyses

GMU Negative Transfer Study

Additional Methods & Supplemental Report of Detailed Analyses

By

Jesse Eisert, Bridget A. Lewis, and Carryl L. Baldwin

George Mason University

Introduction

This experiment investigated the effects of a change in the warning sound on driver response to a FCW alert. If a change from one sound to another results in poorer crash avoidance performance (e.g., longer reaction times), this is referred to as "negative transfer." Each participant took part in three experimental sessions in a driving simulator. Aspects of the appearance of the vehicle interior were changed on the third session and the participants were informed that this was a different simulated vehicle. Occasional potential crash events occurred during all three sessions which required the driver to take evasive action. For experimental groups, the warning sound changed from the sound experienced in Sessions 1 and 2 to a different sound in Session 3. Performance in Session 3 was compared with that of various control groups that did not experience a change in warning sounds. There were six groups of participants in the study. The primary experimental group experienced a change from sound "A" to sound "B." The control groups included one that received sound A in all sessions, another that received sound B in all sessions, and a third that received no warning sound. Another group experienced a change from sound A to sound C, where sound C had some particular similarities with sound A. All of these groups also experienced a variety of background sounds during the drive. Another experimental group also experienced a change from sound A to sound B in Session 3, but for this group no other nonverbal background sounds were presented. The purpose of this condition was to allow for some assessment of the degree to which observed negative transfer effects might be related to the nature of the in-vehicle acoustic environment.

Methods

Participants

A total of 108 participants (63 males) between the ages of 18 and 47 years (mean age of 26 y) recruited from the Northern Virginia area completed this study. However, as further detailed in the data reduction section of the results, full data sets were available from only 71 of these participants. All participants had self-reported normal or corrected to normal hearing and vision as well as a valid driver's license with an average of 116 months of driving experience. The study took place over three separate sessions and all participants were compensated $60 upon completion of the study.

Conditions

There were six experimental conditions as illustrated in Table 1. Each condition varied primarily by the type of auditory forward collision warning (FCW) presented across the three separate drives, the FCW's are further explained in Section 1.2.4 as well as the collision warning section.

Condition					
1 Control A1	**2 Control A2**	**3 Control No Warning**	**4 Experimental**	**5 Comparison – No Background Sounds**	**6 Distinct**
$A_1 \rightarrow A_1$	$A_2 \rightarrow A_2$		$A_1 \rightarrow A_2$ background noise	$A_1 \rightarrow A_2$ no background noise	$A_1 \rightarrow A_3$ background noise

Table 1. Experimental Conditions

In Condition 1, participants heard all the environmental sounds (listed in the next section) in addition to receiving the heavy vehicle collision warning (referred to as A1) throughout all three drives. In Condition 2, participants heard all the environmental sounds in addition to receiving the light vehicle collision warning (referred to as A2) throughout all three drives. In Condition 3, participants heard all the environmental sounds but received no collision warnings in any of the drives. In Condition 4, participants heard every environmental sound, received the A1 heavy collision warning for the first two days but received the A2 light collision warning on the third session. Condition 5 was the same as Condition 4 except participants only heard a synthetic voice. They heard none of the nonverbal environmental sounds experienced by participants in the other conditions. Condition 6 was the same as Condition 4 except in the third session participants received a collision warning (A3) designed to resemble A1 in distinct characteristics without being identical to it.

In each condition participants completed three separate sessions over the course of three days. In each session participants completed 3 different drives that varied in length from 7 to 13 minutes in length. In each drive participants followed a lead vehicle, completed a secondary task, and responded to environmental sounds, depending on the condition.

Environmental Stimuli

To create a rich auditory soundscape, participants received several nonverbal abstract sounds throughout the course of each drive. If participants were going five MPH over or under the posted speed limit they received an abstract tone signifying for them to either speed up or slow down. Occasionally participants would hear a cell phone ringing. They were required to silence the phone by pressing a button on a touchscreen display. Other sounds presented included a police car siren, navigational instructions, email alert, reduce speed ahead auditory display, check engine alert, check wiper fluid alert, and airbag notifications. With the exception of Condition 5, participants heard each of these environmental sounds periodically throughout each of the three drives. Participants in Condition 5 received only synthetic voice commands telling them when to turn in addition to telling them when to speed up or slow down.

Collisions Warnings

Three different auditory FCWs were used in the current study. Their primary characteristics are listed in Table 2. Two of the FCWs (A1 & A2) were used in a previous CWIM negative transfer study and were originally taken from the Integrated Vehicle-Based Saftey Systems-IVBSS study (Green et al., 2008). The A1 warning incorporates two frequencies within a single burst while the A2 warning includes a shorter interpulse interval and shorter pulse duration relative to A1. The third warning (A3) was designed to be distinctly related to one of the main FCWs (A1) based on the results of a separate investigation.

IVBSS Heavy Vehicle FCW Alert (A_1)	**IVBSS Light Vehicle FCW Alert (A_2)**	**Distinct FCW Alert (A_3)**
Abstract tone	Abstract tone	Abstract tone
Frequency Modulation = two tone	Frequency Modulation = none	Frequency Modulation = two tone
Pulse 1 frequency = 1800 Hz	Frequency = 1500 Hz	Pulse 1 frequency = 3000
Pulse 1 duration = 80 ms	Pulse Duration = 70 ms	Pulse 1 duration = 80 ms
Pulse 2 frequency = 600 Hz	Burst duration = 700 ms	Pulse 2 frequency = 1000 Hz
Pulse 2 duration = 80 ms	Interburst Interval = NA	Pulse 2 duration = 80 ms
Burst Duration = 320 ms	Interpulse Interval = 30 ms	Burst Duration = 320 ms
Interburst Interval = 200 ms	Onset Ramp = 5 ms	Interburst Interval = 200 ms
Interupulse Interval = 0 ms	Offset Ramp = 20 ms	Interupulse Interval = 0 ms
Number of pulses per burst = 4 (2 of each frequency)	Number of bursts = 2	Number of pulses per burst = 4 (2 of each frequency)
Number of bursts = 3	Number of Pulses per burst = 7	Number of bursts = 3
Warning duration = 1560 ms	Warning duration = 700 ms (doubled for 1400 ms)	Warning duration = 1560 ms

Table 2. Primary FCW Auditory Characteristics

A1 consisted of an abstract tone containing two bursts of separate frequencies. The first burst had a fundamental frequency of 1800Hz and the second burst had a fundamental frequency of 600 Hz, both bursts played for 80ms. Each burst played twice per pulse and each pulse was 320 ms in duration. There were 3 pulses, each separated by 200 ms of silence lasting for a total play time of 1560 ms. A2 consisted of an abstract tone composed of 14 -50 ms pulses separated by 50 ms of silence. Each pulse had a fundamental frequency of 1500 Hz with a 5 ms onset and 20 ms offset. The warning was played for a total of 1400 ms. A3 was similar to A1 in complexity and temporal rate. However, for A3 the fundamental frequency of the two bursts differed from A1, with the first burst being 3000 Hz and the second 1000 Hz. For the no warning condition, inaudible white noise was played.

Collision Events

Participants were exposed to one potential forward collision event in each of the nine drives. Collision events consisted of the lead vehicle unexpectedly braking hard (without brake lights being initiated) and slowing down to 10 MPH in 1.5 seconds. Scenarios ended shortly after each potential collision situation. Participants were notified of the event via the presentation of one of the auditory FCWs (unless in the no warning control group) when their headway was 1.8 seconds or less. Participants received a total of 9 collision events over the course of the study. The collision event was manually triggered during the first, sixth, and seventh drive when participant's visual attention was diverted. This was accomplished by using a webcam to determine when a participants eyes were diverted from the roadway. The researcher began carefully watching the participant's gaze after approximately 5.2 minutes had elapsed in the drive. Following this target time period the experimenter waited till the participant's eyes were off the road for at least 30 s and then hit a button which triggered the immediate braking of the lead car. For the drives that were not manually triggered the brake event was programmed to take place towards the end of each drive.

Materials

This study was conducted using the George Mason University motion based driving simulator (RealTime Technologies, Inc.), which allows for yaw motion of 180 degrees (90 degree of pivot left and right) and pitch motion which allows for the sled of the cab to slide forward and backwards one degree simulating acceleration and breaking. The simulator features three 40" plasma monitors for 3 channel system allowing for a 180 degree forward field of view. Located underneath each monitor are three LED lights that were used for a secondary peripheral detection task. Located in the center stack of the simulator is a 7" touch screen interface where participants received feedback on the secondary task and pressed a button to cancel the cell phone whenever it rang. The simulator also features a 5.1 channel surround sound system consisting of three front and two rear speakers and a subwoofer for bass and was affixed with a webcam so that the researcher could see when the participant was looking away from the center channel. The simulator recorded the subjects speed, headway distance and time to the lead vehicle, braking input, steering input, when a warning was played, and if a collision occurred at a rate of 30 Hz.

Procedure

The present study consisted of each participant voluntarily completing three separate sessions occurring on three separate days. The first and last sessions were approximately 1.5 hours in duration and the second session lasted approximately one hour. When participants arrived to the first session they were required to present a valid driver's license to be able to proceed with the study. Next, participants signed a University Institutional Research Board approved informed consent document and then took a vision test to ensure they had normal or corrected to normal vision. After completing the vision test, participants completed a demographic survey and a simulator sickness screening form. Next, participants were given a training session to familiarize them with all the sounds they would be hearing over the course of the experiment. Participants were allowed to take as long as they wanted with the training slides until they were comfortable in knowing what each sound represented.

After completion of the training slides participants were told that the purpose of the study was to investigate safe driving when dealing with various activities inside the vehicle, and how that is affected by learning and adaptation. Participants were then seated in the driving simulator and were instructed to adjust the seat to their own preference. Once comfortable, participants were instructed to place the seat belt on and then began three training sessions. The first training session included having participants following a lead vehicle that was yolked to maintain a temporal headway of two seconds in front of the participant's vehicle. Participants were instructed to practice maintaining a speed of 55 MPH, taking the turns, and familiarizing themselves with the brake pedal. During this training session the monitor speed prompts were active as well as the navigation system, however the collision warning system was not active during this time.

The second training session was to familiarize participants with the secondary task, which was a peripheral discrimination task (PDT), without driving. Underneath each of the three plasma monitors were three red LED lights, creating a total of 9 lights. Participants were instructed to respond whenever they saw one of the lights come on, go off, then quickly come back on. Participants were told to refrain from responding if the light stayed on. The last training session had participants completing the first drive again while also completing the secondary task. An example of a participant completing the PDT is shown in Figure 1.

Figure 1. GMU Driving Simulator illustrating LED lights for the peripheral detection task and response apparatus.

Once the three training sessions were completed participants began the actual experiment. Participants then completed three, seven to thirteen minute drives, in which they followed a lead vehicle that was yolked to maintain a two second headway from them at all times. Participants were instructed to maintain a speed of 55 MPH, perform the secondary task, and silence any incoming cell phones on the touch screen. At the end of each drive participants were exposed to the forward collision event and given either the A1 (heavy vehicle), A2 (light vehicle), or no warning based on what condition they were in. After the potential collision event ended participants were instructed to remain stopped as the drive was finished. Since drives varied from 7 – 13 minutes in length with the collision event taking place at the end of each drive, the timing of potential collision events was not predictable by the participant. Participants' first exposure to the collision event was manually triggered by the researcher when they were looking away. After the end of the third drive participants were scheduled for their second session, which had to be at least 24 hours after the start of their first session. When participants returned for their second session they again completed three more similar drives, with their third drive being manually triggered as well. After completion of the last drive participants were again scheduled for their third session.

When participants arrived on the third day they were instructed that they were now driving a different vehicle with features similar to the one they had previously been driving. They were told that some of the features might be different and that the vehicle may handle somewhat differently than the previous one. To make this cover story more convincing, superficial changes were made to the appearance of the vehicle on the third day. Specifically, the steering wheel cover was removed, as well as the seat cover, the license plate was changed, and the instrument cluster was also changed. Again they completed three similar drives, however if they were in conditions 4, 5, or 6 they received a new collision warning alert(condition 4 and 5 switched from the heavy warning to the light and condition 6 switched from the heavy warning to the distinct warning). The first drive of this session was also manually triggered. At the end of their last drive participants were debriefed on the true purpose of the study. Table 3 provides a summary overview of the nine experimental drives distributed across the three days. Note that the primary drives of interest for examining negative transfer are Drives 1, 6, and 7. Drive 1 provides the initial response to the original warning. Drive 6 provides the response after repeated experience to the warning sound. Drive 7 provides the contrast between those groups continuing with the familiar sound versus those experiencing a new sound.

	Learning Phase		**Test Phase**
Session/Day:	1	2	3
Activity:	Training + $\mathbf{D_1}$+D2+D3	D_4+D_5+$\mathbf{D_6}$	$\mathbf{D_7}$+D_8+D_9 +Post
Duration:	1.5 hours	1 hour	1.5 hours

Table 3. Summary of Experimental Drives

Experimental Design

The main analysis examined collision response in a 3 Exposure (first, sixth, seventh) x by 6 (FCW Condition) mixed design with Exposure as a within-subjects factor and FCW condition as a between-subjects condition. Additional analyses examined specific effects of interest.

Results

Data Collection and Reduction

Response time was measured from the time the collision warning played to the time when either a steer or brake response was initiated. A steering response was considered when the derivative value (instantaneous rate of change in steering inputs per second) of the participants steering input during the collision event was greater than 1.5 s and a brake response was considered when their brake force input value was greater than 20 Newtons during the collision event. The fastest response between the two was taken as their evasive maneuver response time (EMRT). Collisions were determined whenever a participant's vehicle occupied the same space as the lead vehicle. If a participant did not collide with the lead vehicle we calculated what their minimum time to collision (TTC) was to determine how close they came to colliding. If participants did not make a response they were given an EMRT of 1.8 seconds. If participants were missing data from drives one, six, and seven or had an EMRT faster than 0.2 seconds for drives one, six, and seven they were not included in data analysis. A few participant's data were lost due to experimenter error (e.g., they received the wrong warning sound during one of the critical drives). Since to the maximum extent possible, experimenters were blind to the condition that each participant was in and were following a code sheet, this procedure (which was implemented in an attempt to reduce experimenter bias) did leave greater room for experimenter error. Some participant's data were lost because they were already braking before the event began or because they made some type of anticipatory maneuver before the onset of the warning (e.g., imitated braking and/or steering less than .2 seconds after the onset of the warning). Only participants who had valid data for drives one, six, and seven were analyzed, resulting in a total of 71 participants included in the main analyses. Mean EMRT in each of the conditions for the drivers drives one, six, and seven are presented in Table 4.

EMRT Analysis

		Drive 1		**Drive 6**		**Drive 7**	
Condition	**Number of Participants**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
1	11	.85	.44	.38	.14	.33	.07
2	12	.98	.49	.55	.29	.50	.28
3	10	.89	.27	.50	.27	.53	.35
4	12	.87	.32	.57	.22	.42	.25
5	12	.73	.29	.49	.24	.62	.23
6	14	.89	.49	.57	.24	.45	.31

Table 4. Mean EMRT (s) and Standard Deviations for Comparison Drives

The EMRT data was submitted to a repeated measures ANOVA with condition as a between subjects factor and exposure as a within subjects factor. Mean EMRT responses can be seen in Table 4 for each condition and exposure. A main effect of exposure was found, F (2, 130) = 40.83, p < .01. Post hoc comparisons show that this effect was driven by the differences between the first and sixth exposure, demonstrating that participants exhibited a learning effect for either the warning, the potential collision scenario, or both. This relationship is illustrated graphically in Figure 2. However there was no significant interaction between exposure and condition, F (10, 130) =.95, p > .05, when analyzed across all conditions. When specifically looking at conditions 1, 4, 5, and 6, there still is no significant interaction between exposure and condition however it was trending in the expected direction, F (6, 90) = 1.53, p = .18.

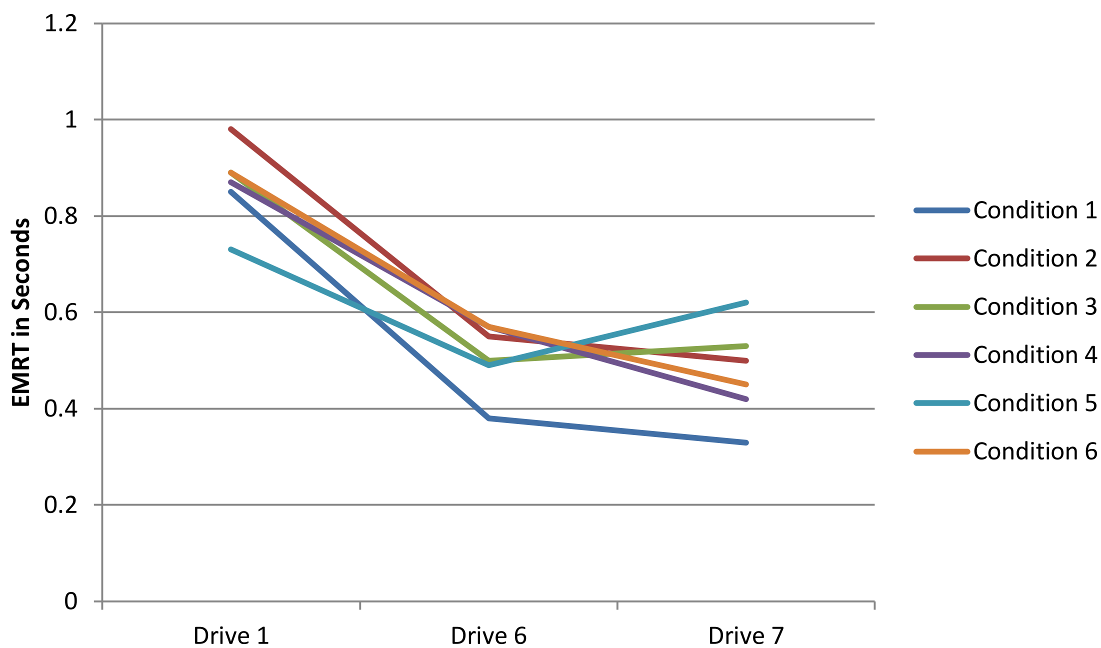

Figure 2. EMRT as a function of exposure and condition.

Examination of EMRT responses during just the seventh exposure (first time participants in condition 4, 5, and 6 would have switched warnings) revealed no statistically significant differences, F (5,70) = 1.59, p = .18. However when looking at time to collision (TTC), which was defined as how close participants came to colliding, there was a significant effect between the Alert Condition for drive 7, F (5,70) = 2.94, p < .05. Participants in Condition 5 got significantly closer to the lead vehicle relative to those in Condition 1, t (21) = 4.47, p < .01. Recall that Condition 1 had a consistent FCW (A1) throughout while Condition 5 experienced a switch from A1 to A2 on the third day and were exposed to no other nonverbal alerts throughout any of the drives.

When specifically looking at the four conditions that received the A1 warning for at least the first 6 drives (conditions 1, 4, 5, and 6) initially no significant differences in EMRT were observed on first and sixth exposure, *F* (3,48) = .41, *p* > .05 and *F* (3,48) = 1.86, *p* = .15, respectively. However, on the day 3 switch drive there was a significant difference between EMRT on the seventh exposure, *F* (3,48) = 2.94, *p* < .05, such that participants in Condition 5 had significantly slower EMRT than participants in Condition 1, *t* (21) = 3.99, *p* < .01.

Minimum Time to Collision (TTC)

Analysis of minimum Time to Collision (TTC) was also examined as another means of determining the potential impact of a consistent versus novel FCW sound. Examination of minimum TTC reveals how close to colliding a participant came regardless of when they responded. A mixed design ANOVA with exposure as a repeated subjects variable and warning condition as a between subjects variable revealed a main effect for exposure, $F(2,130) = 42.48$, $p < .001$, indicating that regardless of warning condition participants who were able to avoid colliding came the closest to colliding during their first exposure relative to the 6^{th} and 7^{th}, which did not differ significantly from each other. The interaction between exposure and condition was not significant, $F(10,130) = .91$, $p > .05$. However, there was a trend pattern similar to that observed in the dependent measure EMRT in the post-switch exposure 7.

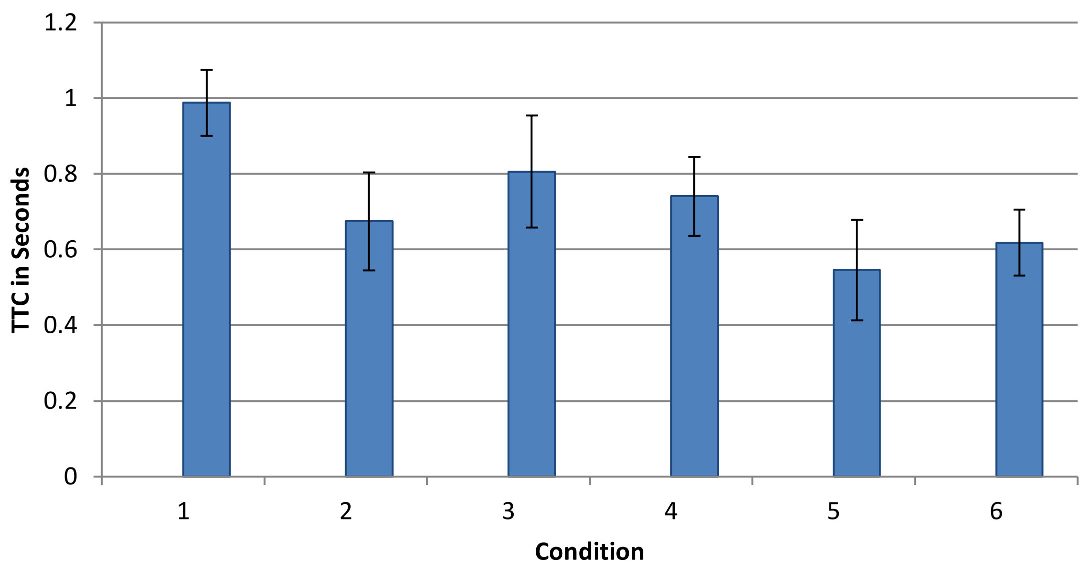

Figure 3. Minimum TTC as a function of FCW condition at exposure 7.

To examine this trend, TTC was also examined at Exposure 7 only. As illustrated in Figure 3, participants in Switch Condition 5 had closer calls (near crashes) relative to those in Condition 1 who received the consistent A1 warning sound. A one-way ANOVA revealed that this was a statistically reliable effect ($p = 0.02$).

Collision Analysis

Table 5 shows the number of participants in each condition and how many collisions they had in the first, sixth, and seventh exposure to the collision event. Collision data was examined using the likelihood ratio statistic. On the participants' first and seventh exposure to the event there were no differences in associations between conditions for whether they crashed or not, $L\ X^2(5) = 1.97$, $p > .05$ and $L\ X^2(5) = 9.17$, $p = .1$ respectively. Further examination of this non-significant trend for the seventh exposure indicated that participants in both Conditions 4 and 5 had a significantly more crashes post FCW switch relative to participants in Condition 1 who experienced a consistent FCW throughout, $L\ X^2(1) = 4.32$, $p < .05$ and $L\ X^2(1) = 5.98$, $p < .05$.

	Number of Participants	Drive 1 Number of Participants who got in Collisions	Drive 6 Number of Participants who got in Collisions	Drive 7 Number of Participants who got in Collisions
1	11	9	1	0
2	12	10	4	4
3	10	9	4	4
4	12	9	4	3
5	12	10	3	4
6	14	13	5	2

Table 5. Number of Collisions as a Function of Exposure and Condition

Brake Response Time

When looking at participants brake responses in the 2-way mixed design ANOVA, an effect of overall exposure, $F\ (2, 130) = 10.65$, $p < .01$, was also found. This effect was again driven by participants responding significantly faster at exposure 6 and 7 (which in general did not differ) relative to their speed of responding at the first exposure. The interaction between exposure and condition for brake response time was not significant, $F\ (10,130) = .51$, $p > .05$. Examination of BRT during just the seventh exposure revealed no statistically significant differences, $F\ (5,70) = .81$, $p > .05$. Furthermore when just looking at the four conditions that received the A1 warning for at least the first 6 drives (conditions 1, 4, 5, and 6) no significant differences were observed on the seventh exposure, $F\ (3,48) = .66$, $p > .05$.

<u>Discussion</u>

A primary purpose of the current investigation was to further examine a finding from the previous CWIM Negative Transfer Study (Lerner et al., 2011) that had revealed substantial "negative transfer" (slower response) among distracted drivers when they became familiar with one FCW "A1" and then encountered an unfamiliar auditory FCW "A2" in a "different" vehicle. Specifically, we sought to determine if the previous results might have been a feature of the specific warnings used in that experiment or potentially an artifact of the environmental sounds used in the scenario. A further objective was to examine whether or not a FCW sound change to another sound that retained certain distinct characteristics with the initially learned sound would be resistant to negative transfer.

Results of the current investigation are mixed. Some evidence for negative transfer was revealed. However, this evidence for negative transfer was primarily observed in only one of the two main switch conditions. We had expected that participants might experience negative transfer in both Condition 4 and 5 when participants encountered a new FCW sound (A2) for the first time on their Day 3 -7th exposure drive. However, only Condition 5 (the no background sounds) demonstrated slowed response time on the 7th drive. There are several possible reasons why negative transfer might not have been observed in the Switch Condition 4. One is the possibility that there was no effect because changing the auditory sound does not result in negative transfer. This alternative is highly questionable, however, since evidence to the contrary was observed in the previous CWIM Negative transfer study (Lerner et al., 2011), as well as in the current study in Condition 5. An alternative explanation is that the precise nature of the warning sound is less important in very environmentally noisy situations. It is possible that in all conditions *except* Condition 5, participants grew accustomed to reorienting their vision forward any time they heard an audible alert due to the presence of the nonverbal speed notifications.

Another potential reason for not observing more robust negative transfer effects may be limitations of the current methodological protocol. Participants in the control condition (Condition 3) who received no warning were only slightly more likely to crash than participants who received warnings. As indicated in Table 5, in Drive 6, which occurred before the potential switch in warning sound, 4 of 10 or 40% of participants in the control condition crashed. With the exception of Condition 1 whose crash rate in Drive 6 was only 9% relative to a crash rate of 81.8% in Drive 1, the crash rates of the other experimental conditions which received a warning were only slightly lower. All conditions had high crash rates in the first drive but crash rates dropped sharply in all conditions by Drive 6. Specifically, for Drive 6 Conditions 2 and 4 had crash rates of 33.3% (or 4 of 12) and Condition 5 had a crash rate of 25%, and Condition 6 had a crash rate of 35.7%. Evasive response times were also similar between the control condition and the other conditions receiving a warning. These results were surprising and point to a limitation of the current study. It appears that with the exception of Condition 1 where a specific (A1) consistent warning was presented across all conditions, even participants receiving a warning had relatively high crash rates.

The observation that participants in the control condition exhibited relatively similar collision avoidance response times and behaviors as those participants receiving the FCW is a limitation of the current study. This observation indicates that participants may not have had ample time to respond to the warnings or perhaps they found the secondary peripheral discrimination task too challenging. We triggered the sudden brake events in Drives 1, 6 & 7 when the participant's eyes were diverted from the forward roadway. The warnings were presented when the lead time between the participant's car and the lead vehicle decreased to 1.8 s. This lead time is well within the existing guidelines (Campbell, Richard, James L. Brown, & MaCallum, 2007) and is ecologically valid. Including a longer lead time under actual driving conditions would not be realistic because most people drive with less than the 2 s lead time required by law. However, a survey of existing crash warning literature indicates that many researchers in fact use significantly longer lead times for triggering warnings. For example, Kramer, Cassavaugh, Horrey, Becic, and Mayhuh (2007) used a lead time of 2.12 seconds and Gray (2011) used a lead time of 3 seconds. Providing the warning sooner would give participants more time to avoid the collision situation though the tradeoff is that it might not be as ecologically valid. It is also worth noting that our scenarios may have been particularly difficult to avoid relative to some other simulator studies due to the deceleration rate of the lead vehicle. While not all studies report this information, some prior studies have reported using a lead vehicle deceleration rate of 6 m/s^2 (Ho, Reed, & Spence, 2007; Gray, 2011) and our rate was much faster. We used a vehicle deceleration rate of 13.41 m/s^2. This likely contributed to the high crash probabilities observed.

One finding the current investigation does make clear is that use of a consistent warning sound similar to the A1 warning resulted in the best collision avoidance response by all measures examined (e.g., EMRT, TTC, crashes). The current investigation also provides support for the idea that minor changes in alert characteristics (from A1 to A3) are unlikely to have dramatic negative performance consequences. No evidence was observed for a negative impact on a FCW sound switch in Condition 6 where the sound remained similar. However, since there was also little evidence of a negative effect in Condition 4 this observation must be interpreted with caution.

In conclusion, some additional evidence was obtained in the current investigation that there is reason to be concerned about the potential for negative transfer. However, the pattern of conditions that might yield it are complex and not entirely clear at present. Further work should examine the range of key sound parameters that can be changed without disrupting people’s general perception of a sound as a highly urgent signal. In other words, it may be most important that people recognize a sound as an urgent warning, regardless of exactly what the sound is. Better understanding of the range within these parameters that can be used to convey high urgency will ensure that drivers can respond appropriately to sounds intended to convey warnings rather than confuse them for less important types of signals.

Driver-Vehicle Interfaces for Advanced Crash Warning Systems: Research on Evaluation Methods and Warning Signals

Appendix D

Perceptual Space of a FCW: Additional Methods and Supplemental Report of Detailed Analyses

GMU Perceptual Space of a FCW

Additional Methods & Supplemental Report of Detailed Analyses

By

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Overview and Approach

A primary objective of the Crash Warning Interface Metrics (CWIM) program is to develop recommendations that facilitate effective driver vehicle interfaces (DVIs) that reduce crash risk among distracted drivers. GMU researchers have played a primary role in examining issues of auditory sound consistency and the potential for negative transfer when auditory warnings are inconsistent (see Lerner et al., 2011). The primary aim of the current series of investigations was to define and validate the parameters associated with key characteristics of a warning sound that enable the sound to be effectively perceived as representing a highly urgent collision warning. Toward this aim, three experiments were carried out to specifically examine the range of key parameters that result in a majority of listeners perceiving a given sound as an urgent collision warning.

First, a survey of existing forward collision warning (FCW) sounds currently in use in automobiles was conducted. An inventory of the sounds was compiled from this survey. From this inventory, as well as existing published guidelines (e.g., Campbell, Richard, James L. Brown, & MaCallum, 2007), a list of key parameters were developed and examined in six experiments.

Perceptual Space Sort Task

Urgency and Descriptions

Best urgency levels were calculated by averaging the best urgency levels for all participants and can be seen in Table 1.

Category	Best Urgency Level
Warnings	92.27
Alerts	71.27
Status	46.27
Social	18.87

Table 1. Average best urgency level by category.

Participants also provided descriptions as to why they grouped sounds into each category (i.e., on what traits or similarities). These descriptions were then summarized down to single descriptor words, with all repeated words removed and are listed in Table 2.

Category	Description
Warnings	Rapid, louder, longer, high pitched, attention-grabbing, consistent, fast, action-needed, frequent, obnoxious, immediate, persistent, different, annoying, alarming, urgent, quick.
Alerts	Longer, less loud, slower, middle pitch, high pitch, not too dangerous, urgent, frequent, not as high pitched, obvious, not too loud, persistent, staccoed, attention-grabbing, stands out, understandable, rapid, lower tone, high frequent, pitch range, not urgent, continuous, long enough.
Status	Repetitive, not critical, lower pitch, slow, not fast, lower key, seatbelt reminder, key left in ignition, lights on, door open, seatbelt reminder, slower, medium pitch, something wrong, noticeable, not irritating, ignorable, alerting, high pitch, drawn out, not loud, not long, attention-grabbing, common sound, not drastic, slow, email sound, long sound, repetitive, does not require action.
Social	Unimportant, short, not distracting, slowest, medium pitch, melodic, short, brief, not important, ringtone, pleasant, one-time, not frightening, not distracting, simple, mellow, harmonious, least drastic, noticeable, unusual, non-alarming, party sound, fun, attention-demanding, not important.

Table 2. Descriptor words used by participants for each category.

Prototypes

The prototypes given for the Perceptual Space Sort Task were quite variable see Table 3. One specific sound, the only sound which met all of our criteria, stood out as the sound which was most likely to be the prototypical warning sound. However, for the other categories, the use of a prototype section yielded a large variation in the type of sound considered to be prototypical of that category.

Category	Number of "Prototypical" Sounds
Warning	5
Alert	14
Status	12
Social	4

Table 3. Number of sounds listed as the prototypical sound for each category.

Validation Sort Task

Urgency and Descriptions

Best urgency levels were calculated by averaging the best urgency levels for all participants and can be seen in Table 4.

Category	Best Urgency Level
Warnings	91.43
Alerts	70.86
Status	40.36
Social	13.21

Table 4. Average best urgency level by category.

Participants also provided descriptions as to why they grouped sounds into each category (ie. on what traits or similarities). These descriptions were then summarized down to single descriptor words, with all repeated words removed and are listed in Table 5.

Category	Description
Warnings	Urgent, important, high pitched, repetitive, jarring, dangerous situation,faster pulses, warning, unpleasant, loud, fast, sharp, piercing, attention-grabbing, harsh, annoying, alarming, distracting, quick.
Alerts	Attention-grabbing, important, moderate urgency, less intense, threatening, less offensive, less demanding, repetitive, middle urgency, urgent, not too unpleasant, fast, high pitch, close together tones, slower, sharp, piercing, lower in pitch, harsh, less attention-grabbing, less urgent, medium speed, medium beeps, quick, less harsh.
Status	Important, less urgent, varying frequency and pitch, non-threatening, slow, short, not intrusive, less urgent, singular, non-repeating, short, slow, calm, similar to current status signals, not as relaxed, important, spaced out, high pitched, quick, noticeable, not unpleasant, pleasant, gentle reminder, something is going on, common, no seatbelt, quick, short, gentle, attention-grabbing.
Social	Similar to social media, pleasant, musical, chime-y, semi-pleasant, least urgent, simple, notification, no interval, no loop, melodic, lower frequency and pitch, not urgent, relaxed, brief, not distracting, not attention-grabbing, not annoying, short, ignorable, non-urgent, telephone, not harsh, briefly attention-grabbing.

Table 5. Descriptor words used by participants for each category.

Prototypes

The variation seen in the first sort task was greatly increased when looking at prototypes used for the second sort experiment see Table 6. The addition of more sounds which met all criteria caused a much larger variation in the likelihood of a participant to list a given sound as a prototype.

Category	Number of "Prototypical" Sounds
Warning	11
Alert	14
Status	8
Social	5

Table 6. Number of sounds listed as the prototypical sound for each category.

Rapid Categorization Under Divided Attention

Urgency and Descriptions

Best urgency levels were calculated by averaging the best urgency levels for all participants and can be seen in Table 7.

Category	Best Urgency Level
Alarms	84.67
Status	44.52
Social	16.57

Table 7. Average best urgency level by category.

Participants also provided descriptions as to why they grouped sounds into each category (ie. on what traits or similarities). These descriptions were then summarized down to single descriptor words, with all repeated words removed and are listed in Table 8.

Category	Description
Alarms	High pitch, fast tempo, noticeable, high intensity, fast, repetitive, blaring, high frequency, loud, annoying, attention-grabbing, faster, louder, staccato bursts, static beat, high urgency, shrill, longer, hard to ignore, faster tempo, urgent, short interval, strong timbre, disturbing, salient, alerting, annoying, grating, obnoxious, hard to ignore, aggressive, harsh.
Status	Moderate tempo, high pitch, warning sound, longer duration, less frequent, lower pitch, softer, starting a car, changing beat, less long-lasting, ignorable, quicker, slow tempo, repetitive, not overly annoying, pleasant, attention-grabbing, not urgent, medium frequency, low sound, not as urgent, something needs to be checked, longer interval, calm, soft timbre, important, not that important, slower, backup system, seatbelt sound, car status sounds, familiar, not intrusive, alarming, not pressing.
Social	One individual sound, low pitch, short melody, calming, not too low frequency, high pitched, don't convey urgency, notification, mellow, emails or text messages, social networking, videogames or computer sound effects, low salience, low pitched, very short, not distracting, familiar, soft, slow, short duration, phone sounds, not urgent, singular sound, pleasant, less urgent, requires less attention, melody, simple, not confusing, musical, not offensive.

Table 8. Descriptor words used by participants for each category.

Additional Social Classification

As we did not specifically attempt to design many sounds that would be considered "Social", these results are somewhat less clear. A backwards stepwise regression of the data from the rapid categorization task indicates that the most important factors for "Social" categorization are Onset, Burst

Duration, Total On Time (the amount of time that sound is playing) and IPI (a normal linear regression indicates an R of .943, Adj R^2 = .868 with all factors being significant, $p < .005$). When these factors are reloaded into a stepwise regression, predicting Social categorization during the drive, Onset is the first coefficient followed by Burst Duration, Total On Time and ending with IPI (R = .711, .766, .911 and .943 respectively). Using these criteria the following cutoffs were arbitrarily set, Table 9.

Criteria	Cutoff
Onset	≥ 30 ms
Burst Duration	≥ 200 ms
Total On Time	≤ 500 ms
IPI	0, or ≥ 125

Table 9. Criteria and cutoffs for social notification classification

Using these criteria and cutoffs in order the following averages for Social sound criteria can be obtained, Figure 1.

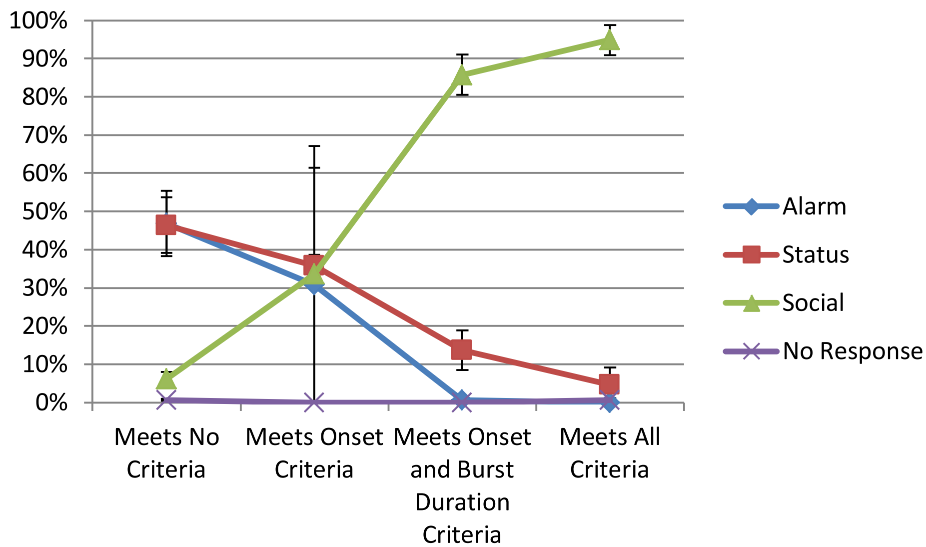

Figure 1. Percentage categorization by criteria met during the Rapid Categorization while driving

Using the same categories and cutoffs, averages were calculated for data from the sort task portion of the Rapid Categorization task.

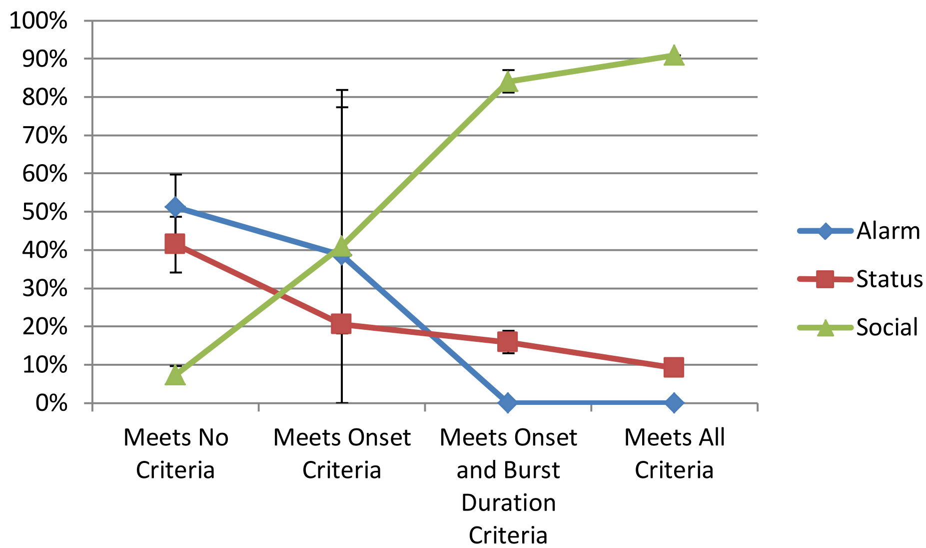

Figure 2. Percentage categorization by criteria met during the sort task segment of the Rapid Categorization task.

Finally, average response times for each category were calculated.

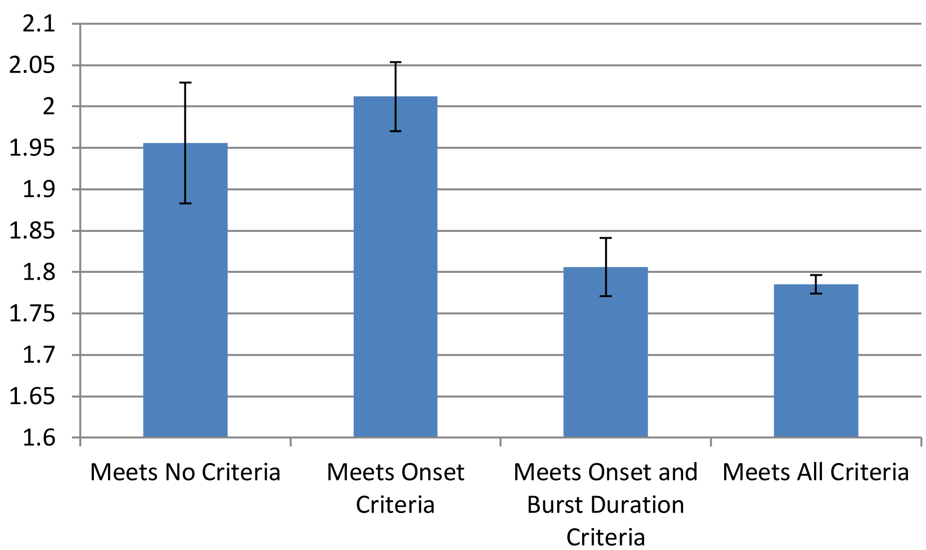

Figure 3 indicates that sounds which met no criteria or only Onset criteria were responded to slower than sounds which met Onset and Burst Duration criteria or all criteria. This may indicate that subjects found it harder to make a decision about sounds which did not meet criteria for inclusion as a social sound.

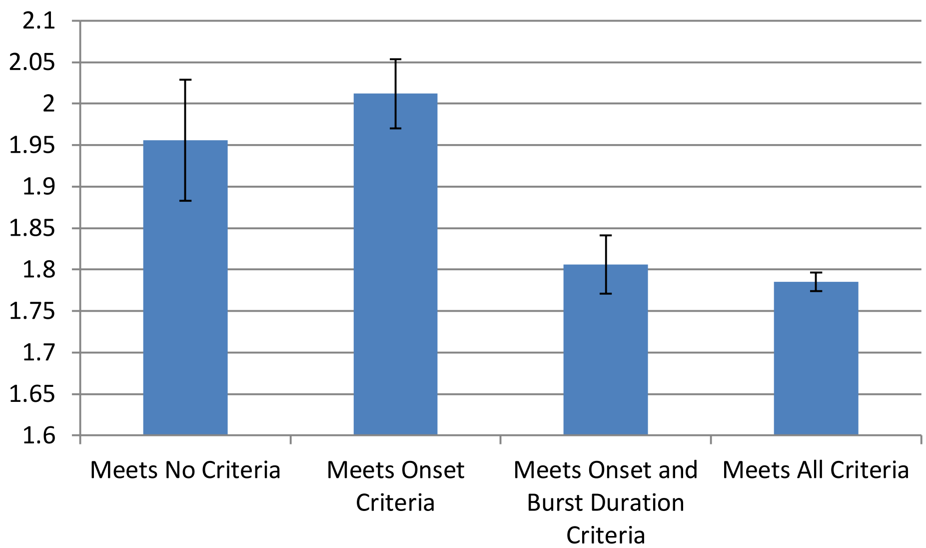

Figure 3. Response time by criteria met.

Only No Criteria and Meets Onset Criteria showed significantly different response times, though this is likely due to unequally sized categories, shown in Table 10.

Category	n
Meets No Criteria	18
Meets Onset Criteria	2
Meets Onset and Burst Duration Criteria	4
Meets All Criteria	2

Table 10. Number of sounds in each category

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Driver-Vehicle Interfaces for Advanced Crash Warning Systems: Research on Evaluation Methods and Warning Signals

Appendix E

Driving Simulator Results for Research on the Safety Implications Of Psychological Refractory Period For Advance Collision Warning System and Early Safety-Related Alerts

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LIST OF FIGURES

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REVISION HISTORY

Version	Date	Notes
DRI-TR-13-01	2013-01-25	First draft
DRI-TR-13-01-1	2013-03-05	Revised per comment from Westat and John Lee. Changed terminologies for the various objective measures. Moved secondary results to Appendix E.
DRI-TR-13-01-2	2013-05-01	Responded to NHTSA comments

ABBREVIATIONS USED IN THIS DOCUMENT

ACWS	Advanced Collision Warning System
CWIM	Crash Warning Interface Metrics
DRI	Dynamic Research, Inc.
DVI	Driver Vehicle Interface
LV	Lead Vehicle
NADS	National Advanced Driving Simulator
NHTSA	National Highway Traffic Safety Administration
PRP	Psychological Refractory Period
RA	Research Assistant
SOA	Stimulus Onset Asynchrony
SV	Subject Vehicle
TTC	Time to Collision

1. INTRODUCTION

With the rise of in-vehicle technologies becoming more popular, vehicles are now being equipped with various warning systems, safety features, and entertainment systems. Although the design of each system is taken into consideration to ensure each performs as intended, little research addresses the integration of these systems and how they may affect the driver's intended response. Time-critical or urgent systems such as those designed to avoid collisions, lane departures, and other potentially critical situations may be in competition of less urgent systems such as those designed for entertainment purposes. If tasks share the same perceptual and response mode, then resource competition is greater. Therefore, two auditory alerts have greater resource competition than systems that differ in perceptual mode, such as an auditory alert and a haptic alert (Wickens 1984, 2002, Haigney and Westerman 2001)[1]. Just as important is the coordination and timing of alerts and how one might affect the driver's response time to another. Wiese and Lee (2004) addressed the issue Psychological Refractory Period or PRP effect, which refers to the delayed response a person has to a second stimulus when the period between it and an initial stimulus is close in time or temporal proximity. Wiese and Lee performed two studies where they varied the onset time between two alerts to examine which of the two times caused less temporal conflict and had less of an effect on the driver's performance. They hypothesized that a less urgent event (and auditory email message alert) would interfere with a more urgent alert (auditory collision avoidance alert). In their first study, Wise and Lee triggered an email alert 300 ms before a collision warning alert and found that the email alert interfered with driver's response to the collision warnings. These also support more recent findings from research by Hibberd, et al. (2013) which found that when participant drivers were given a two-choice response in-vehicle task where they had to discriminate between two stimulus pairs, and a critical lead vehicle braking event, the in-vehicle task had a negative effect (slower reaction times) on driver braking when presented prior to 350 ms. However, in the second study, Wiese and Lee triggered an email alert at 1000 ms and found the opposite effect had occurred; the onset of the email alert enhanced that response to the collision warning by improving the braking process and inducing a faster accelerator pedal release.

A later study by Levy, Pashler, and Boer (2006) tested predictions of the central bottleneck hypothesis, which applies when the information processing stage of response selection limits dual-task performance by acting as a bottleneck, and predictions of hypotheses about interference from common stimulus and response modalities. Participants in the 2006 study were asked to perform two tasks simultaneously while performing a simulated driving task. A choice task was used where participants responded either manually or vocally to the number of times an auditory or visual stimulus occurred. The participants were asked to brake as soon as they observed the lead vehicle brake lights came on. The Stimulus Onset Asynchrony, or SOA, which is the time between the onset of the task stimuli varied between 150, 350, and 1200 ms. Although the choice task was considered to be an easy task, it still suffered from dual-task interference. Reaction times at 0 to 350 ms SOA produced a braking delay of more than 16 ft for a vehicle traveling at 65 mph. Brake reaction times increased as the SOA was reduced which showed signs of PRP effect. However, contrasting the Wiese and Lee study, the 1200 ms SOA participants had slower brake reaction times than those with 350 ms SOA but not slower than

[1] As sited by Wiese and Lee (2004).

those with 0 or 150 ms SOA. This may be due to the fact that participants were less prepared to brake having gotten used to shorter SOAs.

Similar studies have examined the effects of a secondary task or distraction tasks and its effects on driver braking reaction times by varying the SOA. A series of studies by Lee, et al. (2002), varied the initial headway of the participant vehicle to a lead vehicle, initial forward speed, and different levels of rear-end collision avoidance system alerts. In the first study of the series, a rear-end collision avoidance system was triggered at three different alert algorithms, none, late, and early detection. Results showed that early alert provided the greatest benefit and influenced how quickly drivers released the accelerator pedal allowing drivers to brake more gradually.

The overall goal of the present study was to evaluate various onset time intervals between less urgent safety-related alerts and an Advanced Collision Warning System (ACWS) to more fully define the magnitude of the Psychological Refractory Period. It also had the objective to determine if the results may be similar to those in past studies such as those found in the first study by Wise and Lee, and study by Hibberd where shorter SOA times resulted in slower brake reaction times. In contrast, longer SOA times (1000 ms) will result in brake reaction times that are not negatively affected by Early Alerts. Safety-related Early Alerts include non-verbal (tonal) and verbal auditory alerts. In addition, the study hoped to determine if there would be similar results as those found past research where alerts with similar perceptual modes will interfere with one another more than alerts with different perceptual modes (Wickens 1984, 2002, Haigney and Westerman 2001). In other words, pairing Haptic FCW alert events with auditory Early Alerts (both tonal and verbal) may result in quicker braking times than when Auditory FCW alert events are paired with auditory Early Alerts.

The overall test plan was to study driver performance and behavior in potentially risky scenarios in a safe, repeatable, and controlled environment, using the Dynamic Research, Inc. (DRI) Motion Base Driving Simulator. The DRI Driving Simulator is a dynamically realistic, moving base, “driver-in-the-loop” device.

Descriptions of the driving simulator setup, test plan, driving events experienced by the driver participants, and the driver/vehicle data collected can be found in Section 2. A total of 36 driver participants were included in this study. Participants were not be aware of the main purpose of the study but were instead told they are going to be evaluating their comprehension and preferences to a set of signals and alerts. Participants were divided into two groups and experienced a variety of critical and non-critical events through two evaluation drives. This study used a 2 x 2 x 3 mixed factorial design with the Early Alert type as the between subjects variable, and the FCW type and SOA timings as the within subjects variables. The order in which conditions were presented were determined by the group in which each participant was randomly placed in. Objective data and subjective ratings were collected and analyzed for each scenario. The list of driver participant instructions and descriptions of the rating forms are included in Appendix B.

2. EXPERIMENTAL SETUP PROCEDURES

2.1 INSTITUTIONAL REVIEW BOARD

This study was accomplished with the review, approval, and oversight of the DRI Institutional Review Board (IRB). This includes a review of the test plan, protocols, IRB Information Packet (Appendices A and B), and other procedures undertaken to ensure the safety and well-being of the participants (DRI-TM-08-46-1, 2009).

The DRI IRB has been established according to the guidelines of the Department of Health and Human Services (DHHS) Office for Human Research Protections, DHHS Registration No. 00006962.

2.2. PARTICIPANTS

A total of 36 typical drivers were included in this evaluation, 18 males and 18 females participated. Participant drivers were between the ages of 35 to 55 years old with an average age of 44. Although participants were randomly assigned to one of two groups, participants in group 1 were slightly younger (43) than participants in group 2 (46). Participants that were recruited had a minimum of 10,000 miles of driving per year and a valid California driver's license for at least two years. They also had corrected 20/40 vision, were not color blind, had to be able to hear all alerts, and did not have any other limitations that impaired their driving. Participants who failed to complete the study or who were eliminated for any of the reasons summarized in Appendix D, were replaced in order to complete the dataset with 36 total participants. Table 1 summarizes participants' age and group assignment.

Table 1. Participants Summary

Group	Mean Age	SD Age	Males	Females
1	42.83	4.90	9	9
2	46.06	6.60	9	9
Overall	44.44	5.96	18	18

2.3 DRIVING SIMULATOR

The DRI Motion Base Driving Simulator was used to accomplish the driving evaluations (Figure 1). The DRI Driving Simulator is a research grade motion base Driving Simulator. It is a dynamically realistic, moving base with 6 degree of freedom hexapod motion system, "driver-in-the-loop" research device. It has a 180 deg forward field of view, a fully instrumented cab with a control force steering loader, and surround-sound audio system where the speakers are located against the right and left A-pillars of the cab (Figure 1). Cameras were mounted to record the steering by the driver, the forward view of the simulator roadway, the overhead view of the simulator roadway, and the foot movements of the participant while driving.

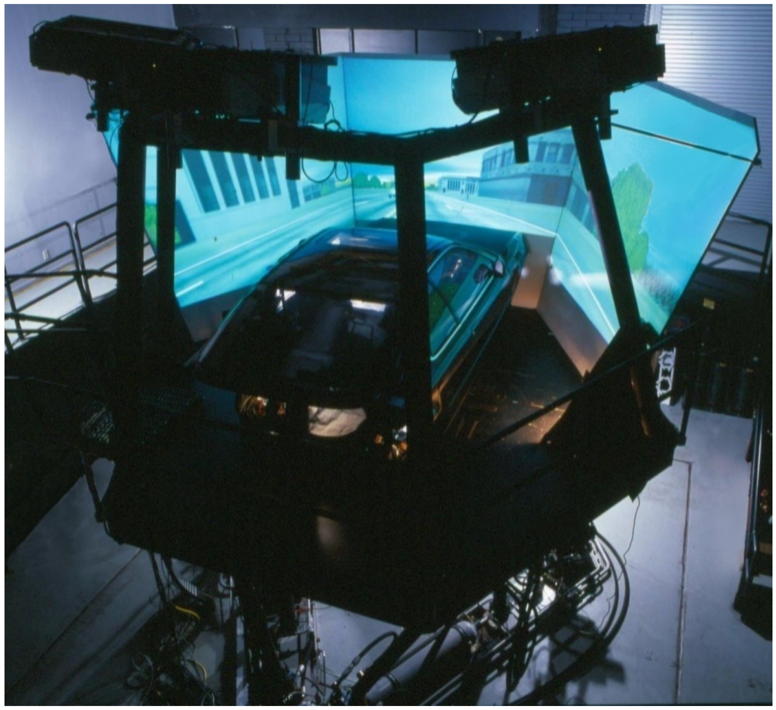

Figure 1. DRI Motion Based Simulator

2.4 INDEPENDENT VARIABLES

The objective of this study was to evaluate various onset time intervals between less urgent safety-related alerts and an ACWS to more fully define the magnitude of the PRP using the following independent variables.

- Lead vehicle braking events (2 types)
- Stimulus Onset Asynchrony (SOA) times (3 intervals)
- Early alerts (2 alert types)
- Forward Collision Warnings (FCW) (2 configurations)

Independent variable descriptions are listed below. The current study used similar variables as those used by other CWIM teams in order to form consistency.

2.4.1 Forward Collision Warning (FCW)

The following FCW alert modes were adopted from the previous CWIM National Advanced Driving Simulator (NADS) study conducted for NHTSA in 2011:

- Auditory FCW Alert: A pulsing tone from with a period of 400 ms, a 50% duty cycle, and a total length of four sec. Approximate peak values between 70-75 dB(A).

- Haptic FCW Alert: A simulated vehicle braking with a simulator platform moving back 4.8 in 0.2 sec and set back to zero in 0.2 sec.

The FCW alert was issued when the lead vehicle began the critical braking (see 2.4.4).

2.4.2 Early Alert (EA)

Two non-urgent Early Alert types were used. Early Alerts were defined as non-urgent safety related alerts that were presented prior to an FCW alert or on their own. Early Alerts included:

- Verbal: "Traffic Ahead", "Curve Ahead", and "Construction Ahead"
- Tonal: non-verbal tone (were used for all early alerts)

2.4.3 Stimulus Onset Asynchrony (SOA)

The following list of SOAs between the EA and the FCW were used in the current study:

- 150 ms
- 300 ms
- 1000 ms

The short intervals of 150 and 300 ms would provide possible better understanding of the interfering effects. Whereas the 1000 ms would provide confirmation of either no negative effect or benefit to the FCW response behavior.

2.4.4 Braking Tasks

Two different types of braking events were used as braking tasks.

1. Lead Vehicle Critical Braking Event

   The SV was traveling at approximately 55 mph on a straight and level road following a LV that was also traveling at 55 mph when the LV suddenly decelerated to 25 mph at a rate of 0.5G. Brake lights were not used when the LV slowed, in hopes to minimize early braking and failing to trigger the FCW (Figure 2).

Figure 2. Example Lead Vehicle Critical Braking Event

2. False Alarm Event

   The SV encountered a vehicle parked along the right shoulder (Figure 3). The FCW was triggered, but the stopped vehicle was not an actual threat to the SV. The SV could have simply continued driving in their current path.

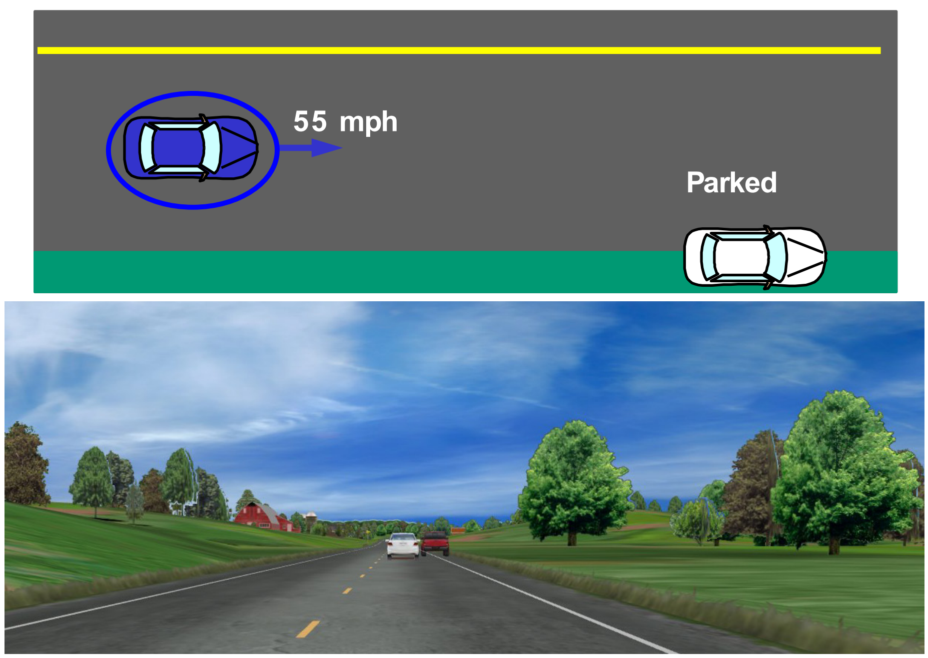

Figure 3. Example Stopped Vehicle Event

2.4.5 Headway Display Gauge

The headway distance or following distance to the LV was displayed using a simulated analog headway display located in the dashboard, which gave the driver feedback on how they should adjust their speed to meet the needs of the study (Figure 4). The Early Alert icon was also displayed on the instrument panel. The icon helped drivers identify Early Alerts for both the audio and tonal conditions. The FCW alert did not have an icon associated with it. Additional details are provided in Appendix C (Scenario Specification).

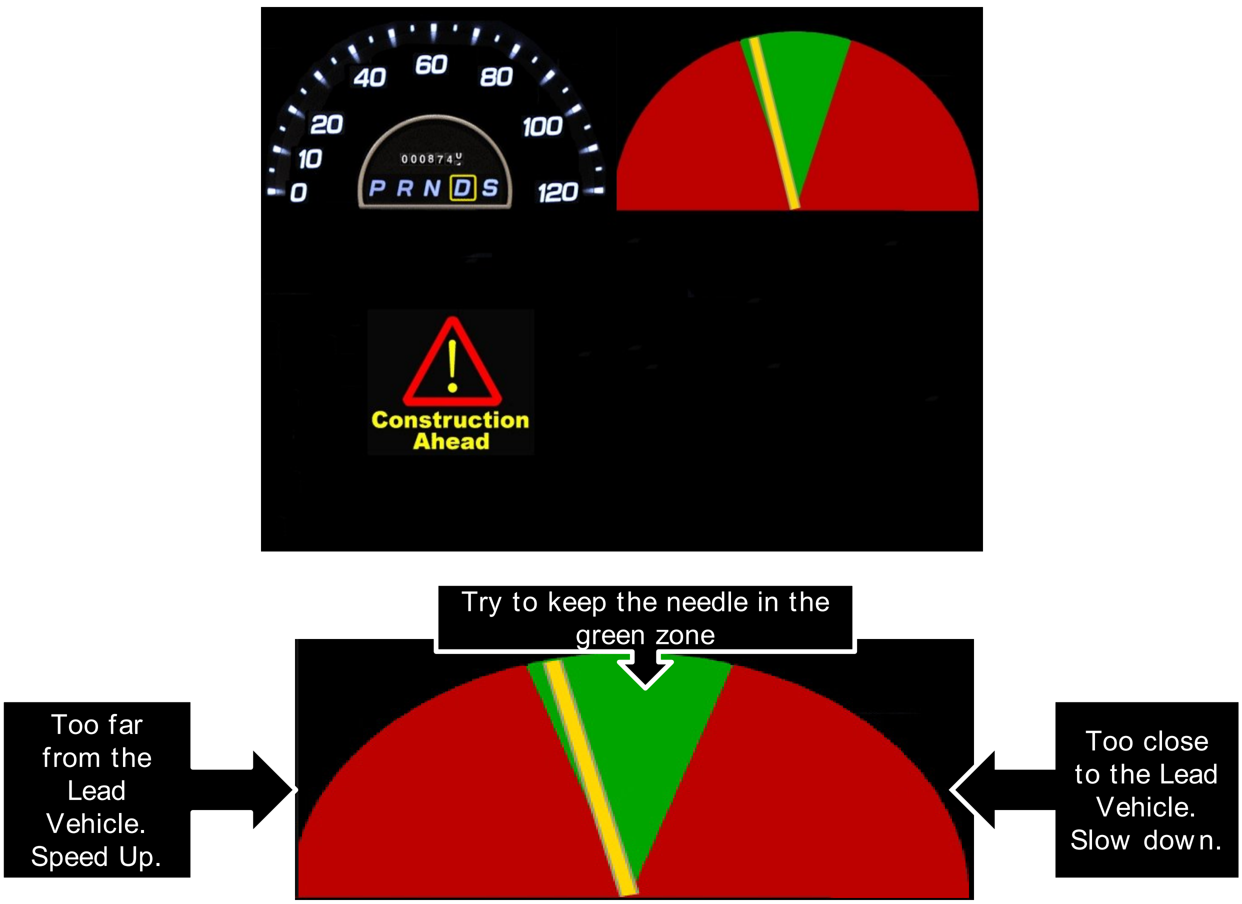

Figure 4. Headway Display Gauge (Upper Right)

2.5 TEST PLAN

The driving simulator evaluation varied FCW DVI modality (auditory, haptic) across blocks of trials. The experimental design also varied the interval between the early alerts and FCW onset within subjects. Whereas, the experimental design varied the early alert type or mode (verbal, tonal) between subjects.

A total of 36 driver participants were included in the driving simulator evaluation. The order of the early and FCW alerts were counterbalanced with the braking events in order to minimize learning effects. Null braking events and alerts were included in order to minimize an association of braking events paired with a particular alert type. Participants were randomly assigned to one of the two main Early Alert Type groups (Verbal and Tonal) with 18 participants per group (Figure 5). A within-subjects experimental design was used in each of the Alert Types. With 2 FCW (auditory and haptic) conditions and 3 SOA intervals, resulting in 6 counterbalanced configurations within each early Alert Type group. The Baseline (Auditory FCW or Haptic FCW without any Early Alerts) was always experienced by the participants as the first condition, and with 3 participants per configuration (3 participants x 6 counterbalance configurations x 2 Early Alert Types = 36 participants). Table 2 summarizes the order of the blocks in which configurations were presented depending on the Alert Type group assignment.

Table 2. Participant Groups

Group 1	Verbal Early Alert Type by order of presentation							
	Auditory FCW				Haptic FCW			
SOA	N/A (Baseline)	150 ms	300 ms	1000 ms	N/A (Baseline)	150 ms	300 ms	1000 ms
1A	1	2	3	4	5	6	7	8
1B	1	4	2	3	5	8	6	7
1C	1	3	4	2	5	7	8	6
1D	5	6	7	8	1	2	3	4
1E	5	8	6	7	1	4	2	3
1F	5	7	8	6	1	3	4	2

Group 2	Tonal Early Alert Type by order of presentation							
	Auditory FCW				Haptic FCW			
SOA	N/A (Baseline)	150 ms	300 ms	1000 ms	N/A (Baseline)	150 ms	300 ms	1000 ms
2A	1	2	3	4	5	6	7	8
2B	1	4	2	3	5	8	6	7
2C	1	3	4	2	5	7	8	6
2D	5	6	7	8	1	2	3	4
2E	5	8	6	7	1	4	2	3
2F	5	7	8	6	1	3	4	2

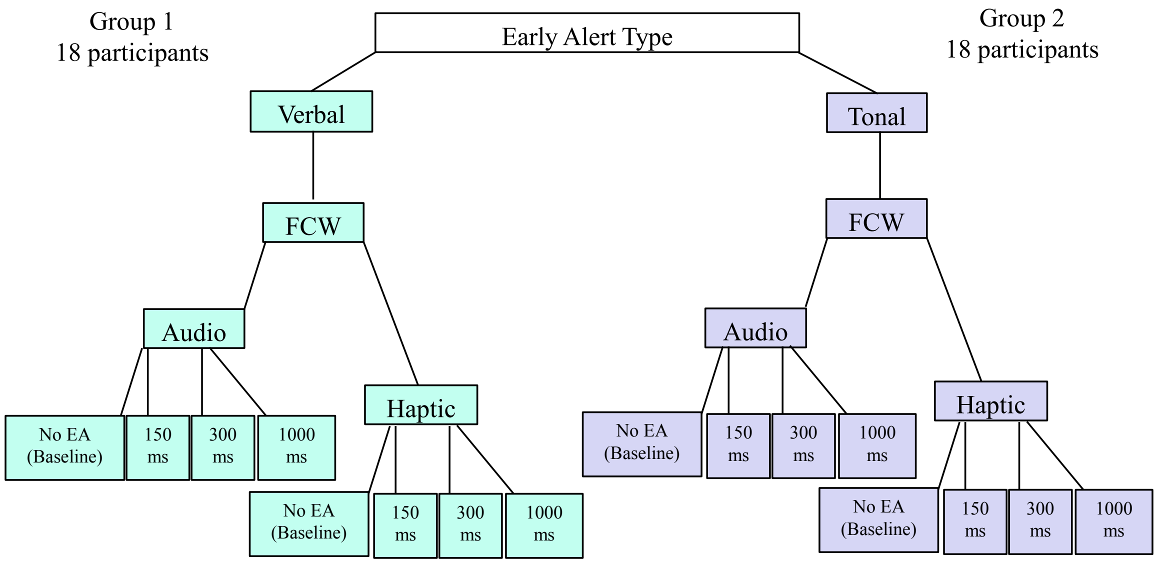

Figure 5. Group Breakdown Details

In addition, each participant drove a warm-up road, which lasted 15 min, to become familiar with the driving simulator before driving the actual road. Specific road conditions depended on group assignments.

2.6 SECONDARY TASKS

Three different types of secondary tasks were used in the current study. These tasks were used to try to mask the true purpose of the study. The tasks included a number recall task, a CD task, and trivia task. Additional details about each distractor task are found in Appendix C.

The number recall task required that participants verbally repeat a sequence of five digits displayed on an LCD screen mounted in the center console to the right of the driver seat. A total of four different 5 digit sequences were used.

The CD task required that participants select a CD from a group of 4 CDs located in the driver's overhead sun visor, place it in the radio, and advance to a particular track. Participants would hear an audio instruction to begin the task and what CD/track they should be looking for. The task was not over until the participant heard the first few seconds of the correct track, ejected the CD, and placed it back in the overhead sun visor.

The trivia task required that the participant driver respond to a trivia question, which was verbally given by the simulator scenario control computer. Participants were asked to respond by pointing to the answer they felt was correct.

2.7 DATA COLLECTION

2.7.1 Objective Data

The objective simulator data collected was saved in an ASCII text format, which made it easy to manipulate using MATLAB, SPSS, or Excel. Objective data collected by the Driving Simulator was recorded at 25 samples per sec and included:

- Subject and lead vehicle forward speed
- X and y position
- Lateral lane position
- Longitudinal acceleration
- Lateral acceleration
- Yaw rate
- Path angle
- Steering wheel angle
- Steering wheel torque
- Accelerator pedal position
- Brake pedal pressure
- Headway distance to lead vehicle
- Event Channel
- Lead Vehicle Braking Task
- Accelerator Reaction Time
- Braking Movement Time
- Warning Type
- Time-To-Collision
- Relative Velocity at Collision

In-cab video recordings (Figure 6) were also collected to include the participant's face, forward view, accelerator and brake pedals, steering wheel, and overhead view of the road environment.

Figure 6. Sample Video Recording Setup

2.7.2 Subjective Data

Subjective ratings were collected at the end of each. Subjective measures included the following:

- Ease of Performing the Driving Task
- Sense of Discomfort (or Risk) Performing the Primary Driving Task
- Ease of Performing the Secondary Entry Task
- Overall Mental Workload
- Appropriateness of alert

All subjective data was compiled into an Excel worksheet and analyzed. The definitions of each of the rating questions are as included in Appendix B.

2.7.3 Eye Glance Data

Eye glance behavior data was attained using video reduction techniques. Data reduction specifications included areas (Figure 7) of interest (e.g., forward roadway, instrument panel, etc.) and time sample durations.

For number recall events, coding started 2 sec after the instruction "number recall" was given, and ended after the last digit on the LCD monitor was displayed.

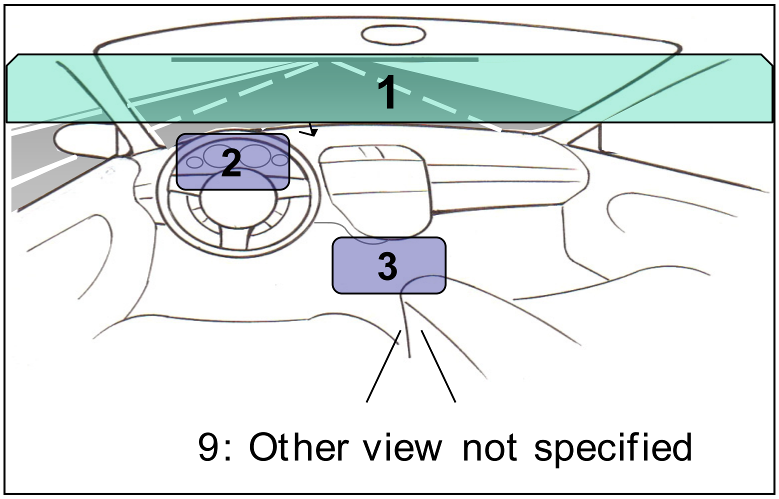

Figure 7. Eye Glance Areas of Interest

3. RESULTS

3.1. OBJECTIVE RESULTS

3.1.1 Measures

The performance measures included the following:

- Accelerator Reaction time, which was defined as the time in which the lead vehicle started braking to when the participant responded to the event by releasing their foot from the accelerator pedal. An Accelerator Reaction was defined as anything less than 1% throttle position movement.
- Accelerator to Brake Movement time, which was defined as the time it took the participant's foot to go from the released accelerator pedal to the brake pedal. A brake press was defined as anything greater than 1.0 kgf in brake pressure.
- Total Response time, which was defined as the start of the lead vehicle braking event to the end of Movement.
- Max Brake Movement time, which was defined as the time it took the participant to go from start of braking to maximum braking.
- Distance, which was defined as the minimum distance between the SV and the LV.

Figure 8 outlines each performance measure by time.

Figure 8 also lists the alerts and how they would interact with the various measures. Figure 8 depicts one possible event type in which the and FCW is combined with an SOA of 1000 ms. In this combination, the two alerts would not overlap but in an event in which and FCW is combined with a much shorter SOA, such as an SOA of 150 ms, the two variables would be overlapping one another in this figure.

Although five main performance measures were examined in this study, only two were of high importance to the study, Total Response time and Distance. The remaining 3 measures (Accelerator Reaction, Movement, and Brake Reaction time) were examined but are not included in the main body of this report; results of these remaining measures are contained in Appendix E.

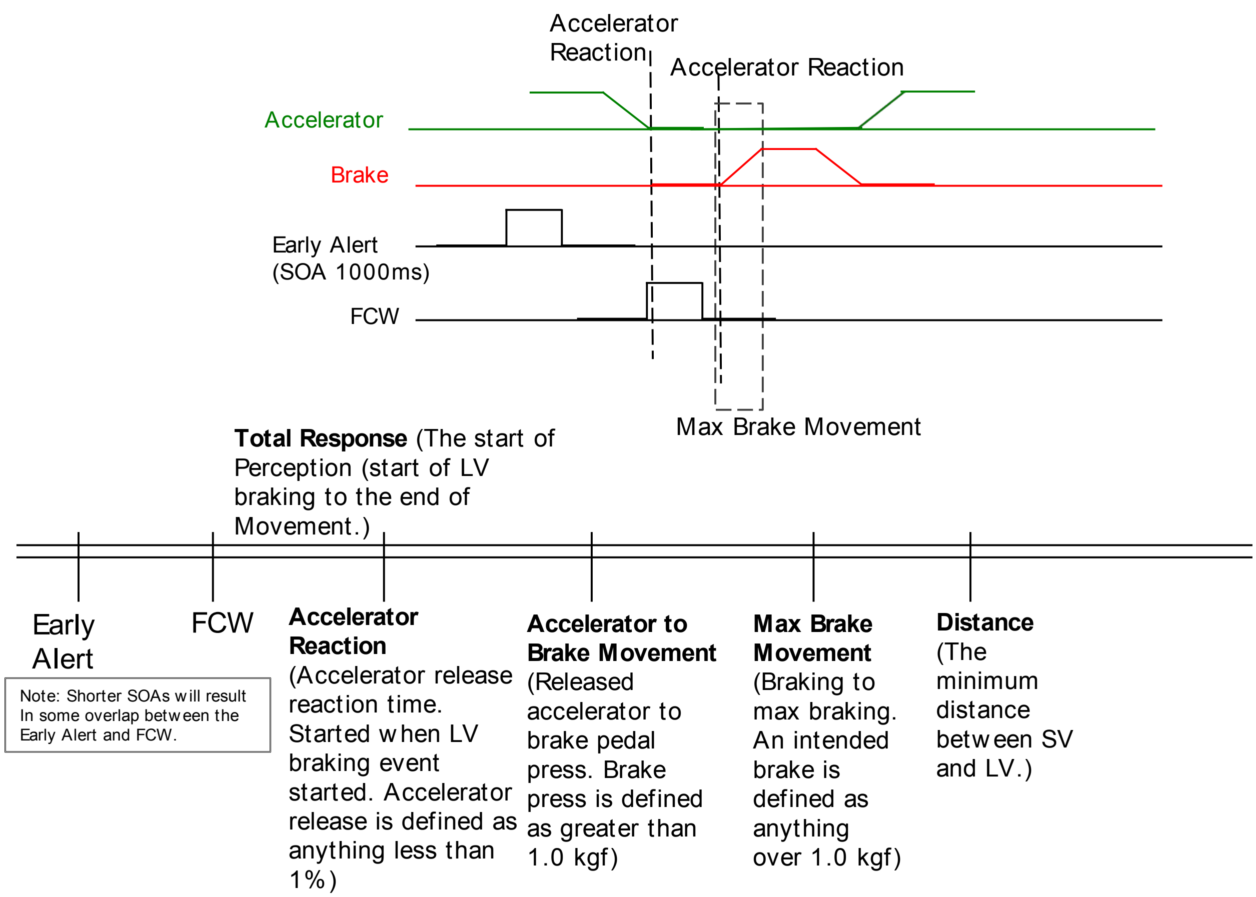

Figure 8. Timeline and Definitions of Measures

3.1.2 Data analysis

First the data was evaluated using a repeated measures ANOVA as a single dataset which revealed a few interesting interactions. Although these interactions were interesting, it was difficult to interpret the cause of these interactions. Therefore, the dataset was split by the between-subjects factor (Tonal and Verbal) before performing further data analysis. A one-way ANOVA was used to reveal any main effects between the two groups. Each group was also analyzed using a repeated measures analysis to determine whether there were any main effects or interactions within each group. A significant value of $p < 0.05$ with Greenhouse-Geisser Epsilon was used. Paired Sample T-tests were further performed to help possibly explain significances found in the previous analysis.

3.1.3 Comparison between Tonal and Verbal groups

There were significant main effects found when comparing Tonal and Verbal groups. The first main effect was an effect of Movement time ($p = 0.012$) where Verbal Early Alerts resulted in quicker Movement times. The second main effect was an effect of Distance ($p = 0.025$) where the Verbal Early Alerts resulted in longer minimum distances between the SV and LV. The last main effect between Tonal and Verbal was of Total Response time ($p = 0.002$) which resulted in shorter Total Response times for the Verbal Early Alert group.

3.1.4 Total Response Time

Table 3 summarizes the number of samples per event type. The missing values are due to early braking instances. The following graph summarizes the means and standard errors by event type.

Table 3. Total Response Time Count (N)

Total Response (Verbal)	N	Total Response (Tonal)	N
Audio FCW	18	Audio FCW	18
Haptic FCW	18	Haptic FCW	18
Audio FCW 150 ms	18	Audio FCW 150 ms	18
Audio FCW 300 ms	18	Audio FCW 300 ms	18
Audio FCW 1000 ms	18	Audio FCW 1000 ms	17
Haptic FCW 150 ms	17	Haptic FCW 150 ms	18
Haptic FCW 300 ms	18	Haptic FCW 300 ms	18
Haptic FCW 1000 ms	17	Haptic FCW 1000 ms	16
Max Number	18	Max Number	18

*Note: Missing Total Reaction Time data is due to early braking.

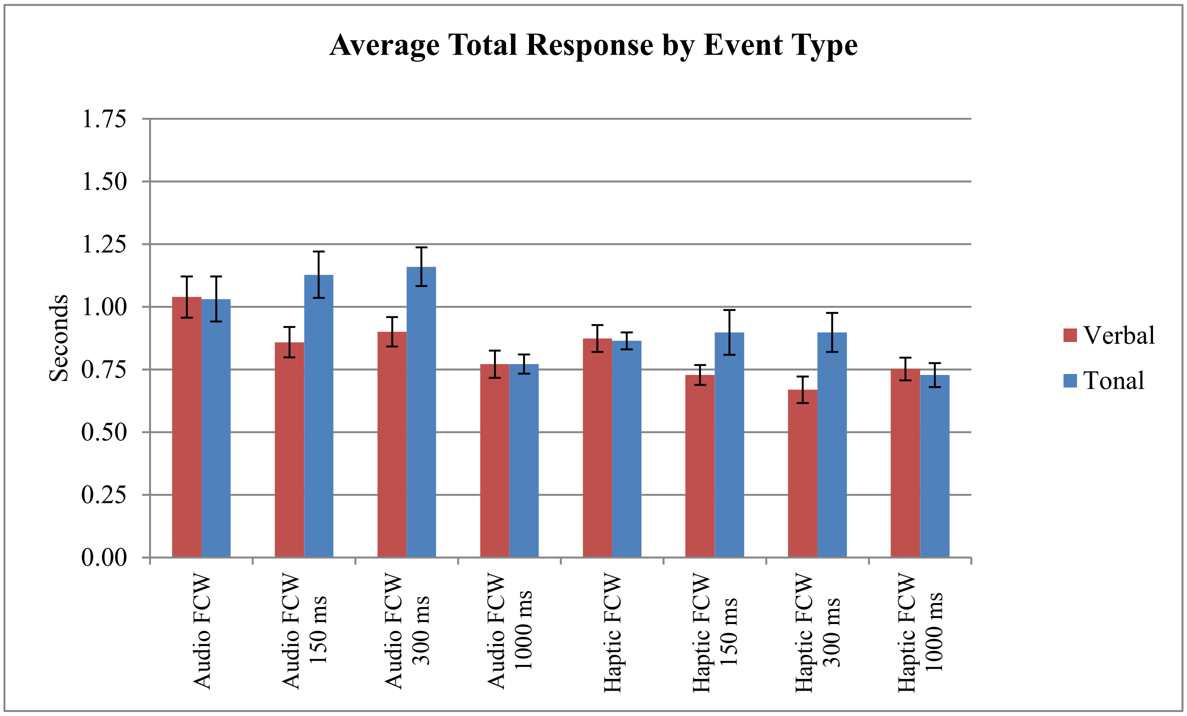

Figure 9. Total Response Time Means and Standard Errors

There was a significant difference for FCW (p = 0.006) in the Verbal Early Alert group where the haptic FCW alert events resulted in shorter Total Response times, compared to the Auditory FCW alert events. There was also a significant difference of SOA for the Verbal Early Alert group (p = 0.020) where having an Early Alert resulted in shorter Total Response times than the Baseline group with 1000 ms SOA having the shortest Total Response time.

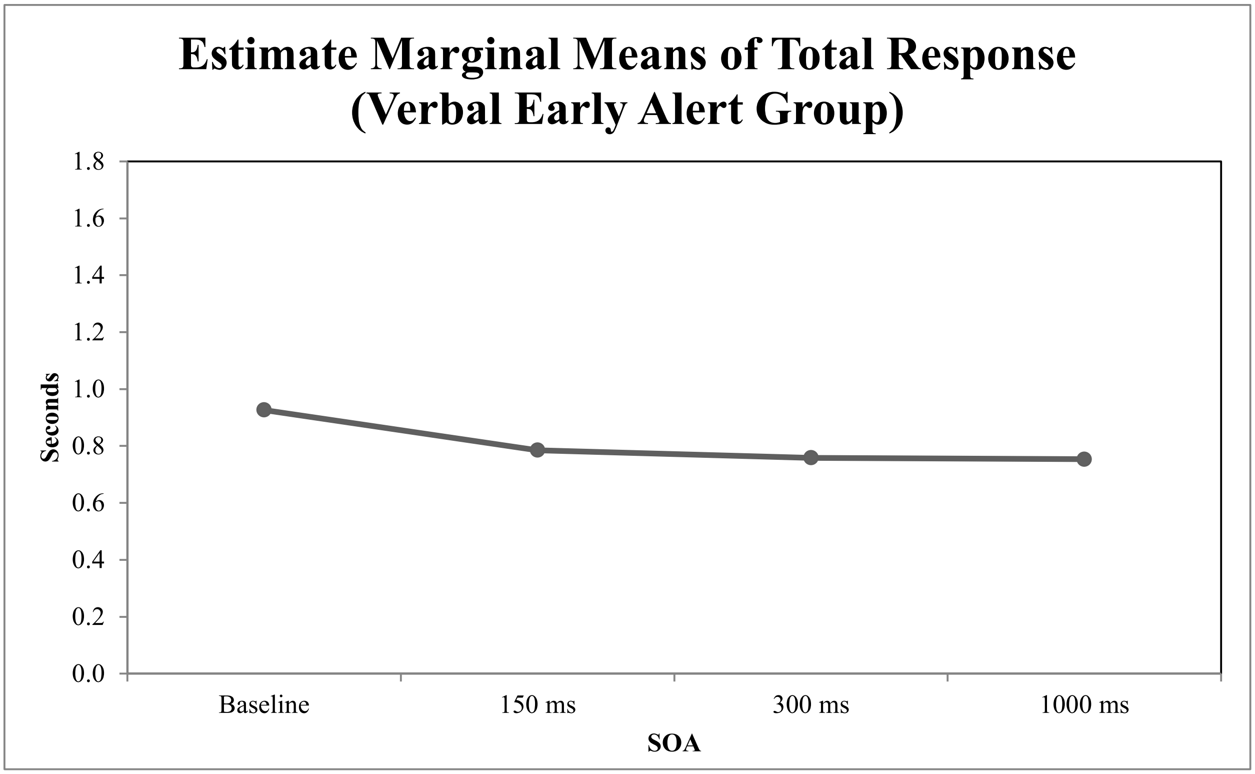

Figure 10. SOA Marginal Means for Total Response Time (Verbal Group)

Similar results were found in the Tonal Early Alert group. There was a marginally significant difference in FCW ($p = 0.045$) where Haptic FCW alert events resulted in shorter Total Response times, compared to the auditory FCW alert events. There was also a significant difference between the various SOA times. Having an SOA of 150 ms or 300 ms resulted in longer Total Response times, but having an SOA of 1000 ms resulted in the shortest Total Response times.

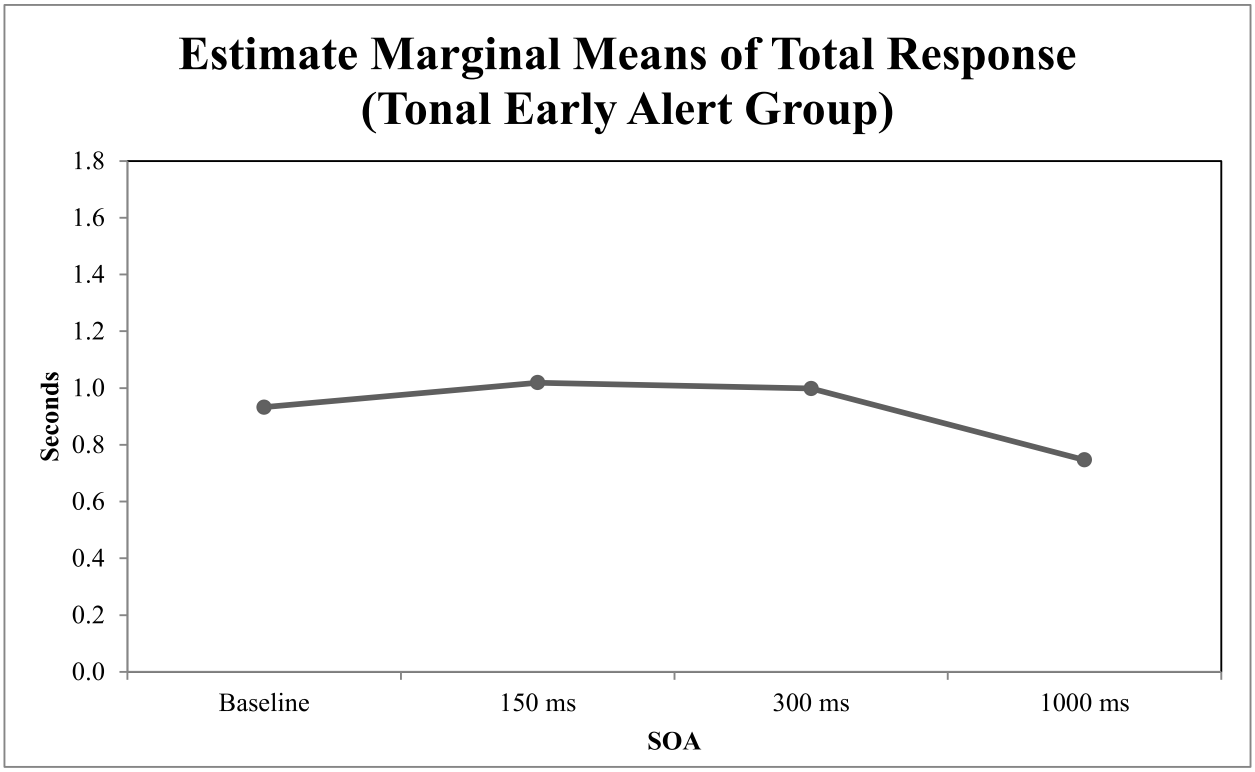

Figure 11. SOA Marginal Means for Total Response Time (Tonal Group)

For all participants, there was significant difference between Auditory and Haptic FCW on Total Response time ($p = 0.007$) such that Haptic FCW alerts produced shorter Total Response times. There was also a significant difference between SOA times ($p = 0.001$) whereas SOA increased, Total Response time decreased with a sharp decrease in 1000 ms SOA.

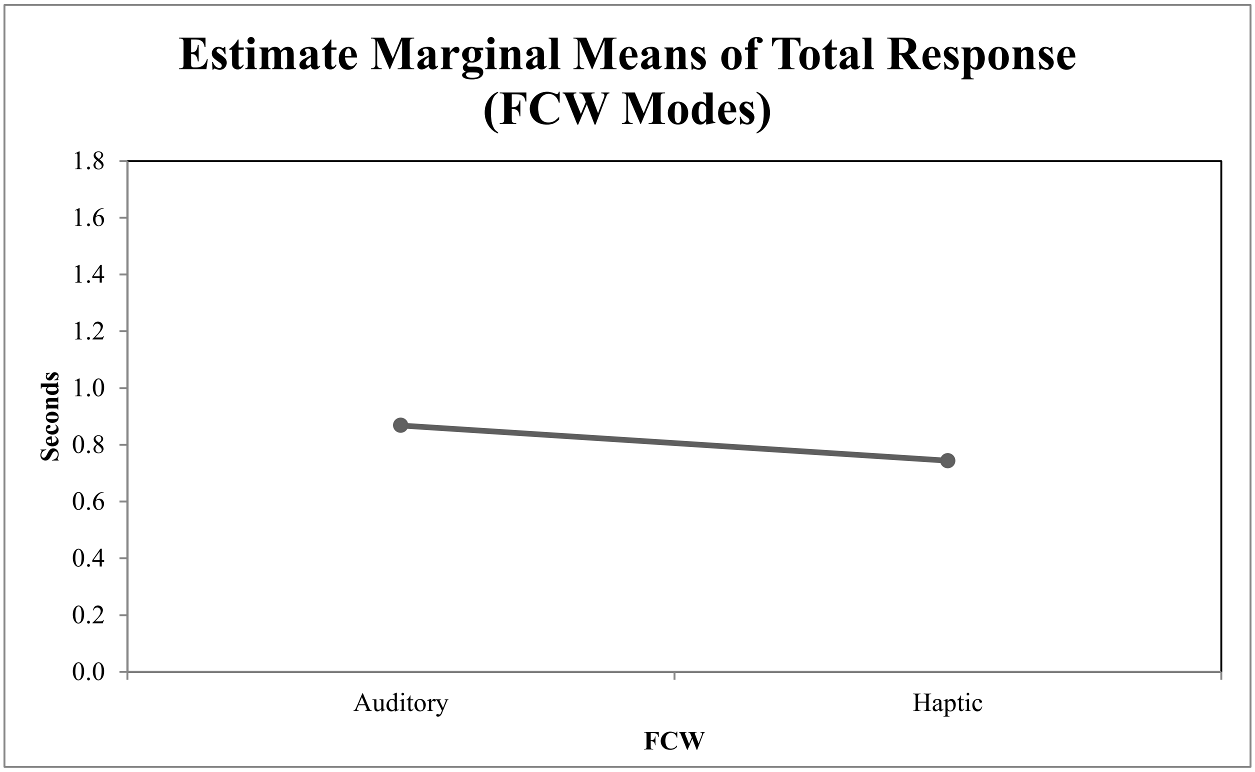

Figure 12. FCW Marginal Means for Total Response Time (All Participants)

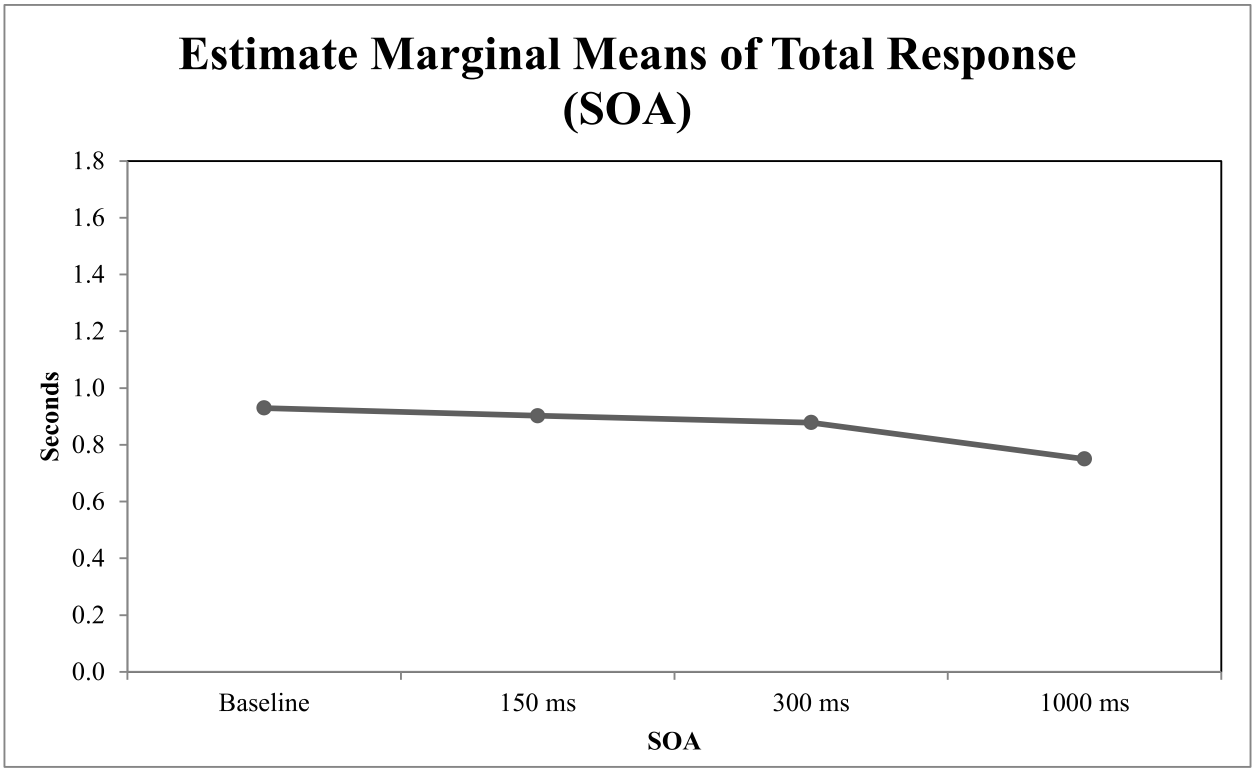

Figure 13. SOA Marginal Means for Total Response Time (All Participants)

There was an interaction between SOA and Early Alert type (p = 0.007) where for Tonal Early Alerts, as SOA increases, Total Response time decreases with a sharp decrease at 1000 ms. In contrast, for Verbal Early Alerts, as SOA increases, Total Response time decreased slightly. There was also a marginal interaction between FCW and SOA (p = 0.052) where for auditory FCW Total Response time had a sharp decrease at 1000 ms but for Haptic FCW Total Response time decreased slightly with every SOA increase.

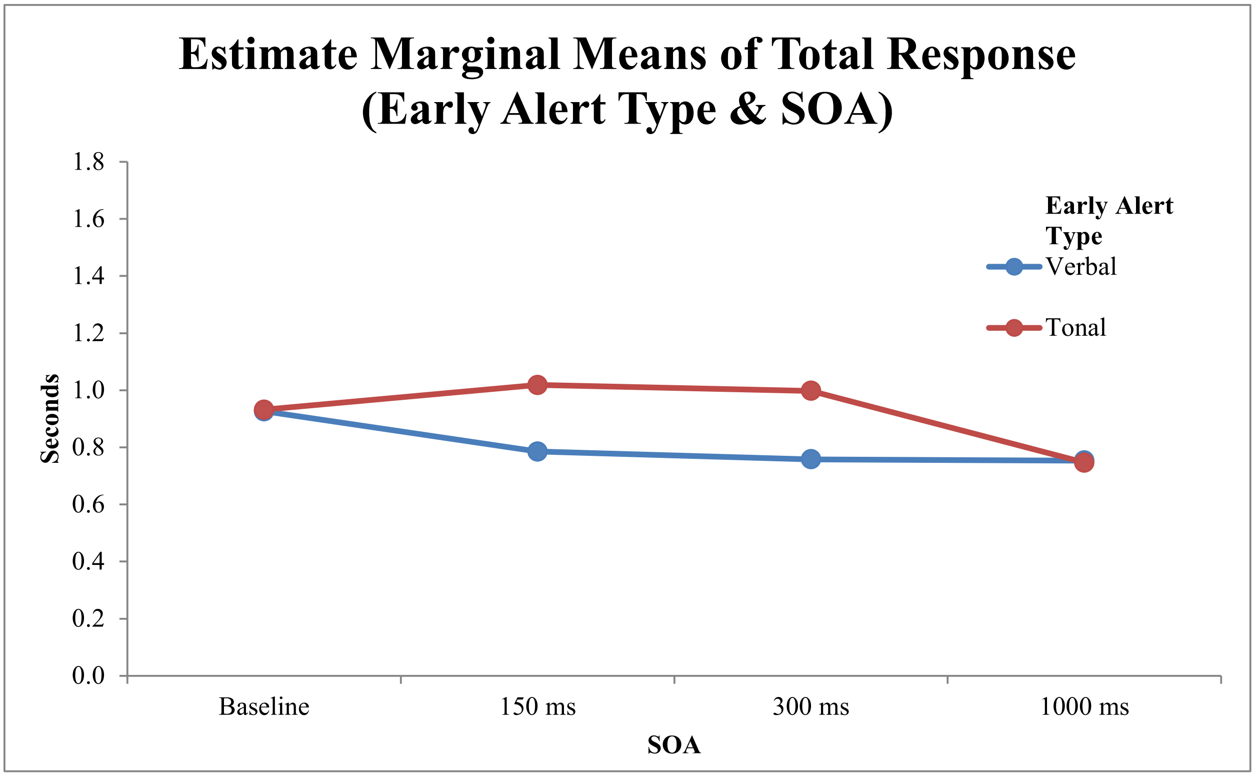

Figure 14. SOA and Early Alert Type Marginal Means for Total Response Time

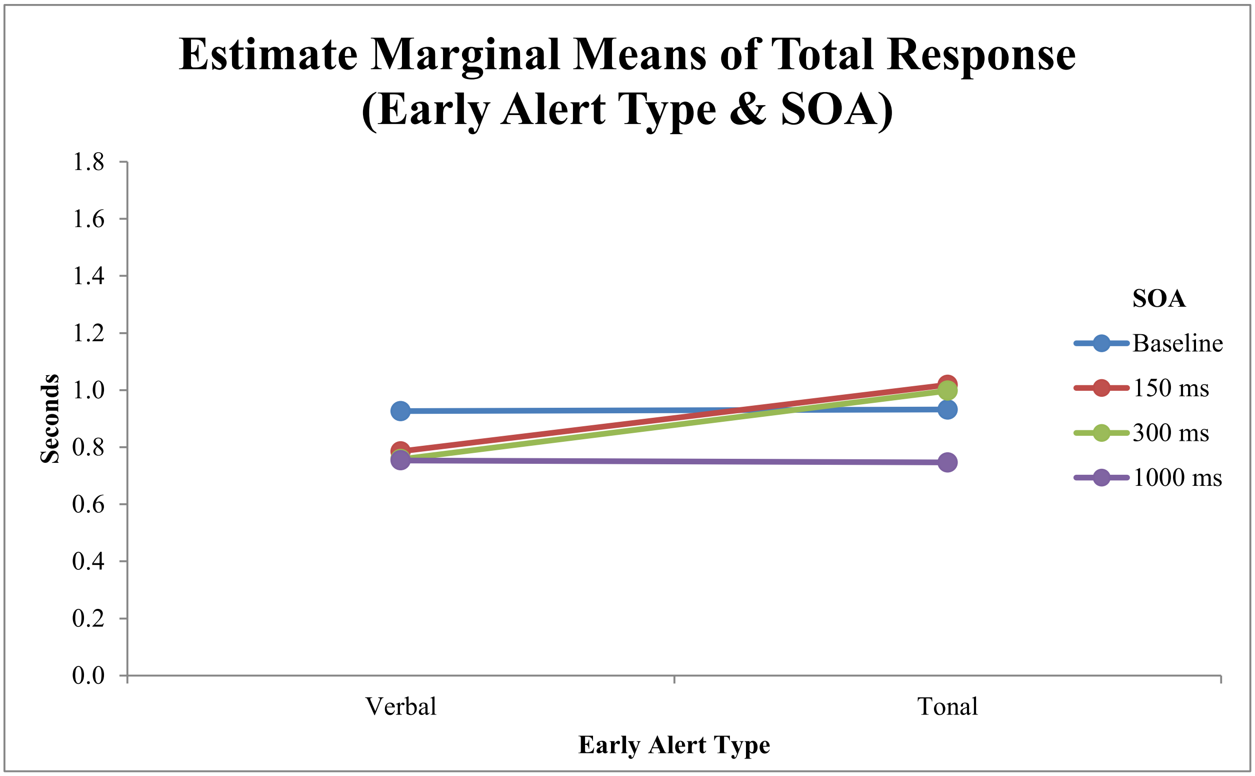

Figure 15. Early Alert Mode and SOA Marginal Means for Total Response Time (All Participants)

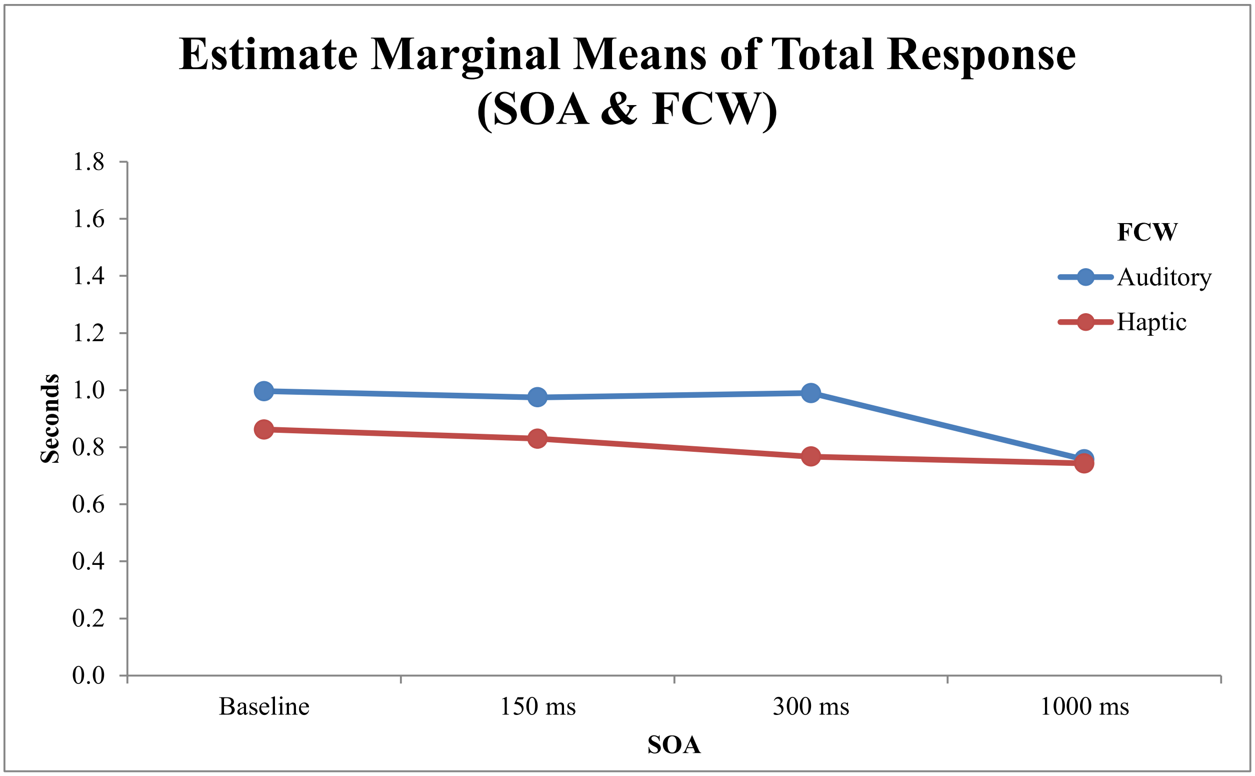

Figure 16. FCW and SOA Marginal Means for Total Response Time (All Participants)

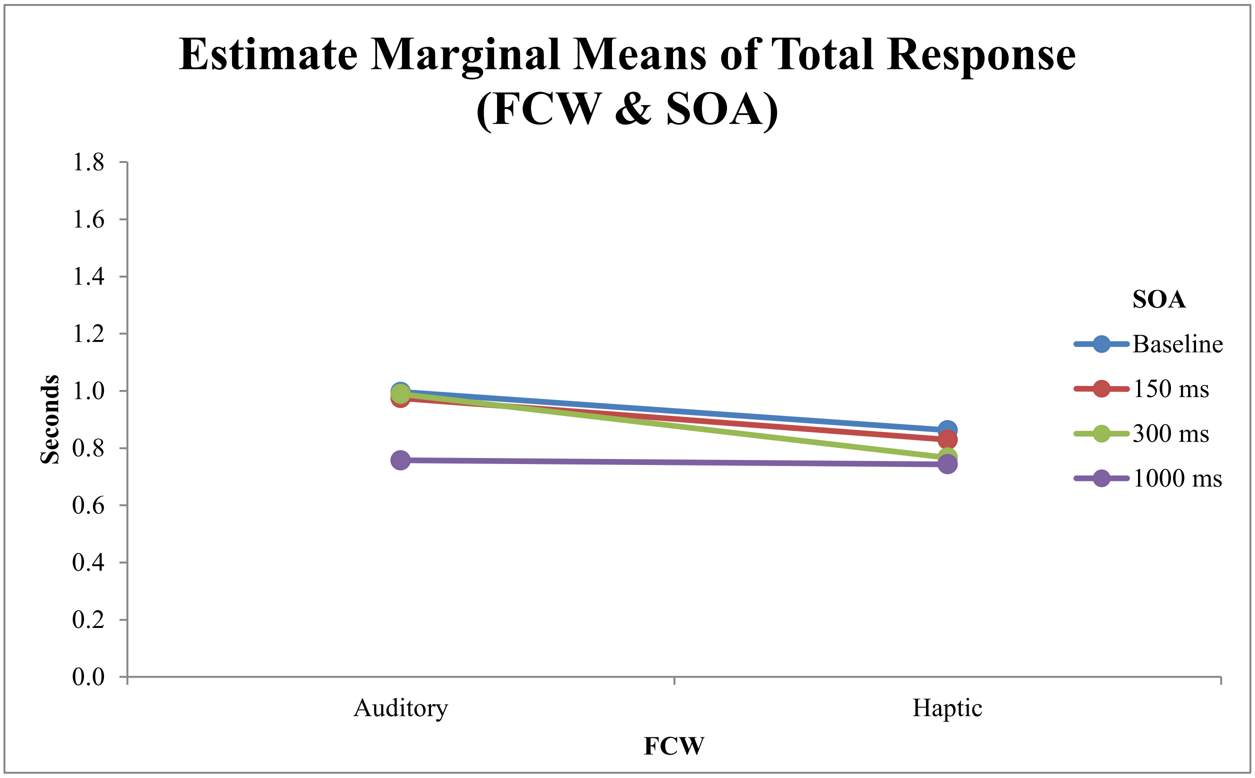

Figure 17. SOA and FCW Marginal Means for Total Response Time

Paired comparisons of Total Response times showed a significant difference between Auditory Baseline events and Verbal and Tonal Early events with an SOA of 1000 ms. There were also significant differences between Haptic FCW Baselines and Verbal Early Alert events with an SOA of 150 ms and 300 ms. Contrary to comparisons with Haptic FCW Baselines and Tonal Early Alert event where there was a significant difference between Baseline events and Tonal Early events with an SOA of 1000 ms.

Table 4. Paired Comparisons of Total Response Times

Total Response T-tests

Verbal							
Audio FCW	150 ms	300 ms	1000 ms	Haptic FCW	150 ms	300 ms	1000 ms
	0.089	0.181	0.011		0.037	0.010	0.091
Tonal							
Audio FCW	150 ms	300 ms	1000 ms	Haptic FCW	150 ms	300 ms	1000 ms
	0.458	0.281	0.014		0.730	0.700	0.026

3.1.5 Distance

There were only two collisions collected during this study, one during an Auditory FCW baseline event and one during a Haptic FCW with Tonal Early Alert and SOA of 150 ms.

Table 5. Collision Tables

Collisions	
Audio FCW	1
Haptic FCW_Tonal 150 ms	1

Table 6 summarizes the total number of samples per event type. The values not accounted for are due to early braking instances.

Table 6. Distance Count (N)

Distance (Verbal)	N	Distance (Tonal)	N
Audio FCW	18	Audio FCW	18
Haptic FCW	18	Haptic FCW	18
Audio FCW 150 ms	18	Audio FCW 150 ms	18
Audio FCW 300 ms	18	Audio FCW 300 ms	18
Audio FCW 1000 ms	18	Audio FCW 1000 ms	17
Haptic FCW 150 ms	17	Haptic FCW 150 ms	18
Haptic FCW 300 ms	18	Haptic FCW 300 ms	18
Haptic FCW 1000 ms	17	Haptic FCW 1000 ms	16
Max Number	18	Max Number	18

*Note: Missing Distance data is due to early braking.

The following graph contains the means and standard errors by critical event for distance.

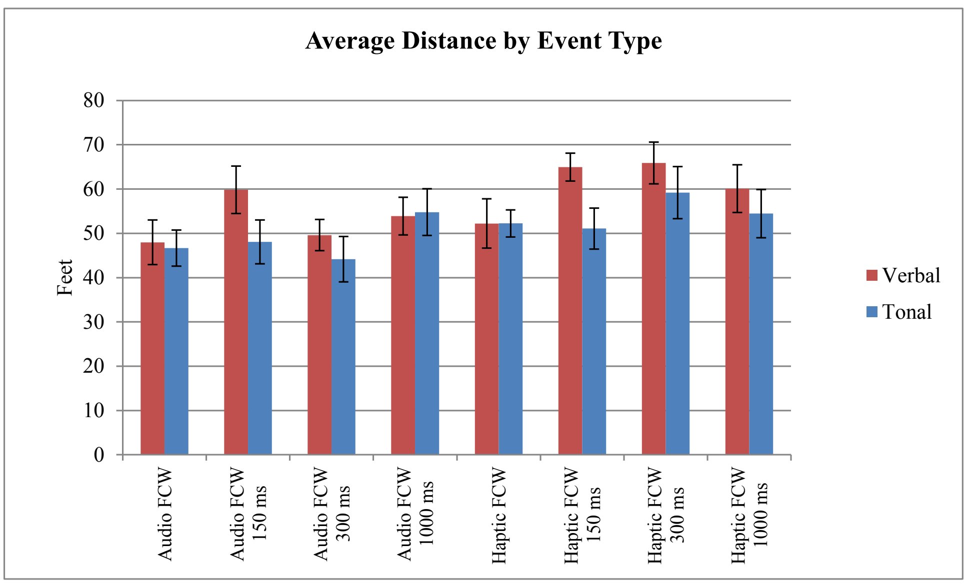

Figure 18. Distance Means and Standard Errors

There was a statistical difference between FCW alerts ($p = 0.025$) in the Verbal Early Alert group where the Haptic FCW alert events resulted in longer minimum distances between the SV and the LV. In contrast, there were no statistical differences within the Tonal Early Alert group.

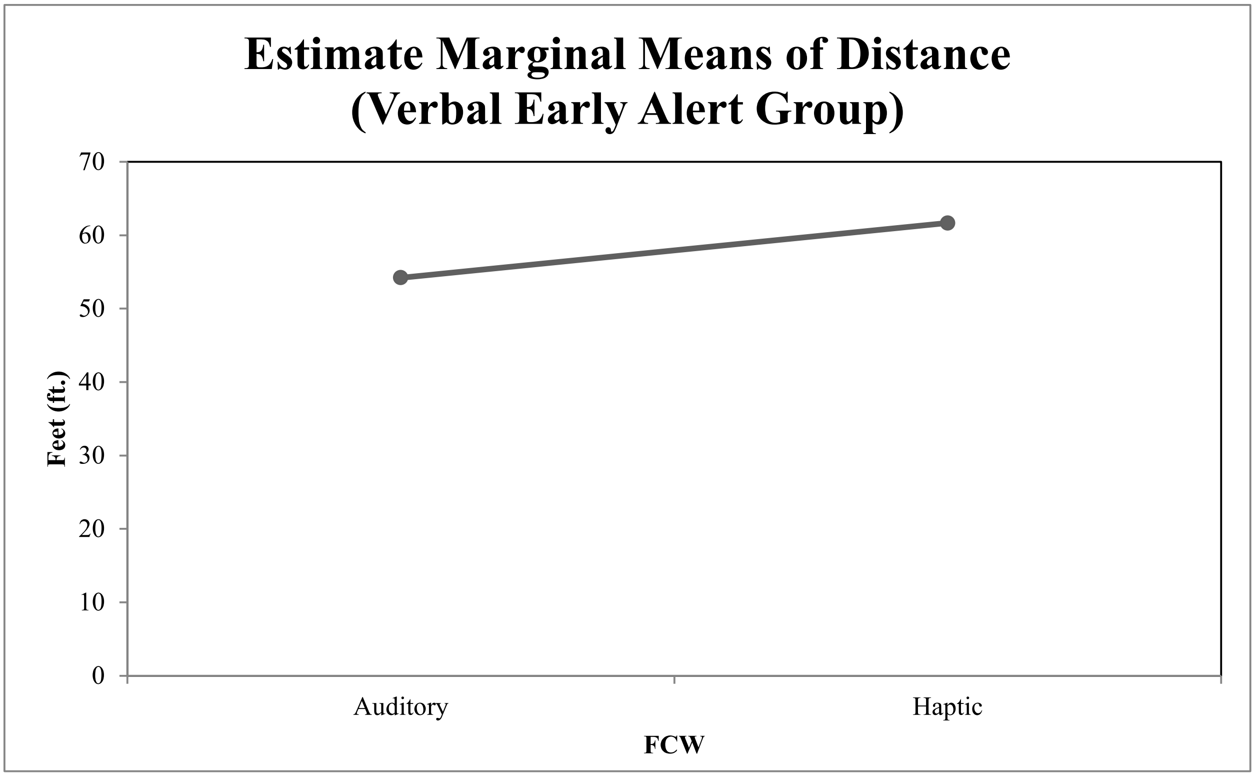

Figure 19. FCW Marginal Means for Distance (Verbal Group)

A repeated measures analysis found that there was a significant difference between Auditory and Haptic FCW ($p = 0.002$) where Haptic FCW resulted in longer minimum distances between the SV and LV. There was also an interaction between SOA and Early Alert type ($p = 0.042$), where for verbal Early Alerts, Distance decreased as SOA increased, but for Tonal Early Alerts there is a sharp increase in Distance for alerts with SOA of 300 ms and 1000 ms.

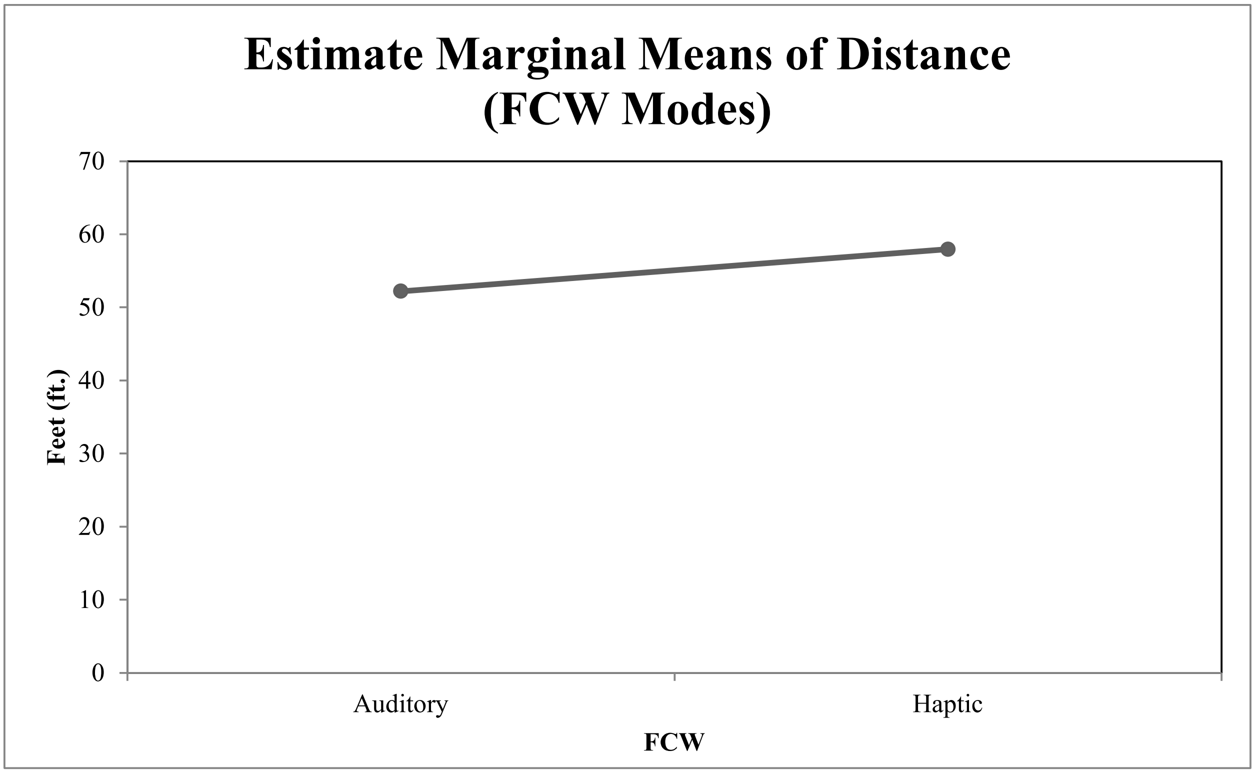

Figure 20. FCW Marginal Means for Distance (All Participants)

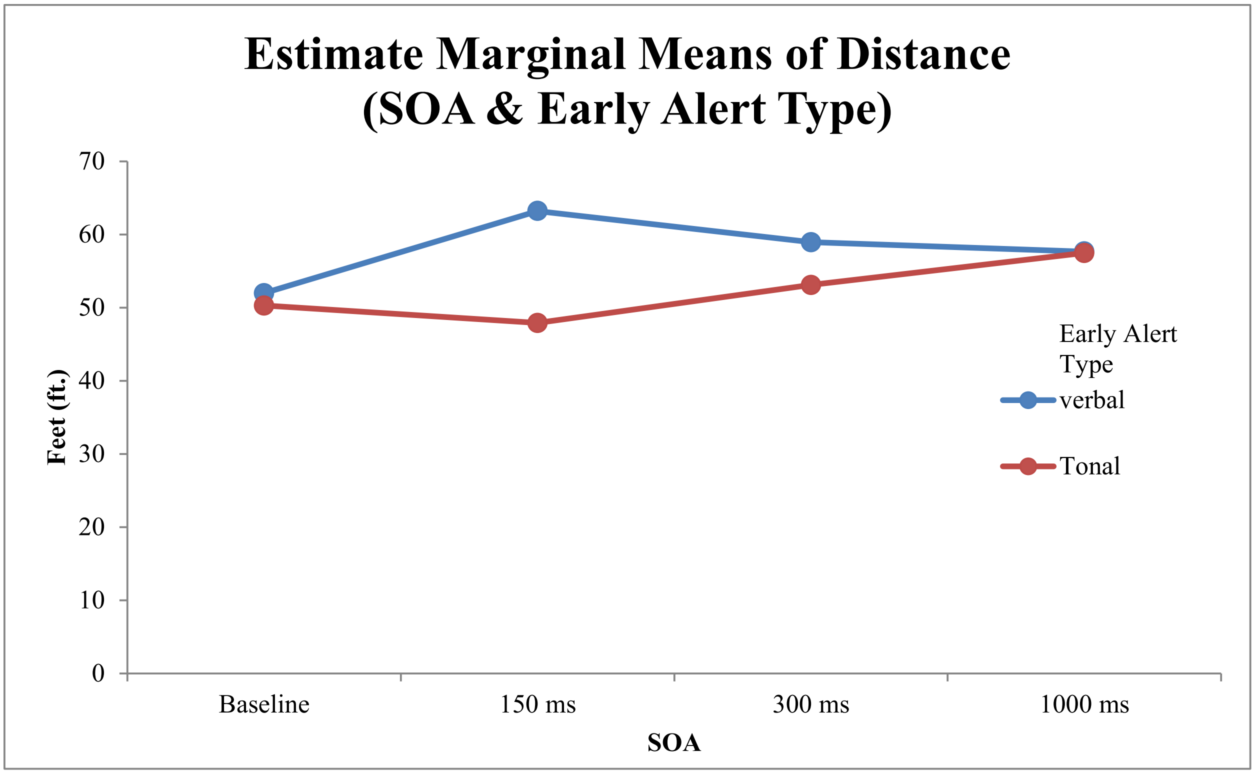

Figure 21. SOA and Early Alert Type Marginal Means for Distance (All Participants)

Paired comparisons revealed that there were no statistical differences between Baseline events and Verbal and Tonal Early Alert events for Distance.

Table 7. t-Tests for Paired Comparisons Between Baseline Events for Distance

Distance Ttests

Verbal							
Audio FCW	150 ms	300 ms	1000 ms	Haptic FCW	150 ms	300 ms	1000 ms
	0.115	0.791	0.375		0.057	0.069	0.318
Tonal							
Audio FCW	150 ms	300 ms	1000 ms	Haptic FCW	150 ms	300 ms	1000 ms
	0.833	0.702	0.234		0.836	0.303	0.726

3.1.6 Additional Results

In order to determine if gender acted as a confounding variable, a repeated measures analysis with gender as a covariate was performed. There was a significant interaction (p = 0.014) between FCW type and gender for Movement time but no other statistical differences were found. A separate repeated measures analysis was performed with age as a covariate. Although, there was a 3-way interaction (p = 0.043) between FCW, SOA, and age for Total Response time, there were no other significant differences found.

3.2 EYE GLANCE RESULTS

3.2.1 Number recall eye glance results

Number recall was used as a secondary task for this study. Based on the eye glance results, most participants did not focus completely on the number recall LCD for the duration of the task. This was mostly due to the task starting 3 sec after the audio cue was given to participants. Participants tended to look away from the LCD early on in the task. It was planned to have the task start 0.6 sec after the audio cue was given but computer delays and software response resulted in a delay window of approximately 3 sec. Because of this unforeseen issue, the data eye glance window was changed to the start of the task as 2 sec after the audio cue and the end of the task the time in which the last digit was displayed.

The following graphs plot out the glance duration to each location by participant. When the participant crossed a Number Recall tripwire, the task would begin There were a total of 4 different Number Recall or tripwire (TW) events, therefore there are 4 separate plots.

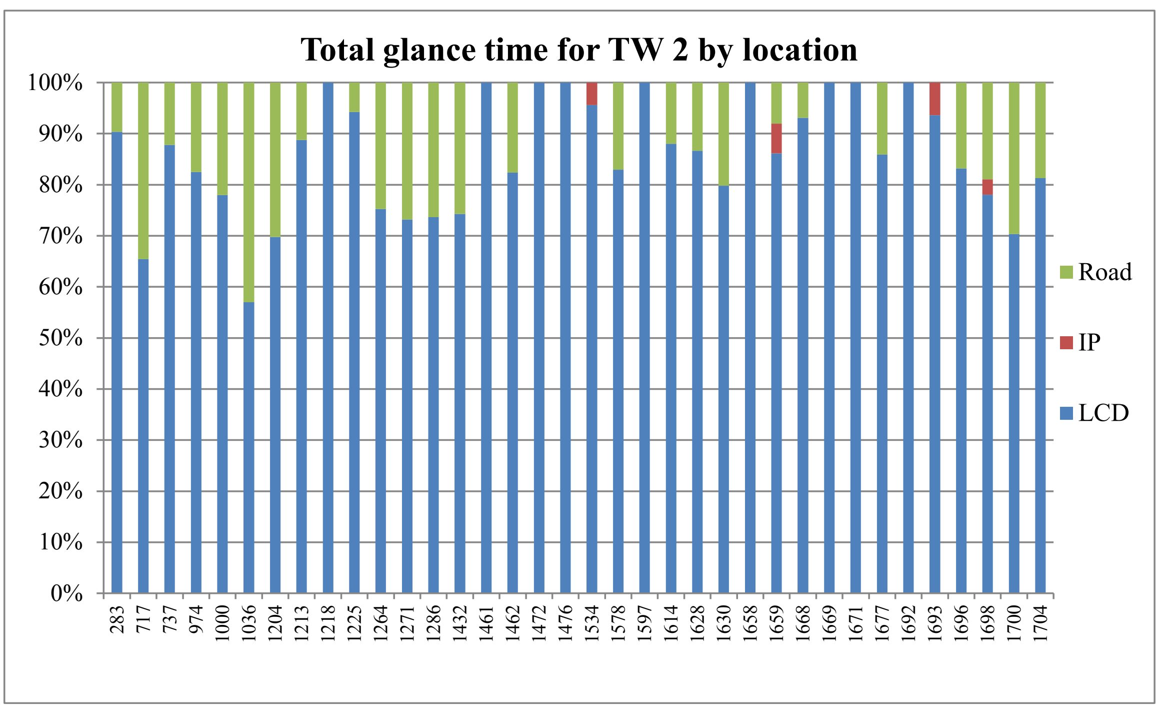

Figure 22. Total Glance Time for Number Recall TW 2

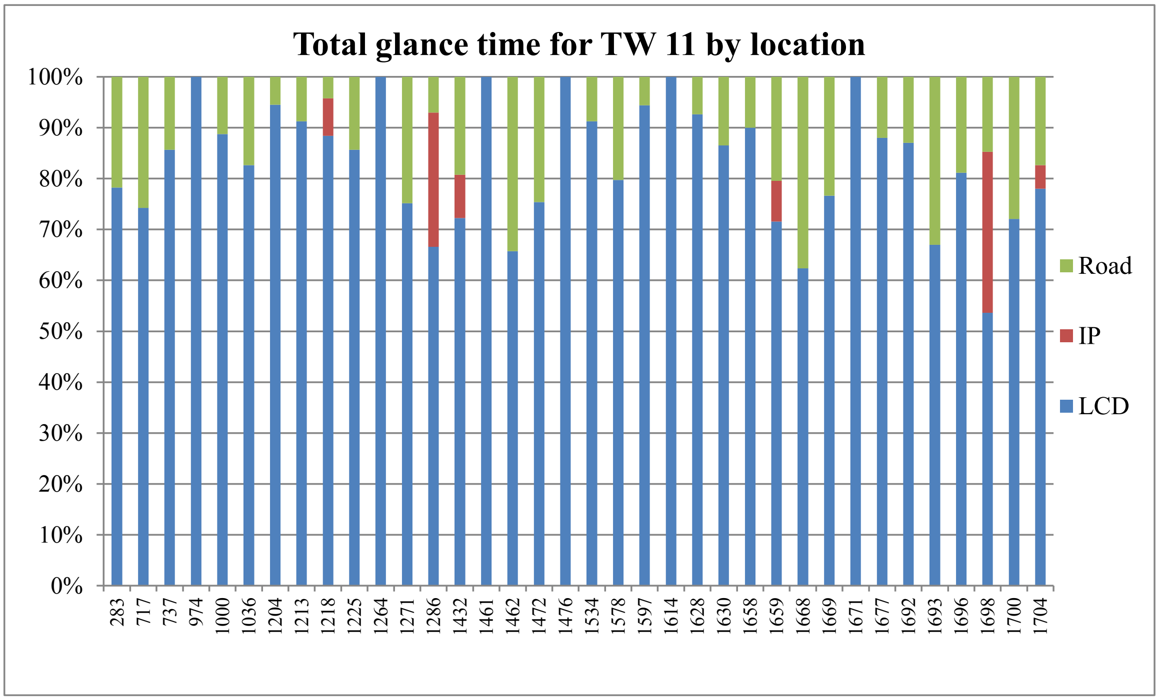

Figure 23. Total Glance Time for Number Recall TW 11

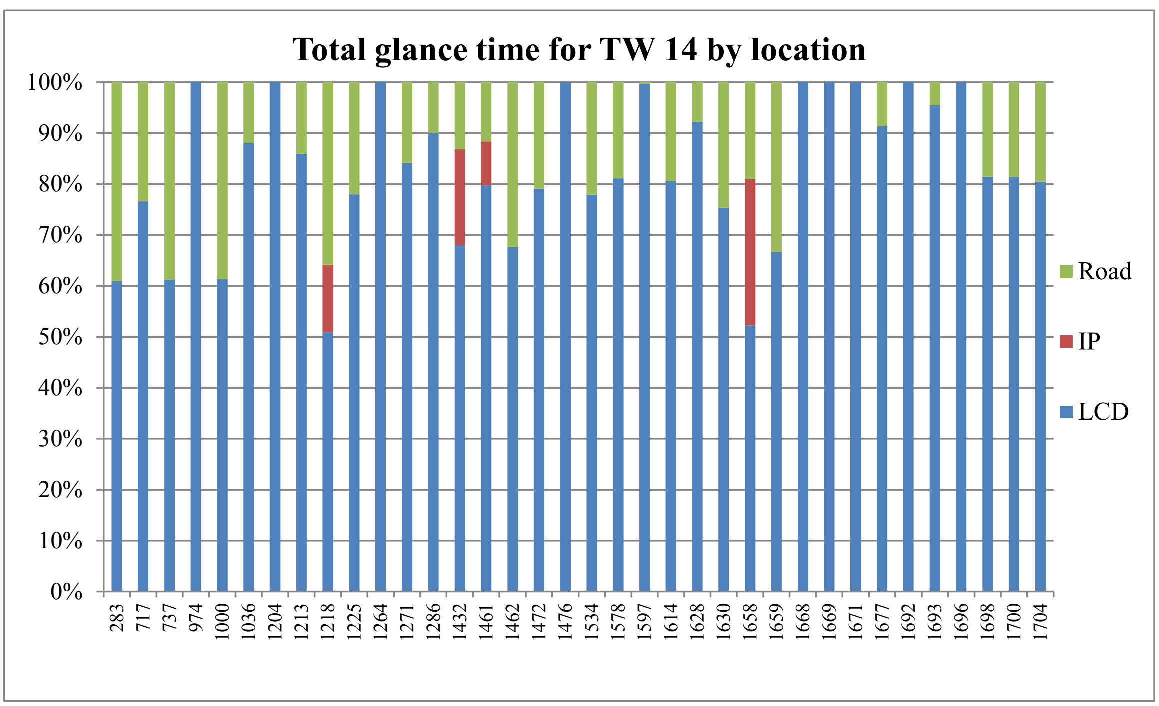

Figure 24. Total Glance Time for Number Recall TW 14

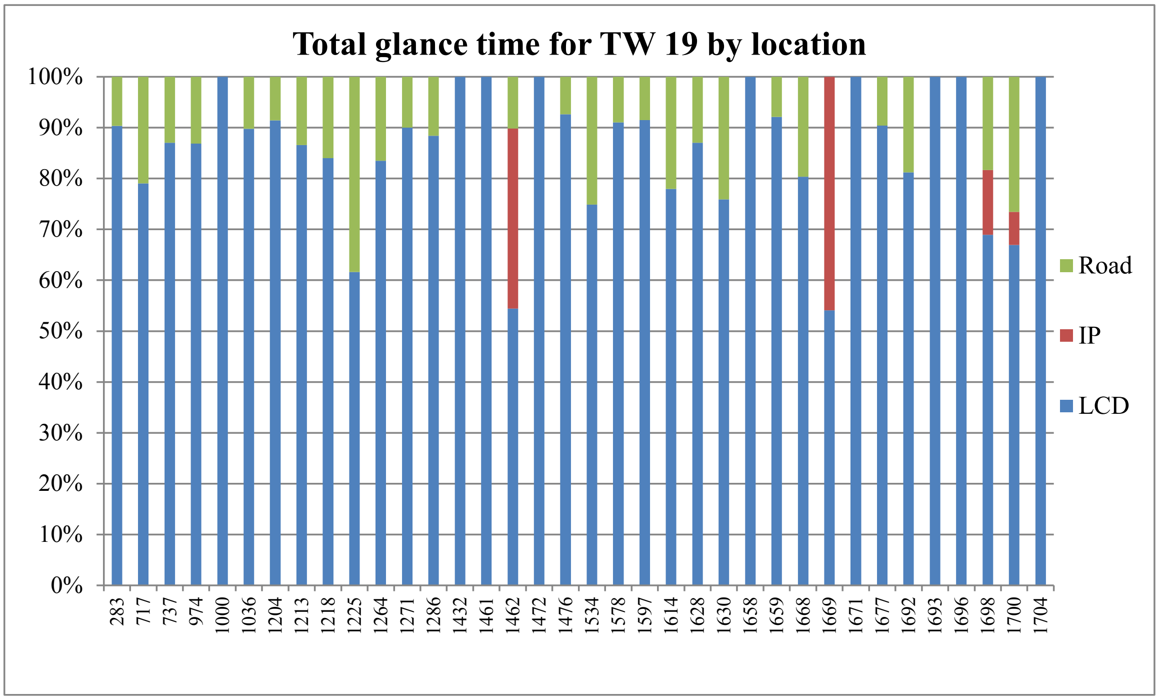

Figure 25. Total Glance Time for Number Recall TW 19

3.2.2 Critical events eye glance results

Data coding eye glances for critical events with only 1 alert (either FCW or Early Alert) started 3 sec prior to the alert and ended 3 sec after the start of the alert. Coding for critical events with two alerts started 3 sec prior to the first alert and ended 3 sec after the start of the second alert (Figure 26).

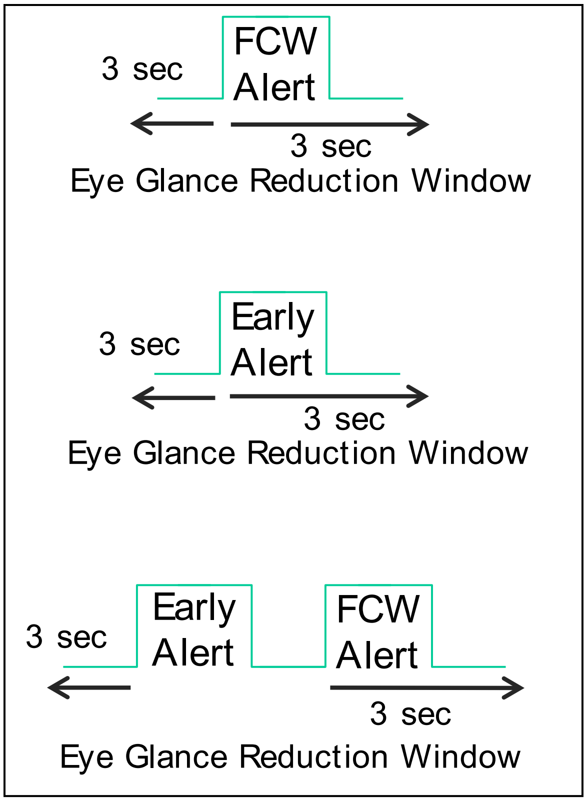

Figure 26. Eye glance reduction windows

On average, participants tended to spend more time looking at other locations during Haptic FCW critical events than when they received the Auditory FCW. During the Baseline Haptic events, participants did spend some time looking at the LCD perhaps seeking an explanation for the FCW haptic cue. But both Total Glance Time (TGT) and Single Glance Time (SGT) to the road were similar for both the Auditory and Haptic FCW.

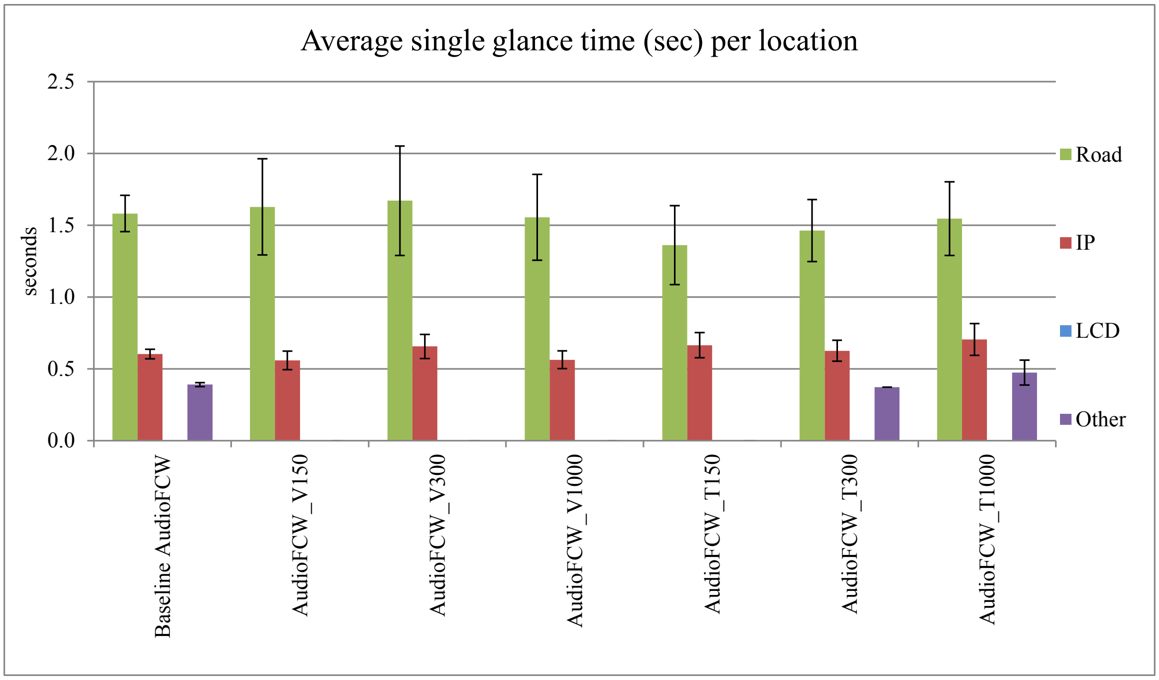

Figure 27. Average Single Glance Time for Audio FCW Critical Events by Location

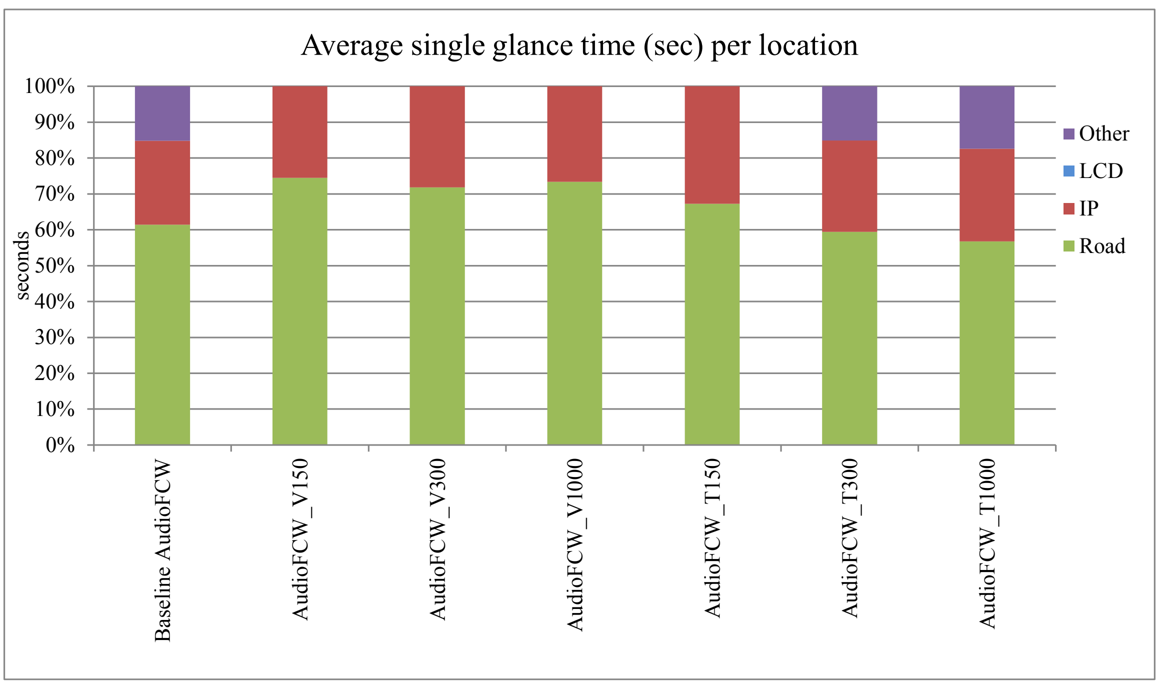

Figure 28. Average Percent Single Glance Time for Audio FCW Critical Events by Location

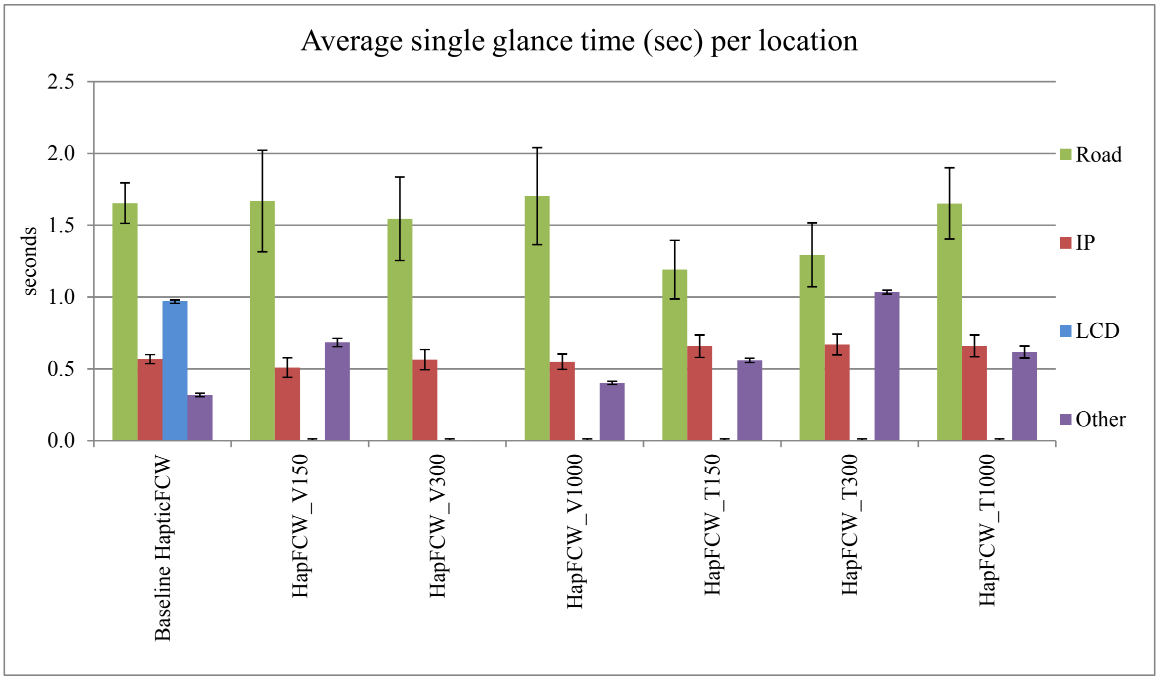

Figure 29. Average Single Glance Time for Haptic FCW Critical Events by Location

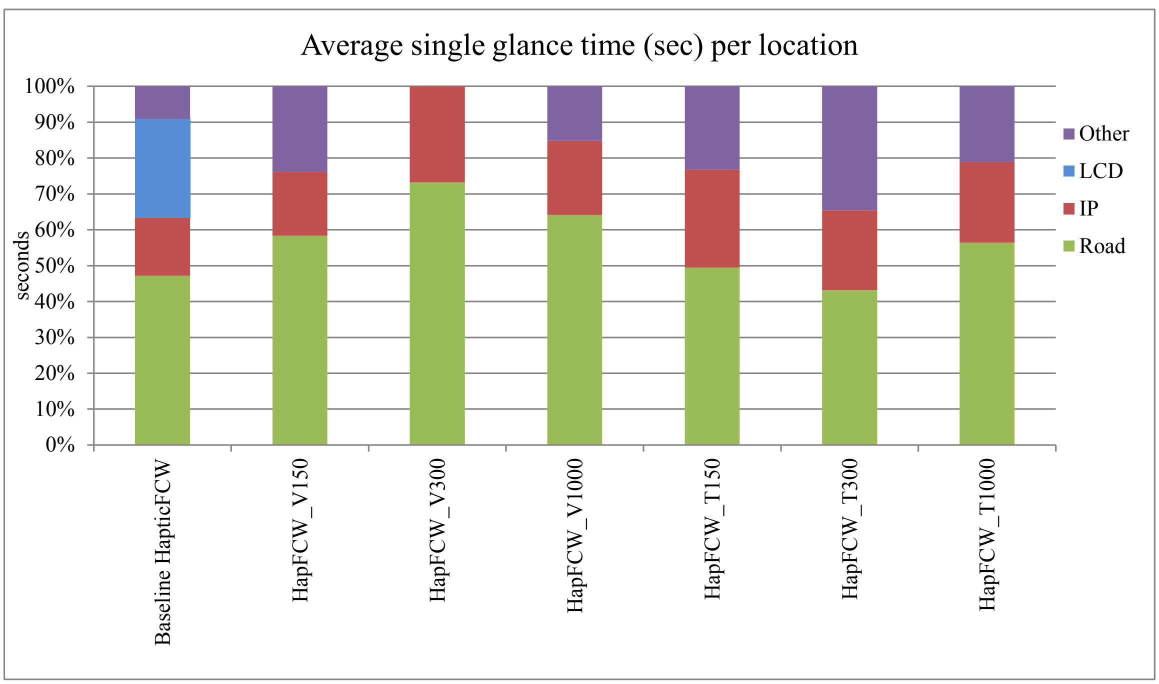

Figure 30. Average Percent Single Glance Time for Haptic FCW Critical Events by Location

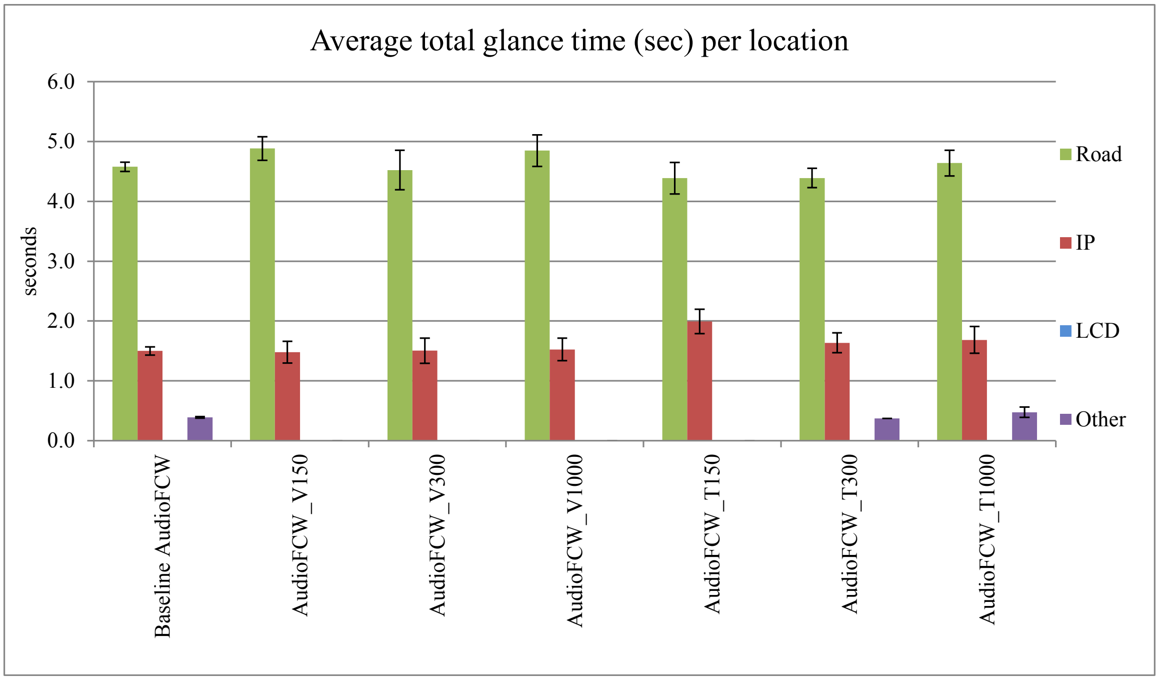

Figure 31. Average Total Glance Time for Audio FCW Critical Events by Location

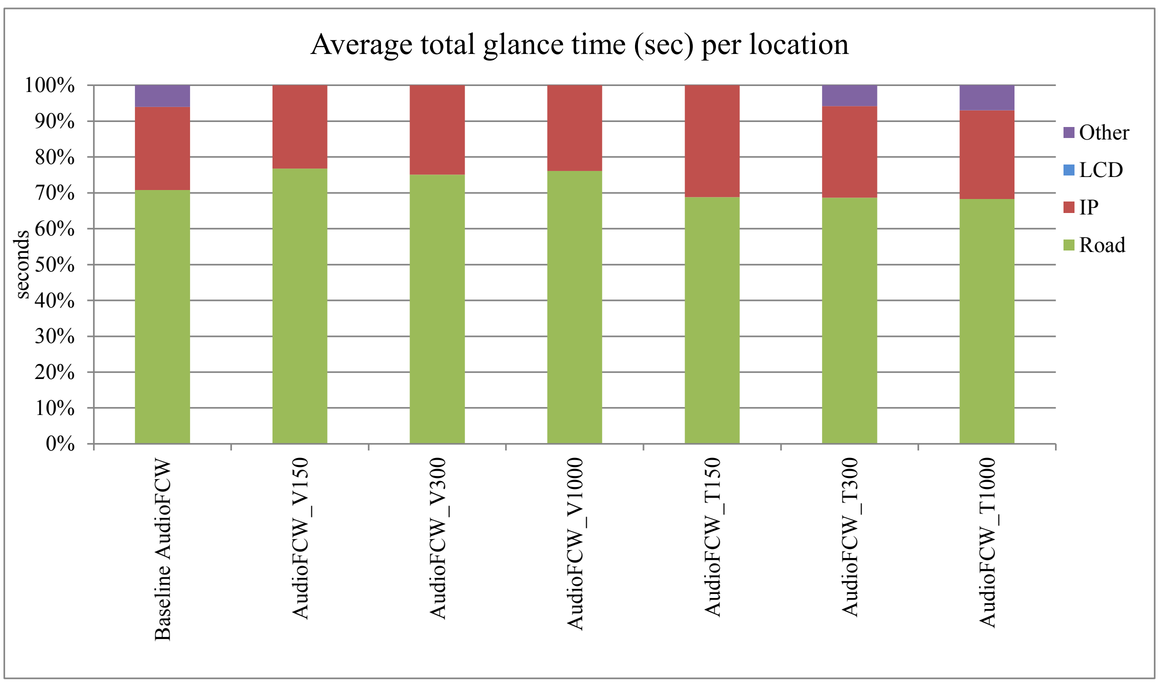

Figure 32. Average Percent Total Glance Time for Audio FCW Critical Events by Location

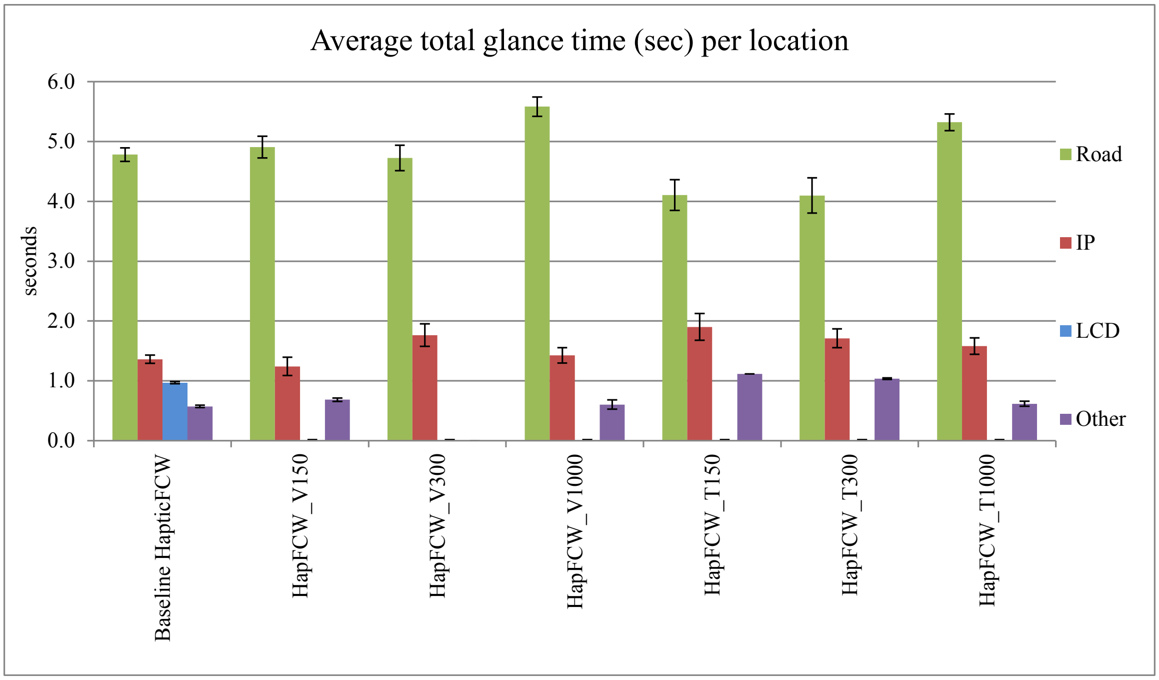

Figure 33. Average Total Glance Time for Haptic FCW Critical Events by Location

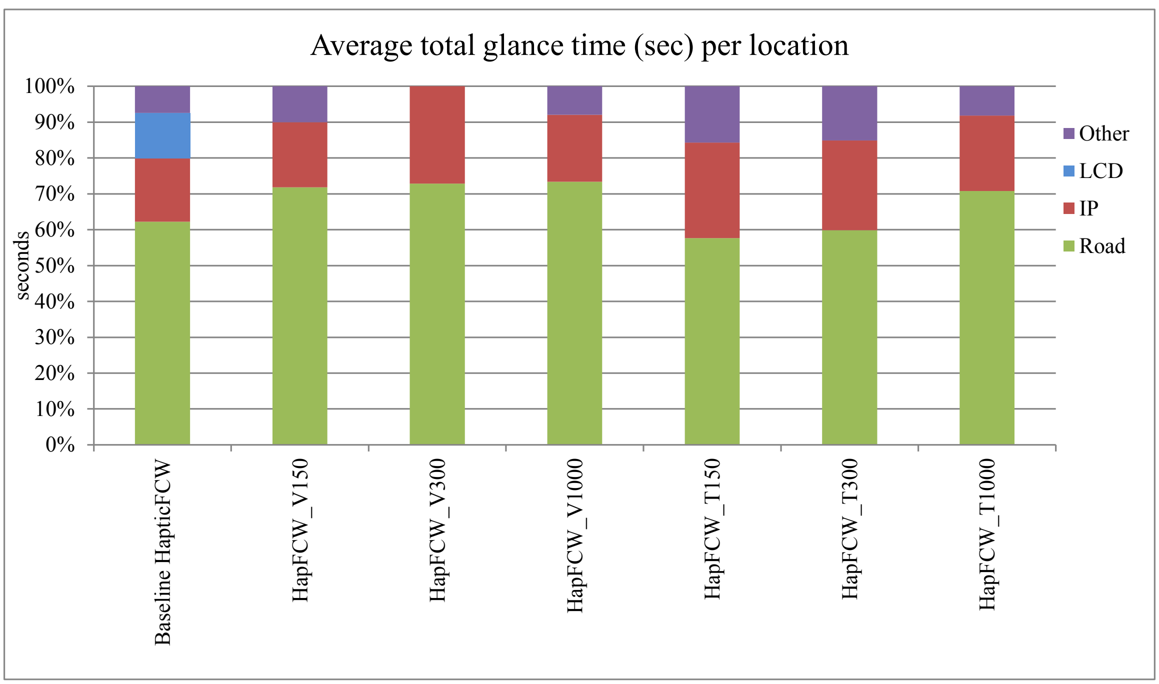

Figure 34. Average Percent Total Glance Time for Haptic FCW Critical Events by Location

3.3 SUBJECTIVE RESULTS

Participant comparison ratings on appropriateness, understandability, ease of performing the task, and overall mental workload were collected and analyzed. The following graphs represent counts, mean ratings and standard errors results.

More Auditory FCW Tonal participants noticed that two alerts were given during critical events than the Auditory FCW Verbal participants. A few more noticed both alerts when Early Alerts were paired with Haptic FCW alerts, than when both alerts were auditory.

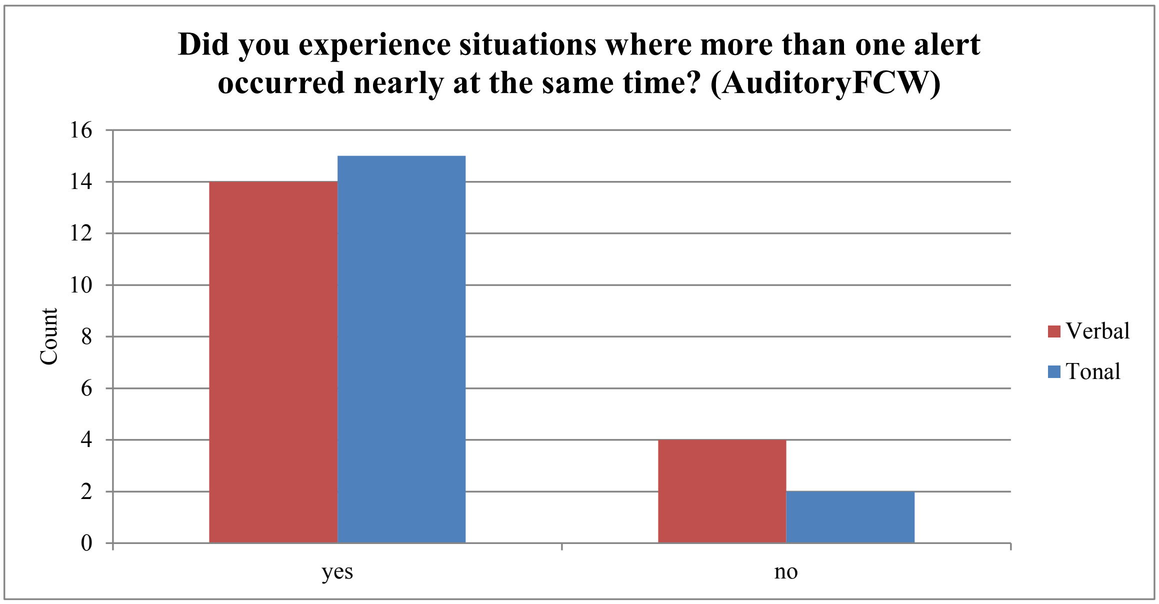

Figure 35. Number of Alerts Experienced (Auditory FCW)

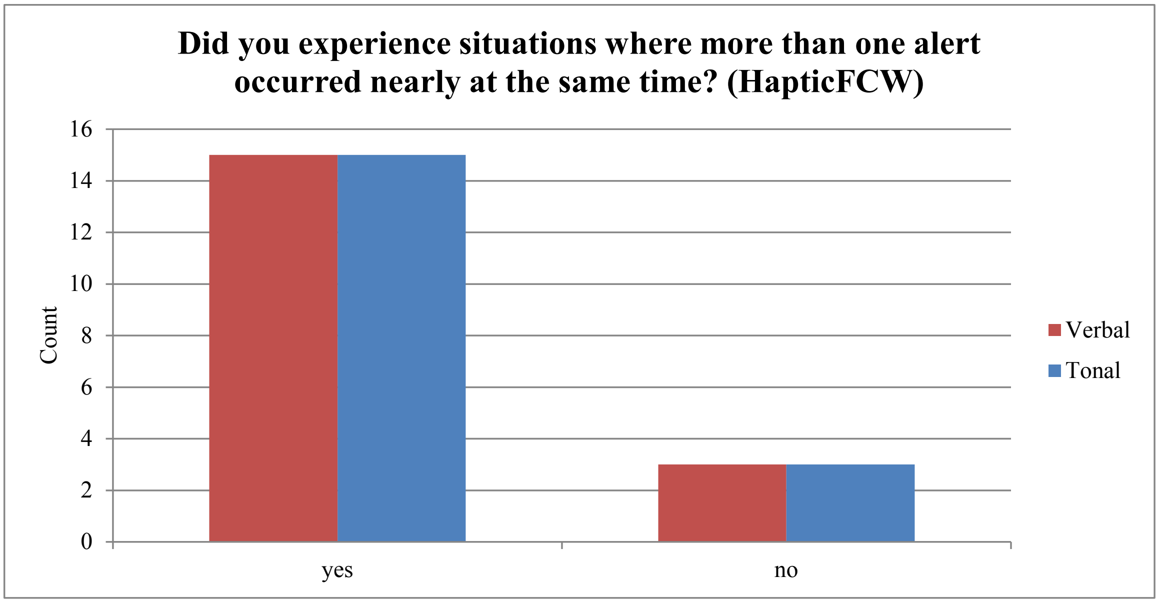

Figure 36. Number of Alerts Experienced (Haptic FCW)

Participants tended to understand alerts better when Early Alerts were paired with the Haptic FCW than when paired with the Auditory FCW.

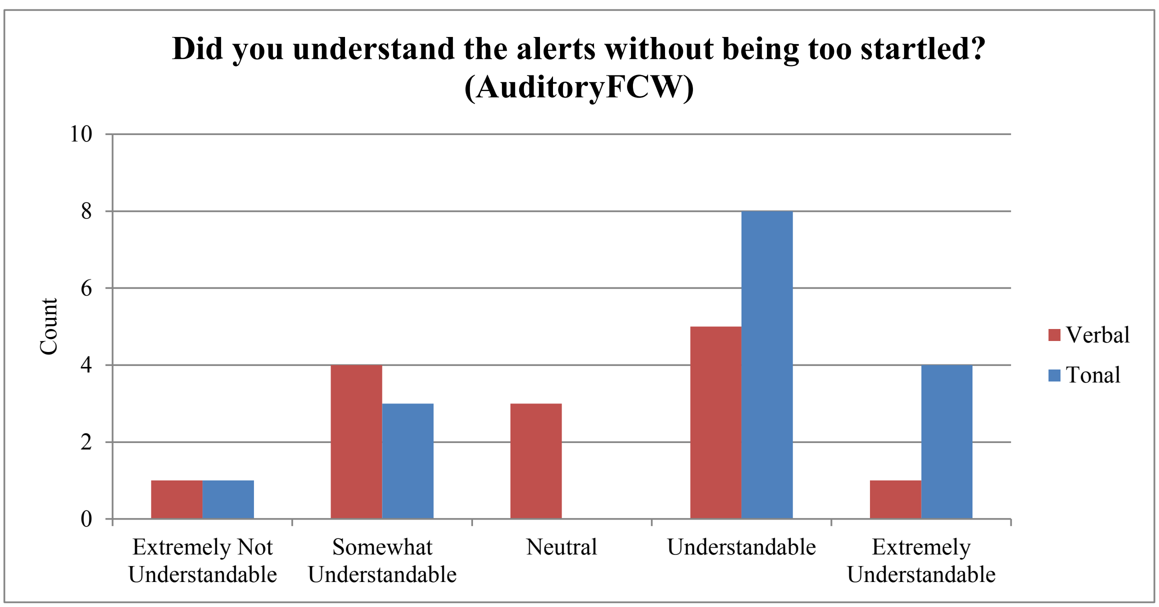

Figure 37. Understandability of Alerts (Auditory FCW)

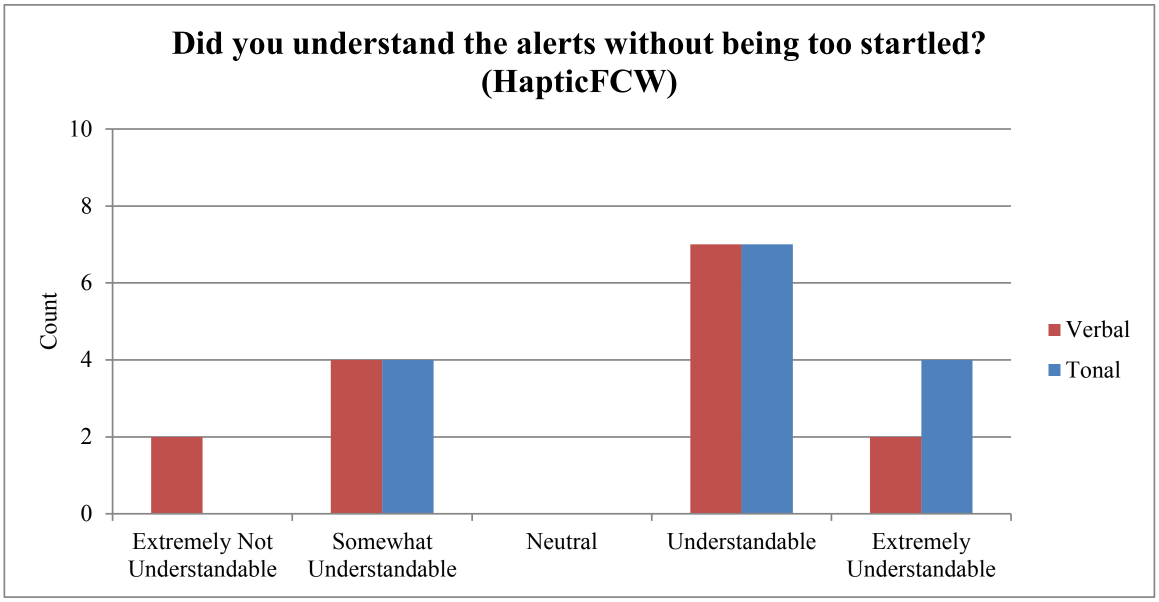

Figure 38. Understandability of Alerts (Tonal FCW)

More participants were confused by the pairing of the FCW and early alerts when both were Auditory than when the FCW was Haptic and Early Alert was auditory.

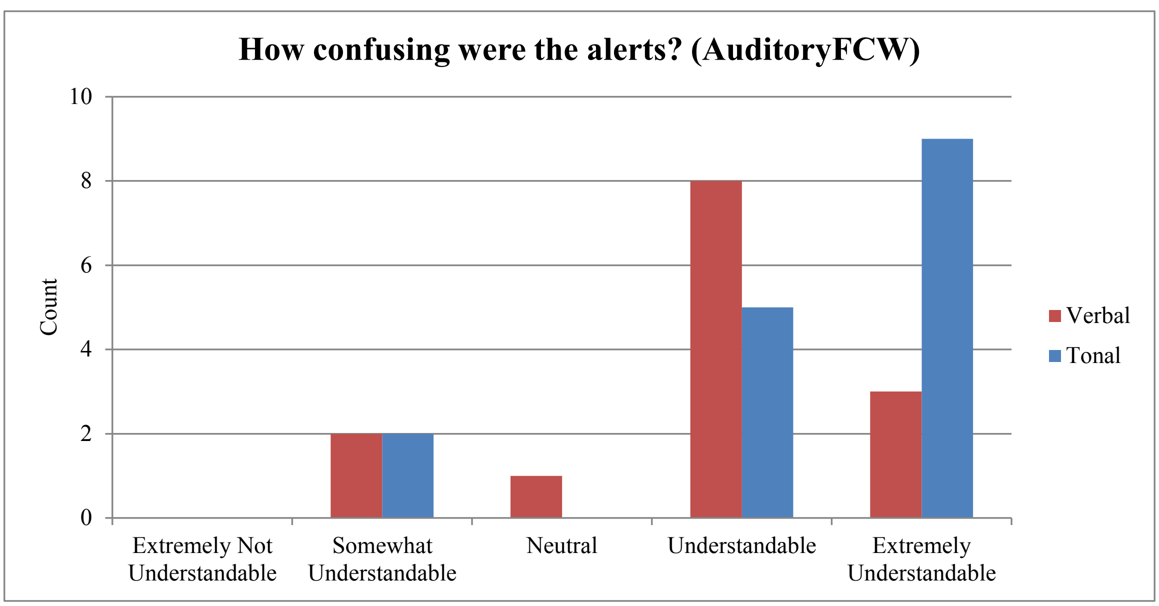

Figure 39. Level of Confusion (Auditory FCW)

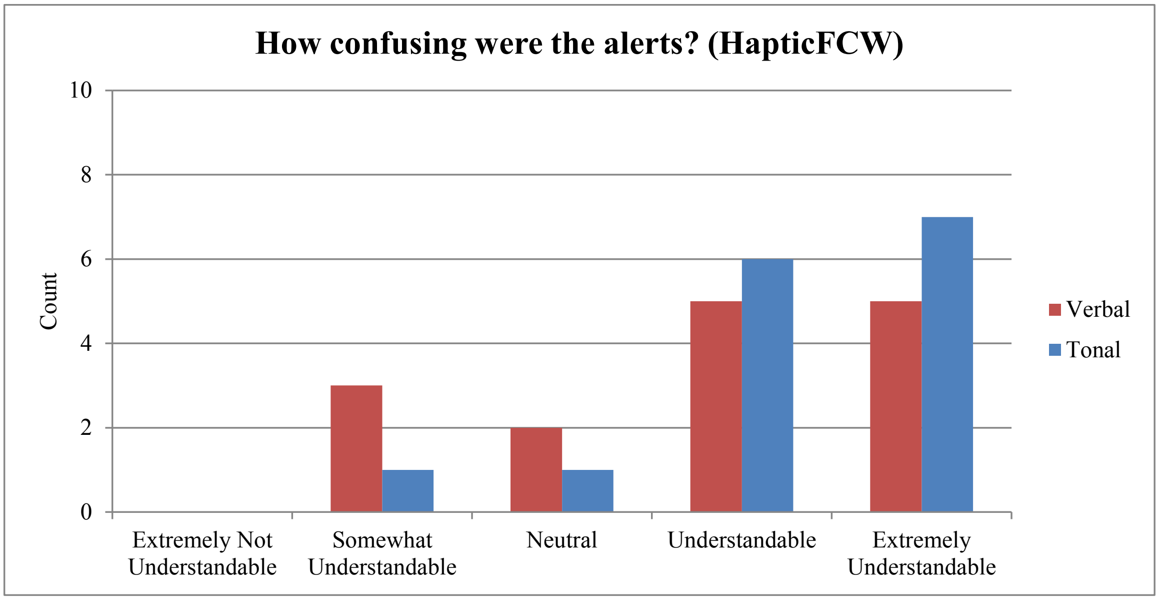

Figure 40. Level of Confusion (Haptic FCW)

Participants rated their drive with Tonal Early Alerts as being easier than those with Verbal Alerts. The combination of Tonal Early Alert with Haptic FCW was rated as being the easiest.

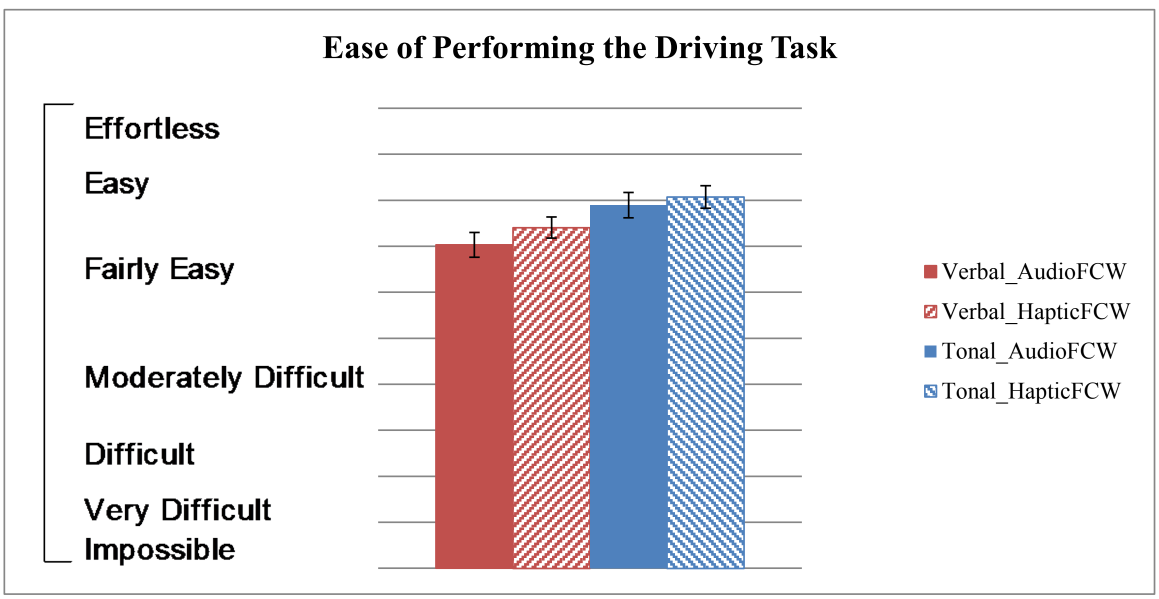

Figure 41. Ease of Performing the Driving Task

Participants found that Early Alerts combined with Haptic FCW alerts were a little easier on performing in-vehicle tasks, although all combinations were rated as being closer to "Fairly Easy."

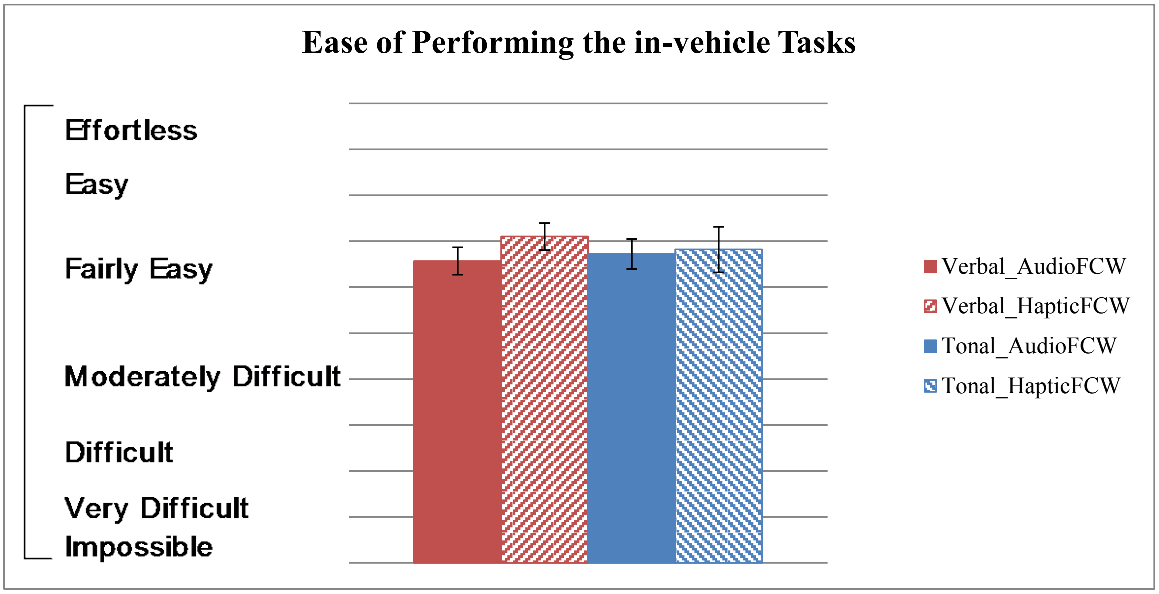

Figure 42. Ease of Performing the in-vehicle Tasks

Having a tonal early alert with haptic FCW was rated as having the least amount of discomfort or sense of risk than the other combinations.

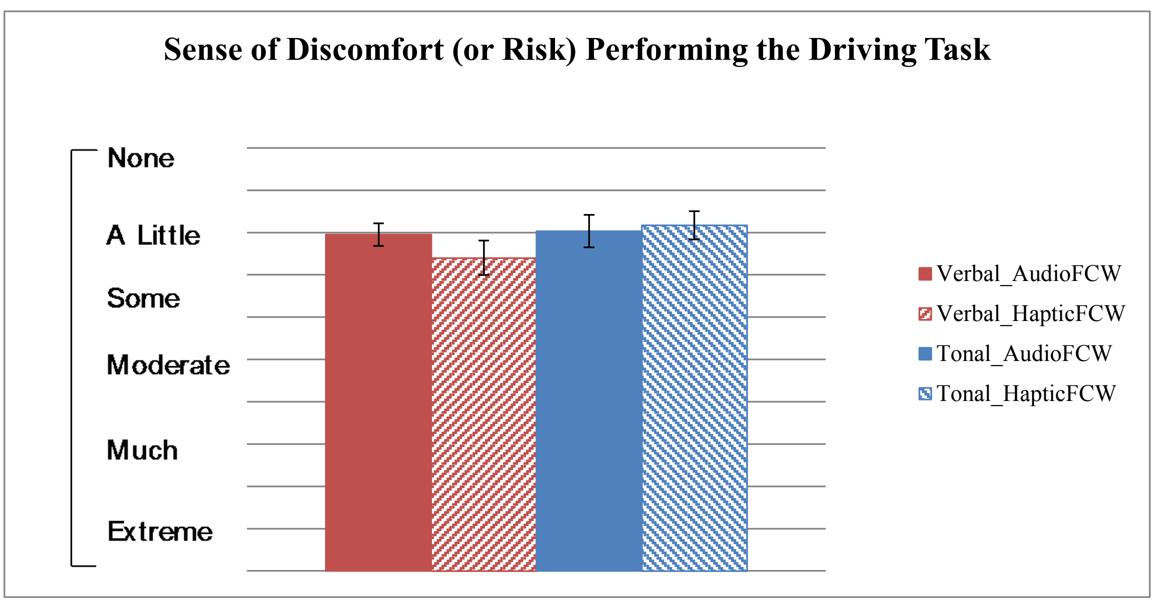

Figure 43. Sense of Discomfort or Risk Performing the Driving Task

Although Tonal Early Alert with Haptic FCW resulted in the least amount of discomfort, it also rated highest overall mental workload. All combinations were rated as being between “Moderate” and “Low.”

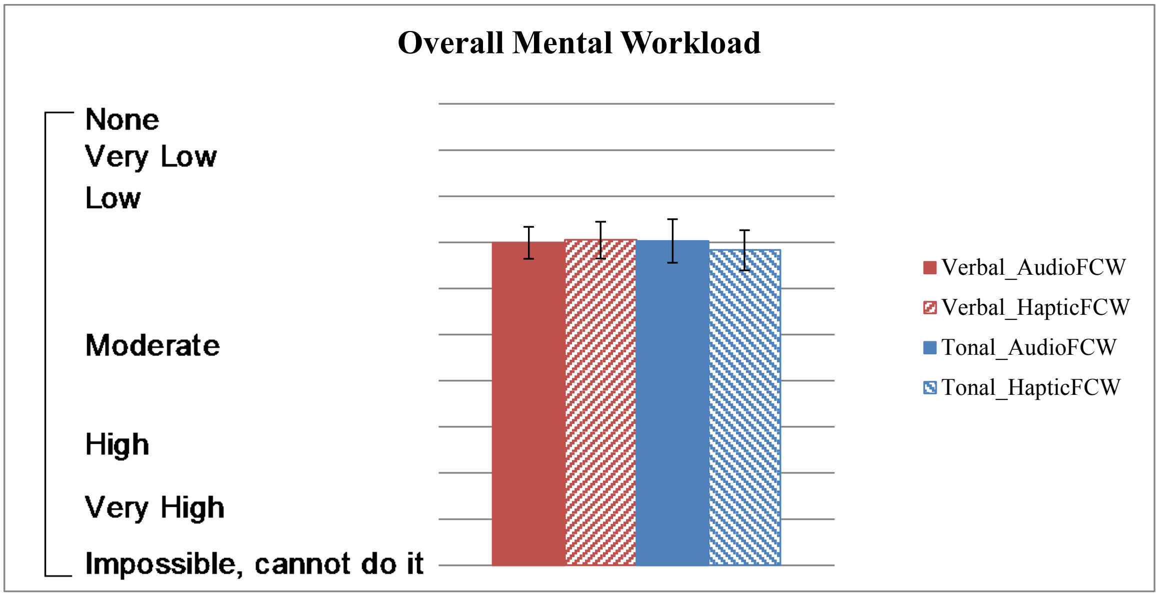

Figure 44. Overall Mental Workload

The following rating questions asked participants how appropriate they thought the early alerts were during each road. The Tonal Early Alert with Haptic FCW combination was most often rated as being the most appropriate.

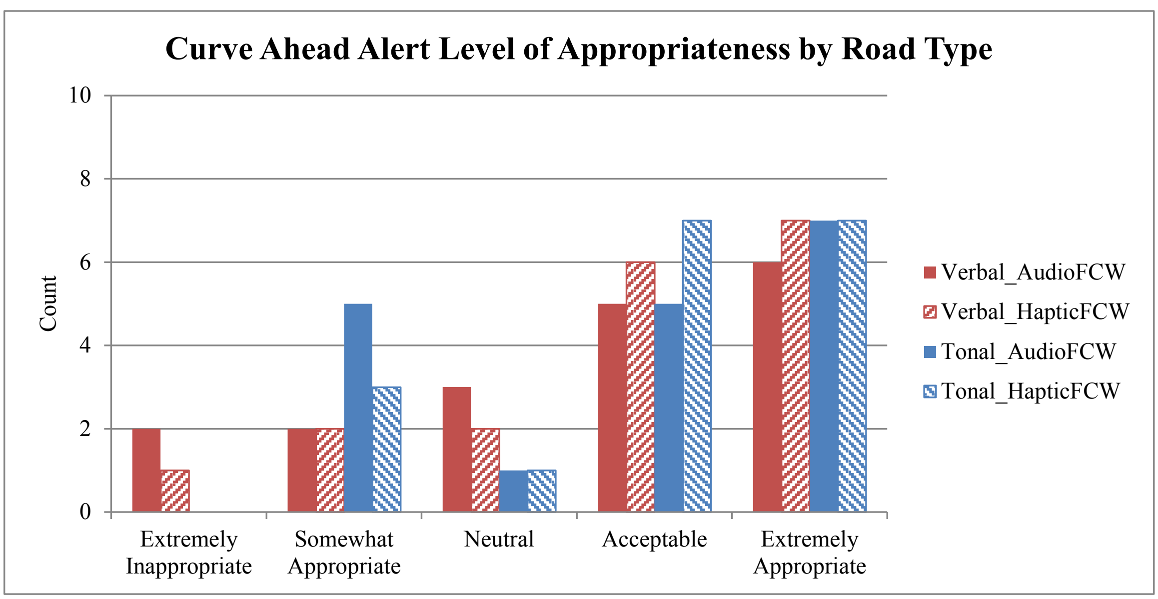

Figure 45. Curve Ahead Level of Appropriateness by Road Type

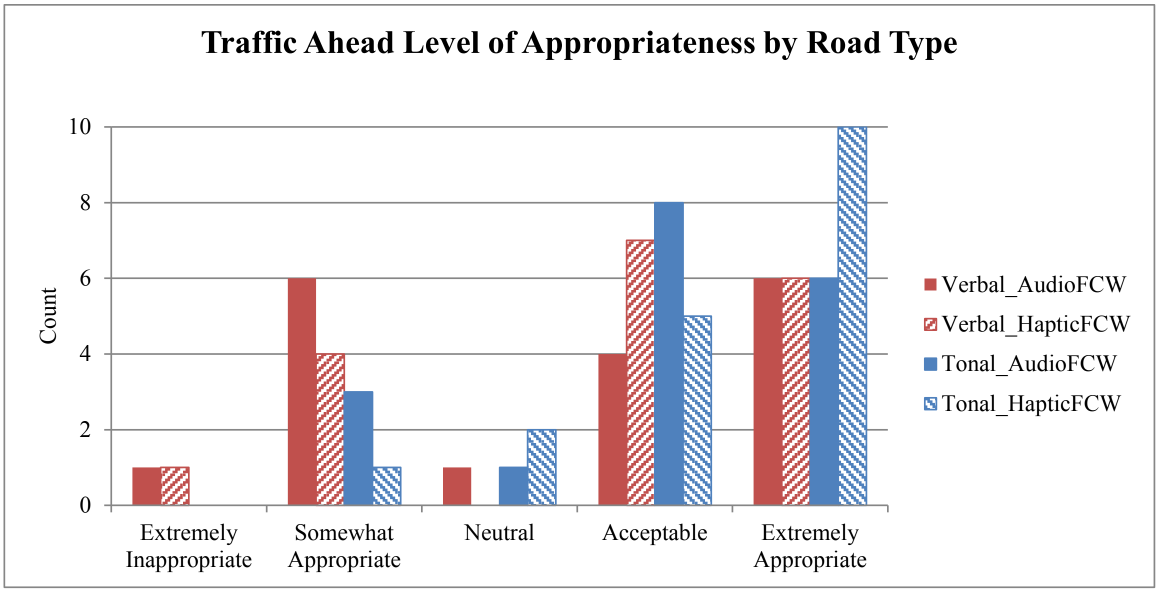

Figure 46. Traffic Ahead level of Appropriateness by Road Type

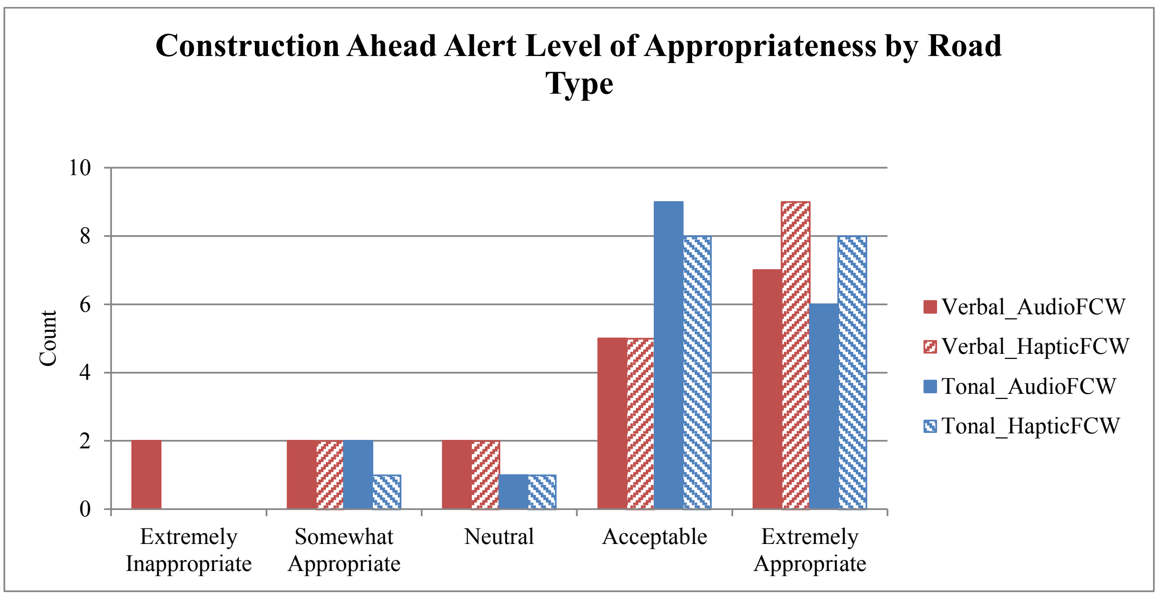

Figure 47. Construction Ahead Leel of Appropriateness by Road Type

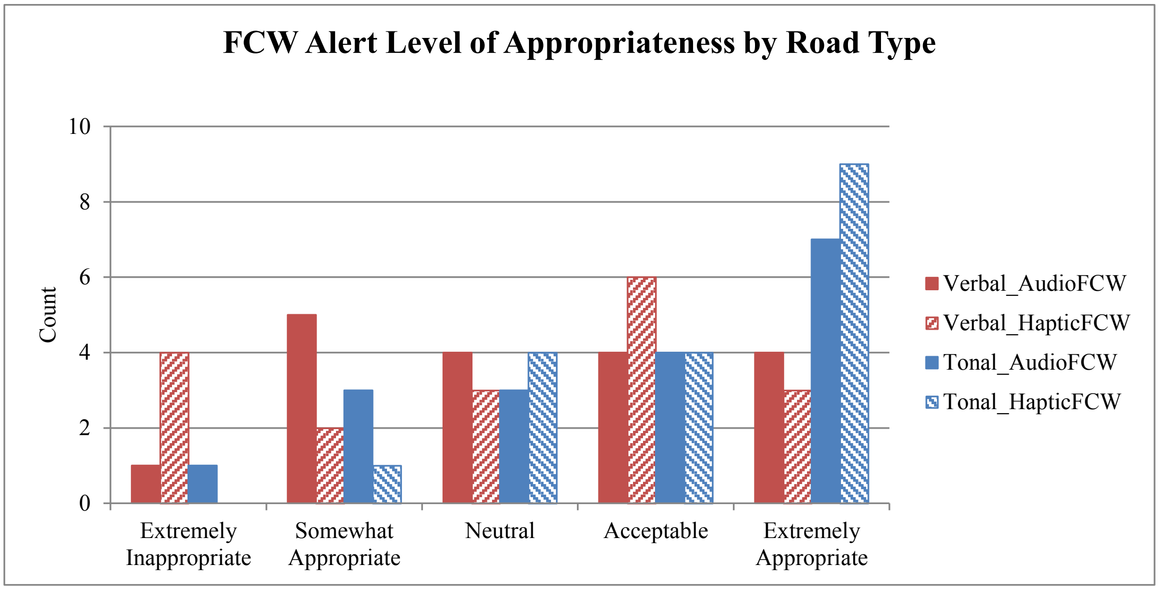

Figure 48. FCW Alert Level of Appropriateness by Road Type

4.0 DISCUSSION AND CONCLUSIONS

4.1 DISCUSSION

The overall goal of the present study was to evaluate various onset time intervals between less urgent safety-related alerts (Early Alerts) and an Advanced Collision Warning System to more fully define the magnitude of the Psychological Refractory Period. This research also hoped to determine if the results would be similar to those in past studies where shorter SOA times resulted in slower Max Brake Movement times. In contrast, longer SOA times (1000 ms) it was hoping to determine if results of Max Brake Movement times are not negatively affected by Early Alerts. Lastly, this research was also hoping to determine if alerts with similar perceptual modes would interfere with one another more than alerts with different perceptual modes.

The two measures of most interest were Total Response time and Distance. Total Response time was defined as the start of the LV critical braking event to the end of Movement or when the participant put their foot on the brake pedal. The data for Total Response time provided a more complete analysis than Accelerator Reaction time and Accelerator to Brake Movement time individually since it captured the missing Accelerator Response and Movement times. Distance was defined as the minimum distance between the SV and LV after a critical LV braking event. These measures are used to answer the question this paper hoped to answer.

The first question asked if shorter SOA times slowed Total Response time and the second asked if having a longer SOA time would be negatively affected by an Early Alert prior to an FCW. These data showed that an SOA of 1000 ms resulted in the shortest Total Response times for both the Verbal and Tonal Early Alert groups. These results fall in line with past research from

Wiese and Lee where an SOA of 1000 ms enhanced response time but shorter SOA times interfered with response time.

Interactions between Early Alert type and SOA were found such that for the Tonal Early Alert group, Total Response time decreased sharply for 1000 ms SOA, but only gradually decreased with the Verbal Early Alert group. In this instance, the Tonal Early Alert events were consistent with the findings from Hibberd et al. (2013) which implied that negative effects of in-vehicle distractors could be mitigated through controlling the presentation of in-vehicle task such that they are not presented in the period immediately before the driver is required to brake, or before 350 ms. Total Response times were still better than when Early Alerts were presented at SOA 150 ms.

For the Tonal Early Alert group, having an Early Alert aided Total Response time when it was presented at 1000 ms when compared to no Early Alert (Baseline). For the Verbal Early Alert group, having an Early Alert presented at any SOA resulted in shorter Total Response times than if not having an Early Alert (Baseline). Early Alerts in general may be acting as pre-cue to a critical event. This combined with the fact that Verbal Alerts did not require that participants look for an icon to decipher what the alert meant may explain why Verbal Alert events resulted in shorter Total Response times.

The data also revealed an interaction between FCW type and SOA times. When Verbal Early Alert events were presented at 300 ms Distance time was decreased, but increased Distance time for Tonal Early Alert events presented with the same SOA.

For the Verbal Early Alert group, having any type of early alert resulted in larger minimum distances, than if having an FCW on its own (Baseline). On contrast, for the Tonal Early Alert group, having an early alert presented at an SOA of 150 ms caused shorter distances than any other SOA.

Thirdly, this study hoped to find out if having warnings with similar perceptual modes interfere with each other. For both the Verbal and Tonal groups, Total Response time was shorter when paired with a Haptic FCW alert than when paired with an Auditory FCW alert. These results support Pashler's (1994) findings that found that alerts that share similar modes compete with one another for resources and will interfere more with one another than if the accelerator release modes of the alerts are different. Distance results were similar as those found for Total Response and Accelerator to Brake Movement, where having a Haptic FCW was more of a benefit than having an Auditory FCW.

Although overall Haptic FCW resulted in shorter Total Response times, Auditory FCW events had a sharp decrease in Total Response time for SOA times larger than 350 ms. Both Auditory and Haptic FCW events resulted in similar 1000 ms Total Response times. Again, these results supported previous research that found that shorter SOA times delayed response compared to 1000 ms SOA times which enhanced response time.

4.1 CONCLUSIONS

The finding from this study tend to suggest that having an non-urgent safety related Early Alert prior to a FCW during a LV braking event was a benefit most of the time, than not having an Early Alert present. The only times this was not the case was when and a Tonal Early Alert was presented at 150 ms SOA. It should be noted that in doing a quick review of foot behavior for non-critical events (events which set off the Early Alerts without an FCW), data showed that participants tended to either release the accelerator or move their foot from accelerator to brake after the Early Alert more often times than not. This may suggest that the Early Alerts served as a type of pre-alert or pre-cue for participants in this study. Further analysis would have to be performed to determine how often this occurred for Early Alert only events (non-critical events).

If considering an FCW system in a vehicle, these results tend to support a Haptic FCW over an Auditory FCW in producing shorter response times and longer minimum distances during LV braking events.

When combining an FCW system with an earlier non-urgent safety related warning, these results suggest that a combination of Haptic FCW and Verbal Early Alert would enhance response time and thus improving braking response. These findings support Pashler's (1994) that alerts with similar perception modes would interfere.

For SOA interval times, the results from this study tend to support previous research from Wiese and Lee, and Hibberd, that shorter SOA times may hinder brake response time as opposed to larger SOA times, such as 1000 ms, which may in fact enhance response time.

In this study the FCW and Early Alerts were presented to the participant without distraction. The next phase of this study hopes to examine if results change, when participants are given a distraction task before an Early Alert and FCW are presented.

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APPENDIX A

DRI Institutional Review Board Forms

Note: The following section includes paperwork that needs to be submitted and approved by the DRI IRB before the study can begin.

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DESCRIPTION OF PROJECT AND ASSOCIATED RISKS

Project Description

Provide a summary description of the project, including a statement of research objectives. Attach detailed Project Test Plan.

The overall goal of the present study is to evaluate various onset time intervals between non-time-critical or non-safety-critical alerts and an Advanced Collision Warning Systems to more fully define the magnitude of the Psychological Refractory Period. The overall test plan is to study driver performance and behavior in potentially risky scenarios in a safe, repeatable, and controlled environment, using the Dynamic Research, Inc. (DRI) Motion Base Driving Simulator. The DRI Driving Simulator is a dynamically realistic, moving base, "driver-in-the-loop" device.

A total of four roads are planned to be used for each condition. All participants will drive all four roads with the following independent variables, which will be counterbalanced to limit learning effects: lead vehicle braking events, Stimulus Onset Asynchrony times, Situational Awareness alerts, Driver State alerts, and Forward Collision Warning alerts.

After each road, participants will be asked to rate. Total session time expected for the study is 3 hours; including paperwork, rest breaks, and simulator drive time.

Describe the expected project outcomes and results.

The data will consist of measurements provided by the simulator, video recordings, and subjective ratings provided by the participants. Data will be analyzed to evaluate driver reaction to critical events.

Planned use of Participants

Number of participants: 36 Adults

Age of participants: 35 - 55

Duration of each participant's participation: 3 hours

Number of sessions: 1

Duration of each session: 3 hours

Test/rest cycle in each session: Participants will be measured and video recorded while seated in the full motion simulator cab in one session of 3 hours.

Source of participants: Recruits from DRI Participant database

Characteristics of the planned participant population:

This study will consist of 36 adults from age 35 through 55 years old, equal number of males and females, and with minimum of 10,000 miles of driving annually or a minimum of two years with a valid driver's license. Participants will need to be in generally good health and be able drive the full motion simulator. Participants who do not meet these requirements will be excluded in the study.

Anticipated Risks to Participants

List and describe any potential risks to participants in this study. If possible, compare the risk to a similar ordinary or common activity.

Note: A risk is a potential harm or discomfort associated with the research that a reasonable person would consider to be a factor in deciding whether or not to participate in the research. Risks can be generally categorized as physical, psychological, social, economic or legal.

Potential risks to the participants in this study are believed to be generally similar to those involved in riding an amusement park ride. An additional risk of Simulator Induced Sickness (SIS) is present due to the length of the study and number of turns.

Some risk is associated with the surprise element of the events. There is an additional risk of fire (in the facility) similar to that found in office environments.

Classify the anticipated overall level or risk to participants in the study using the following scale (put a mark on the vertical line). If there are several tasks or roles in the study, each with a different level of risk, identify and explain the risk of each task or role.

Risk of SIS:

High
Moderate
Some
Minimal
None

Risk of motion system hard-over:

High
Moderate
Some
Minimal
None

The possible psychological (surprise factor) risk of the scenario:

High
Moderate
Some
Minimal
None

Plan for Risk Mitigation

The increased risk of SIS is planned to be mitigated by screening test-participants for susceptibility, taking breaks often, and monitoring participants for signs of SIS. At any sign of or report of discomfort or illness, use of that participant will be suspended or discontinued.

If SIS occurs, the participant's well-being shall be assured before leaving DRI, and the participants will be escorted home if there is any question as to how they feel.

Dynamic Research, Inc. recognizes that there are certain risks associated with the use of the DRI Driving Simulator, and has well established procedures for risk analysis and risk mitigation. These include categorizing the known risks into several main groups and then identifying the particular risks and the mitigation methods. The potential simulator related risks and mitigation strategies that are applicable to this study are described below and adapted to the current project from our basic procedures.

Simulator As A Whole Risk

Comparison	Amusement park rides with motion
Discussion	The DRI Moving Base Driving Simulator has been in operation for over 15 years. In that time there have been several system failures for various reasons, but no catastrophic or harmful to the driver participant. The motion system is designed so that these events result in the hydraulic system dumping pressure such that the motion system platform slowly returns to its rest position (all actuators retracted). In 15 years there has only been one occasion where an actuator did not return to its retracted position. In that single case the platform assumed a non-horizontal resting position until it was repaired.

Potential Risk	Mitigation
Motion system hard-over (moves rapidly to its limit of travel)	Controlling software has motion limits built in. Motion hardware has limit switches to prevent over-extension. Motion hardware has hydraulic cushions to provide "soft" stops and limit severity of hard-over condition. Hoist available for lifting heavy objects.
Motion system transients (shocks and bumps)	Motion shocks limited by bandwidth and authority of motion system hardware. Controlling software filters transients. Controlling hardware filters transients.
Motion system stuck in full up position or other extremes	Emergency escape ladder installed on platform. Emergency stop switches located in-cab, at motion base and in control room. In-cab researcher and other simulator staff trained in evacuation procedures. Battery operated lift available in the facility.
Hydraulic leaks (low or high pressure)	All hoses, etc., are below the platform, isolated from the cab occupants. Emergency stop switches reduce hydraulic pressure.

Potential Risk	Mitigation
Falling objects	The only over-head objects have additional restraints and tethers installed other than mounting bolts. Mounting bolts inhibited from loosening by through-bolt safety wire. Hoist available for lifting heavy objects.
Structural failure	Motion system is a standard product designed for heavy payloads and adequate safety margins with high reliability.

Simulator Occupant Risks

Comparison	Amusement park rides with motion
Discussion	There are several potential risks and associated mitigations associated with operating any simulated vehicle atop the motion platform. For example when the simulated vehicle is an automobile or light truck, the participant is seated in a modified vehicle interior, and uses the OE restraint system. Also in these cases a research assistant is always present in the passenger seat to monitor and instruct the study participant.

Potential Risk	Mitigation
Steering system hard-over - potential breaks or sprains to fingers, wrist or arm.	Participant instructed to keep hands away from steering wheel except during actual operation. Research assistant observes participant and enforces rules. Emergency stop switches to de-energize system located in cab, at motion base and in control room.
Fall from the platform	Participants will wear an OE restraint system/seatbelt while in the car cab. Participants will be instructed by the research assistant when to release the seatbelt and open the door to exit the cab.

Potential Risk	Mitigation
Fire	No smoking allowed in the facility. Flammable materials kept to minimum. No open flames. Electrical wiring performed to NEC standards. Researcher and simulator staff trained in fire response and evacuation procedures. Constant voice communication line established between cab and operator in control room. Emergency stop switches located in-cab, at motion base and in control room.
Simulator induced sickness (SIS) or motion discomfort	Screening of test-participants for susceptibility. Observation by trained researcher by means of open voice communication and video and observation. Observation by trained simulator operator via remote video. Motion-base helps to eliminate motion cue mismatch (cause of SIS). Temperature controlled to minimize likelihood or effects of SIS. Use of participant suspended or discontinued at signs of or report of discomfort or illness.
Fingers/ feet caught in moving equipment, etc.	Presence of moving equipment is minimal. Instructions to participants to keep clear; guards provided where practicable; rely on practical experience and observing researcher supervision.

PROGRAM MANAGER'S ASSURANCE

I certify that:

- I have prepared and/or reviewed and approved the Project Plan and associated documents, and have filled out all IRB forms to the best of my knowledge.

- The information provided in the resulting IRB Information Packet is complete and correct to the best of my knowledge.

- As the Program Manager, I will have direct responsibility for the conduct of the study, the ethical performance of the study, the protection of the rights and welfare of human subjects, and adherence to any stipulations imposed by the IRB and DRI.

- To the best of my knowledge and ability, I agree to comply with all DRI policies and procedures, as well as with all applicable Federal, State, and local laws regarding the protection of human subjects in research, including, but not limited to, the following:

  - Performing the study by qualified personnel
  - Implementing no changes in the approved protocol or consent form without prior IRB approval
  - Obtaining the legally effective informed consent from human subjects

____ __________________

Signature of Program Manager Date

I have reviewed and approved the IRB Information Packet, the Project Plan and associated human use protocols.

____ __________________

Signature of the Technical Director or other Principal Investigator Date

HUMAN USE PROTOCOL APPROVAL FORM

Date:

Project Title and Job Number: CWIM-2, 167-5

Project Manager or Project Engineer: Dean Chiang

Other DRI Staff Members: Ana Bakker

Project Start Date: June 2012 End Date: August 2012

Location of project (check those that apply):

DRI Torrance facility ✓

- Moving base simulator ✓
- Fixed base simulator __
- Other laboratory __

DRI Minter facility __

Over-the-road tests

- Torrance __
- Minter __
- Other (describe) __

Tests at other site (describe): ____

____

The following forms are attached:

- Description of Project and Associated Risks (filled out) ✓
- Project Manager's or Engineer's Assurance (filled out) ✓
- General Information and Health Questionnaire (blank) ✓
- Daily Health Questionnaire and Consent Form (blank) ✓
- Informed Consent Form (blank) ✓
- Introduction to the Study (written) ✓
- Applied Research Participant Confidentiality Agreement (blank) ✓
- Preliminary Test Plan, DRI-TM-11-91, is included herein by reference

Is this a new application or renewal? New

If renewal, summarize history of protocol and project: ______________________________

____

____

The IRB hereby affirms that the proposed protocol and Plan satisfactorily describe the planned research, and how the human subjects are to be protected from unreasonable risk.

The Human use plan and protocol are hereby approved by the DRI Institutional Review Board.

Name ____

IRB Title ____ on behalf of the DRI IRB
(Chairman or Member)

Date ____

APPENDIX B

Driving Simulator Participant Documents and Forms

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INTRODUCTION TO THE DRIVING SIMULATOR STUDY

The purpose of this study is to evaluate driver behavior interaction with a series of vehicle system technology enhancements, which include various alert types and technologies. This study will be conducted in the DRI Full Motion Driving Simulator. The DRI Driving Simulator is a high-tech device designed to simulate the actual driving conditions of a vehicle, allowing you to experience feelings similar to real-life driving conditions. You will sit in a modified vehicle "cab" with instrumented controls and displays. Computer generated roadway scenes are used, and simulator motion is provided by a hexapod motion system. The driving simulator is similar to a flight simulator with a moving cab, or an easy ride at a theme park, such as Disneyland. The risks you will experience are similar to those of an engineering office environment, combined with some aspects of a mild amusement-park-like ride. A DRI Research Assistant will be in the cab with you at all times.

During this study, you will be driving on a four-lane highway with two lanes in each direction. You will be following a lead vehicle at all times. The simulator computer records driving data for each drive, such as your path and steering control actions and in addition, video will be recorded.

The study will consist of a single session and the total completion time will be about 3 hours. This includes arrival, preparation, driving, evaluations, and rest periods outside of the simulator.

Please read and fill out all of the accompanying documents. This should include:

- General Information and Health Questionnaire
- Driver Consent Form
- Applied Research Participant Confidentiality Agreement
- Daily Health Questionnaire

TYPICAL EVALUATION SESSION

During this study, you will be asked to drive on a variety of roads. The simulator will automatically record data for each drive, such as your path and steering control actions.

At the beginning of the driving session, you will have a practice driving session. The main purpose of this is to acquaint you, or re-acquaint you, with the simulator itself and the characteristics of the simulated car.

After the practice run, the evaluation will begin. Your primary task is to drive in the manner instructed by the DRI staff member. It is important that you be alert and comfortable throughout the session.

SAFETY PRECAUTIONS WITH THE DRIVING SIMULATOR

DRI knows that it is important to ensure the safety and well-being of all study participants. Toward that end, we want to make you aware of a number of safety precautions and procedures that have been implemented. Important among these are hardware and software safety interlocks built into the simulator. In addition are precautions you can take as follows:

In general, if you think there is a problem with the simulator procedures, say "STOP" in a loud voice. The operator will immediately shut down the simulator.

GENERAL INFORMATION AND HEALTH QUESTIONNAIRE

This questionnaire is intended to help us determine your suitability to participate in this study. The information you provide will be kept strictly confidential by the research team within DRI.

Name (Legal name) ____ Date ___________

Address ____ Phone - Home ______________

City/State/Zip ____ - Work ______________

Email Address (optional) ____

Note: Your email address will only be used to contact you about future DRI Projects.

Emergency Contact __________________________________ Their Phone _______________

PERSONAL INFORMATION:
Height ________________ Gender ________ Birthdate (MM/DD/YY) __________________

Occupation ____________________________ Employer _____________________________

General Availability for Future Studies ____

____

HEALTH INFORMATION:

1. How would you rate your general health?

   ❑Excellent ❑Good ❑Fair ❑Poor

Note: If your answer is fair or poor, you should not participate.

2. Do you wear glasses or corrective lenses for driving? ❑Yes ❑ No
3. Do you have any uncorrected visual impairment? ❑Yes ❑ No
4. What is your level of night vision?

   ❑ Excellent ❑Good ❑Fair ❑Poor

5. Are you color blind? ❑Yes ❑ No
6. Do you have any hearing impairment? ❑Yes ❑ No
7. Do you have a heart condition? ❑Yes ❑ No
8. Do you currently have back/neck pain or have you received treatment for back/neck problems within the last 3 years? ❑Yes ❑No

GENERAL INFORMATION AND HEALTH QUESTIONNAIRE (cont.)

9. Have you had or do you have any disorders that would impair your current driving ability? If yes, describe ❑Yes ❑No

____

10. Do you have any physical disability that might affect your ability to drive a car or to participate in the evaluation? If yes, describe ❑Yes ❑No

____

11. Have you had any seizures or loss of consciousness within the last 6 months? If yes, describe ❑Yes ❑No

____

12. If you are female, are you pregnant? ❑Yes ❑No

13. Are you addicted to or have you taken any illegal drugs within the last 6 months? ❑Yes ❑No

14. Do you smoke?

❑No ❑Occasionally ❑ Regularly

15. Do you consider yourself to be susceptible to motion sickness, such as car sickness or sea sickness?

❑No ❑Seldom ❑Occasionally ❑ Often ❑Always

16. Please list any medications or drugs you are currently taking

____

OTHER INFORMATION:

1. Are you or anyone in your family currently involved in a lawsuit regarding a vehicle, use of a vehicle, or a vehicle accident; or have you or they been involved in such a lawsuit within the past 5 years?

❑No ❑ Yes ❑Decline to answer

If yes, please briefly describe your or their involvement:

____

____

DRI PARTICIPANT RECRUITMENT DIALOGUE

Hello, may I please speak to *subject's name*?

This is *your name* from Dynamic Research, Inc. You participated in a driving study with us about *# of months/years* ago and we wanted to know if you would be able to help us out again. **pause to allow subject to respond**

This study involves a single session and you will receive an honorarium of *$200* for approximately 3 hours of your time. The study will take place at our Torrance location.

Do you think you would be available to participate?

(if Yes) That's great!
(*List any prerequisites required to make sure the subject qualifies*)
Are you available on *date* at *time*? *(state the first date and time available. Continue to schedule for other appointments, if necessary)*
Do you need our address and phone number? *(355 Van Ness Ave #200 Torrance CA 90501 310-212-5211)*

Thank you for your time, *subject's name*. We will see you on *scheduled date* at *time*. If for any reason you are running late or are unable to make your appointment please give us a call.

(if No)I'm sorry to hear that. Thank you for your time, *subject's name*. Please call back if you become available.

ID#

DAILY HEALTH QUESTIONNAIRE

1. How would you describe your general health today?

   ☐ Excellent ☐ Good ☐ Fair ☐ Poor

   If your answer is fair or poor you should discuss how you feel with a project team member.

2. Has there been any change in your general health in the past few days? If yes, please describe ☐ Yes ☐ No

   ____

   ____

3. In the last 24 hours have you experienced any of the following conditions?

Unusually tired feeling	☐ Yes	☐ No
Unusual hunger	☐ Yes	☐ No
Hangover	☐ Yes	☐ No
Headache	☐ Yes	☐ No
Cold symptoms	☐ Yes	☐ No
Depression	☐ Yes	☐ No
Emotional upset	☐ Yes	☐ No
Other illness or injury	☐ Yes	☐ No

4. Have you taken any prescription or non-prescription drugs in the last 48 hours? If yes, please describe ☐ Yes ☐ No

   ____

   ____

ID#

DAILY HEALTH QUESTIONNAIRE (cont)

5. Have you consumed any alcohol (beer, wine, liquor, etc.) in the last 24 hours?

   If yes, please describe type and amount. ☐ Yes ☐ No

   ____

   ____

6. Is the main car you are currently driving different than the one you were using when you completed the General Information Questionnaire? ☐ Yes ☐ No

There are some small risks you may be exposed to as a volunteer in this study. The driving simulator is similar to a video game. Since the driving simulator projects the road ahead on a screen, you may experience some of the symptoms of motion sickness; such as a headache, uneasiness, or other discomfort. You will not be driving an actual automobile or truck. So, the risks you will experience are similar to those of an office environment, combined with some aspects of a mild amusement-park-like ride. If you feel uneasy, disoriented, or motion sick, please tell a member of the evaluation team, so you can take a break. You can stop participating in this study at any time, by just telling a member of the team.

I understand the purpose of this study and the possible risks involved, and I am in good health today and ready to participate.

Signature ____ Date ________________

Team Member (Witness) ____________________________

INFORMED CONSENT FORM

Please read and understand the following.

1. Your participation. You are being asked to volunteer as a driver subject in a research project whose purpose and description are contained in the document entitled "Introduction to the Driving Simulator Study." Please read that description now, if you have not done so. Your participation will involve a single session, for about 3 hours.

2. Risks in the Study. There are some risks that you may expose yourself to in volunteering for this research study. The evaluations will be accomplished in the DRI Driving Simulator Laboratory at its facility in Torrance. The driving simulator is similar to a video game. Since the driving simulator projects the road ahead on a screen, you may experience some of the symptoms of motion sickness; such as a headache, uneasiness, or other discomfort. You will not be driving an actual automobile or truck. The risks you will experience are similar to those of an office environment, combined with some aspects of a mild amusement-park-like ride. If you feel uneasy, disoriented, or motion sick during the driving portion, please tell a member of the research team, so you can take a break. If you become too uncomfortable you can end your participation at any time (see Item 9, below).

3. Precautions. The following precautions are taken prior to and during your participation:

   – A member of the research team will be in the cab with you.

   – You will be asked to wear the shoulder/lap restraint system while in the cab.

   – Before and during the evaluations, you will be briefed on the procedures and what we want you to do.

   – DRI staff will be directing all activities and serving as safety observers.

355 Van Ness Avenue • Torrance, California 90501 • 310-212-5211 • FAX: 310-212-5046

INFORMED CONSENT FORM (cont.)

4. Use of Data and Confidentiality. The data from this study will be treated anonymously, and your name will not be identified in any publically available records or reported results. You will be video recorded during the study for data reduction and analysis purposes **only**. If you do not agree to be video recorded please let a research team member know. The data and the results of the evaluations will be the exclusive property of DRI and its customer.

5. Benefit of the Study. While there are no direct benefits to you from this research (other than an honorarium for participation), your help with the study will contribute to our knowledge of how drivers interact with various automotive technologies and driving situations.

6. Qualifications to Participate. You should not participate in this research if you are under 18 years of age, or you do not have a valid driver's license, or you are pregnant, or you have taken any drugs, alcoholic beverage, or medication within the last 24 hours that might interfere with your ability to drive or to operate a vehicle safely. It is your responsibility to inform a research team member of any conditions that might interfere with your ability to participate or drive safely. Such conditions would include inadequate sleep, fatigue, hunger, hangover, headache, cold symptoms, depression, allergies, premenstrual syndrome, emotional upset, uncorrected visual or hearing impairment, seizures (fits), nerve or muscle disease, or other similar conditions.

7. No Smoking. There will be no smoking in the simulator or inside the DRI facility.

INFORMED CONSENT FORM (cont.)

8. Questions. You should know that the research team will answer any questions that you may have about this project. You should not sign this consent form until you are satisfied that you understand all of the previous descriptions and conditions. If you have any questions please contact:

Ana Bakker
Project Engineer
Dynamic Research, Inc.
355 Van Ness Avenue, Torrance, CA 90501
Ph: 310-212-5211

or another DRI staff member

9. Okay to Stop Participating. You may withdraw from participation in this study at any time you wish now or during the session and without any penalty. Should you, for any reason, feel the need or desire to stop participating, please do not hesitate to let the safety observer or another research team member know. The DRI research team also reserves the right, for any reason, to terminate your participation in the study. You will still be paid the honorarium.

INFORMED CONSENT FORM (cont.)

10. Signature of the volunteer and date:

I have read and understand the description and scope of this research project, and I have no questions. I understand the risks outlined in Item 2, I acknowledge reading about the safety features of the driving simulator, and I satisfy all the requirements and restrictions of Item 6 (Qualifications to Participate). I hereby agree and consent to participate, and I understand that I may stop participation if I choose to do so at any time, either prior to or during the evaluation day.

Signature ________________________________

Date ___________________________________

11. Witnessing signature of a member of the research team or other responsible DRI employee and date:

Signature ________________________________

Date ___________________________________

APPLIED RESEARCH PARTICIPANT CONFIDENTIALITY AGREEMENT

As a participant in an applied research study at Dynamic Research, Inc., (DRI), I recognize that such research studies involve confidential and proprietary information and matters. This includes data, information, software, hardware, and inventions that are considered proprietary by DRI or its customers.

I agree not to divulge or discuss the details of these confidential activities, and related data, information, software, hardware, and inventions to anyone outside of DRI, either during the study period or at any time in the future. I further agree not to remove from DRI any such data, information, software, hardware, or inventions.

I hereby waive the rights to any results, findings, or consequences thereof which may result from my activities for DRI.

I agree that this research activity participation is on a voluntary at-will basis, which means that either I or DRI can terminate the relationship at any time, without prior notice, and for any reason or for no reason or cause.

I understand and agree to the above.

Signed_________________________________

Printed_________________________________

Date__________________________________

Witnessed____________________________

355 Van Ness Avenue • Torrance, California 90501 • 310-212-5211 • FAX: 310-212-5046

RESEARCH ASSISTANT PROCEEDURES AND SUBJECT INSTRUCTIONS

The following items are to be discussed with the participants before they participate in the driving simulator evaluation. Instructions in *italic* are to be given to the participants.

1. Give the participant a copy of the pre-test documentation package, and ask him to fill it out. Answer any questions the participant has while filling it out. Review the completed form. If any of the conditions listed on the daily questionnaire indicate that the participant would not be suitable to test in the simulator, thank the participant for his willingness to participate but tell him that he is being excused, and that the reason will be kept confidential. If the form is acceptable, sign and file it.

2. Review the purpose of the study, and descriptions of the evaluation.

3. How the evaluation will be conducted:

   "Today's evaluation will consist of 3 drives with a break. The entire study should take approximately 3 hours including paperwork, and ratings.

   When you are asked to drive the simulator, you will be driving a two-lane highway with a single lane going in each direction at approximately 55 mph. We ask that you drive on the main road at all times unless otherwise instructed. The conditions are daytime, and the weather will be clear. To start driving the vehicle you simply need to depress the accelerator, and to stop the vehicle you would use the brake. You will not need to worry about shifting gears.

   During your drive, you will be exposed to various alert systems and technologies in the vehicle. Please respond promptly by stating aloud what you thought each alert is/meant. Keep in mind that today's study may ask you to do things while driving that you may not ordinarily do in the real world. The simulator allows you to perform such tasks in a safe and controlled environment therefore please perform all tasks to the best of your *ability but keeping in mind that driving safely and keeping the correct distance from the vehicle traveling in front of you is your primary task.*

Anytime you are driving, I will be in the passenger seat to answer questions, give you the proper instructions, and to be a safety observer. If you feel uncomfortable in any way or you want to take a break at any time, please let me know right away.

After we are in the cab, I will need you to adjust your seat so that you can easily reach your pedals, and adjust your steering wheel so that you can easily see all the displays on your dashboard. When adjusting your seat, please keep in mind that I will need you to be able to reach the radio on your right, the CDs on your sun visor above your head, and the LCD monitor located in the center console. Once we are in the vehicle we will double check that everything is adjusted properly. For safety reasons, I will need you to fasten your seatbelt and keep it fasted until I indicate it is safe to unfasten it.

Before starting, we're going to do a quick color blindness test. After passing that, we'll go down to the simulator and get started.

4. Ratings:

   Before each driving task, review all ratings and rating scales. Describe what is being asked exactly, so that each participant will answer with the same considerations. This makes the data more consistent and more meaningful. Explain how to complete the rating scales.

The following items are to be performed as the participant enters the simulator room and proceeds to the cab.

1. Assist the participant into the cab.

2. Have the participant adjust the seat position.

3. Assist participant with the seat belt.

The following items are to be described and performed with the participants after getting in the car.

1. Review safety features:

    - Stay seated until told they can get out of the cab.
    - Use of seat belt.
    - If the participant feels any discomfort, RA should inform the Simulator Operator (SimOp) immediately.
    - Use small, smooth steering inputs and corrections. Also use smooth brake and throttle applications.

Miscellaneous pre-test tasks to be performed by the SimOp:

1. Inform the business office that testing is in progress. If testing is being performed at night, please let the business office know you will be there after hours.

INSTRUCTIONS: WARMUP

The following instructions are to be given to the participants while in the driving simulator. Instructions in *italic* are for the participant.

[In the Cab]

You will first drive a warm up highway. This time is intended to familiarize you with operating the driving simulator, to introduce you to all alerts, and to practice performing the other in-vehicle tasks (or secondary tasks) you will be asked to do during the actual study. At the beginning of your drive, you only need to depress the accelerator to start the vehicle moving. You will be following a lead vehicle during your drive, so as soon as you see the lead vehicle appear, you may begin driving. Generally, you will use small, smooth steering inputs and corrections to control your vehicle. [Demonstrate to Participant]

You will be driving approximately 55 mph on a two-lane highway with one lane going in each direction. We ask that you drive on the main road at all times and do not pass the lead vehicle unless otherwise instructed. In the event that you encounter an obstacle, please feel free to brake to avoid any collisions. Your primary task is to drive safely and maintain the proper distance from the lead vehicle, but try to do the other in-vehicle tasks to the best of your ability. The gauge located in your dashboard will indicate if you are at the correct distance from the lead vehicle in front of you[point out gauge to driver]. *When the needle on the gauge is in the green zone, you are at the correct distance. If the needle is in the right red portion of the gauge, it means you are following too closely to the vehicle in front of you. If the needle is in the left red potion of the gauge, it means you are falling too far behind. You will get a chance to test the gauge during your warm-up drive. Please try to maintain your distance within the green zone as much as possible. If for some reason you stay in red zone for too long, you will be given an audio reminder to "Stay in the green zone."*

During your warm-up drive, you will be exposed to various alert systems and technologies in the vehicle.

You will also have the opportunity to practice each in-vehicle task so that you are comfortable with them. The tasks include a number recall task, a CD task, and a trivia *task. We will need you to complete each one of these while driving. Before starting, let's go through the instructions for each of those in-vehicle tasks.*

INSTRUCTIONS: CD PLAYER TASK

First, I need you to look up at the sun visor and find the CDs stored there. Go ahead and examine each CD, and read the titles aloud. Be sure to place the CDs back in their stored location. During the study, when you hear the prompt "CD task" followed by the track number and artist name, I need you to select the correct CD from the visor, put it into the CD player, advance to the appropriate track number, and wait to hear the music. As soon as you hear the music start playing, it is important that you eject the CD and return it to the visor.

Please take a moment to examine the radio before getting started so that you are familiar with radio before we begin [Point out controls to participant]. *Let's try performing a practice before we drive. Go ahead and find the Whitney Houston CD and go to track 8. Remember to eject the CD as soon as you start to hear the song, and return the CD to its original location. Do you have any questions about the CD task? If not, let us move on to the next type of in-vehicle task.*

INSTRUCTIONS: NUMBER RECALL TASK

You will know it is time to perform a number recall task because you will hear an audio instruction say "Number Recall." A sequence of five digits will be displayed on this small LCD screen [Point to LCD screen]. *The number recall happens quickly so please look over at the screen immediately after hearing the number recall command. Make sure to see the entire sequence before responding. Once the sequence is complete, I need you to recite back all five numbers in order, aloud. When you are done reciting the sequence of numbers the task will be over. Do you have any questions about the Number Recall Task? If not, let us move on to the last type of secondary task.*

INSTRUCTIONS: TRIVIA TASK

When it is time for you to answer a trivia question, you will hear an audio instruction say "Trivia Task" indicating that there is a trivia question for you to answer. The computer will read you the trivia question and a list of possible answers will appear on the small LCD touch screen to your right [Point to LCD screen]. *Touch the answer you feel is correct and say it aloud. Be aware that the answers will be displayed for a limited amount of time so it is important to answer as quickly as possible. I am able to provide you with the correct answers for the trivia task after the drive but not during the drive. Do you have any questions about the Trivia Task?*

The warm-up drive will be approximately 15 minutes long and will give you the opportunity to become familiar with all the items we have discussed. If after your warm-up you still feel like you require more practice, please let me know. Are you ready to begin?

[to SimOp] Okay, we're ready to begin the warm-up 1.

INSTRUCTIONS: DURING WARMUP DRIVE

The following instructions are to be given to the participants while driving the warm-up road in the simulator. Make sure to read each instruction prior to the event occurring. Please follow along with a runlog to ensure that instructions are given in the proper order. Instructions in *italic* are for the participant.

[In the Cab]

During your drive I will be narrating what events are coming up so that you know what to expect.

1. Curve: *You will be receiving an audio cue alerting you that a curve is coming up on the road.*

2. LV_Brake (Aud): *You will experience a situation in which the auditory FCW will play so that you are familiar with the system.*[After alert] *That was the auditory version of the FCW.*

3. CD Task: *When you hear the "CD task" audio cue you will try to complete a CD task while driving.*

4. Traffic: *You will be receiving an audio cue indicating that there is traffic ahead.*

5. Construction: *You will be receiving an audio cue letting you know that a construction zone will be coming up on the road.*

6. Recall: *When you hear the "Number Recall" audio cue you will be trying out the number recall task while driving. Remember that after you get the cue to start you should immediately look down at the LCD monitor on your right and keep looking until all numbers are displayed. After all 5 digits are displayed you can recite the numbers aloud.*

7. Trivia: *When you hear the "Trivia task" audio cue it will be followed by a question. The possible answers will then be displayed on the LCD screen. You should say and point to the answer you feel is correct.*

8. CD Task: *You will get a second chance to practice the CD task while driving. If you are still feeling uncomfortable about doing this task while driving after the practice please let me know.*

9. Traffic: *You will be receiving an audio cue indicating that there is traffic ahead.*

10. Number Recall: *You will get a second chance to practice the Number recall task while driving. If you are still feeling uncomfortable about doing this task while driving after the practice please let me know.*

11. LV_Brake (Hap): *You will experience a situation in which the haptic FCW (forward collision warning) will activate so that you are familiar with the system.* [After it occurs] *That was the Haptic FCW you just felt. Haptic refers to that feeling of braking you felt.*

12. Trivia: *You will get a second chance to practice the trivia task while driving. If you are still feeling uncomfortable about doing this task while driving after the practice please let me know.*

13. Curve: *You will be receiving an audio cue alerting you that a curve is coming up.*

14. Construction: *You will be receiving an audio cue letting you know that a construction zone will be coming up on the road.*
    That was the end of the Warm-Up. Are you feeling comfortable with using the following distance gauge? Are you comfortable performing each secondary task while driving? Do you have any questions about tasks? Alerts? Or other items you experienced during your Warm-Up drive? Do you feel you are ready to continue on to the actual study?

[if Ready to move on]
Ok, let's get started.

[if not ready to move on]

Either start at the middle of the Warm-Up road for more practice or consult with the SimOp on how to proceed. If consulting with SimOp, take a break and consult in private.

INSTRUCTIONS: STUDY DRIVE (ROAD 1 AND 2)

[If second drive] *This drive will be very similar to the first.*

This is not a practice drive, which means we will be collecting data from this point forward. I will no longer be narrating the events before they occur. You will experience the various alerts you experienced during your warm-up/first drive. While driving I need you to promptly respond to each alert verbally by telling me what you think the alert means, aloud. [If auditory drive] *During this drive, all of the alerts you experience on this drive will be auditory.* [If haptic drive] *During this drive you will have both auditory and haptic alerts on this drive.*

You will also have the same in-vehicle tasks we practiced during the warm-up. Do you have any questions about either one of those tasks before getting started? The CD task? The trivia task? Or the number recall task? [If yes, review the secondary task instructions once again]. *Keep in mind your primary task is to drive safely and maintain the correct distance from the lead vehicle, but please try to do the in-vehicle tasks to the best of your ability.*

You will continue to use the color gauge display in your dashboard to determine if you are at the correct distance from the lead vehicle. Try to maintain your distance within the green zone as much as possible. If for some reason you stay in red zone for too long you will be given an audio reminder to "Stay in the green zone" to ensure that you are at the correct following distance.

You will be driving approximately 55 mph on a two-lane highway with one lane going in each direction. We ask that you drive on the main road at all times and do not pass the lead vehicle unless otherwise instructed. In the event that you encounter an obstacle, please feel free to brake to avoid any collisions.

This drive will be approximately 25 minutes long. During your driving talking will be kept to a minimum but please speak up if you feel uncomfortable or if you need to take a break.

Do you have any questions? Ok, we are ready to start].

Break – be sure that participant does not remove seatbelt until the SimOp indicates it is safe to do so. Make sure ratings are completed during the break. Take at least 10 minutes between drives and allow participant to stretch their legs, use the restroom, or grab a drink/snack.

FOLLOWING THE STUDY

You have now completed all of your test drives. Please complete this wellness survey and rating form [hand the SSQ and rating form to the subject]. *To complete each rating, please draw a short horizontal line on each vertical scale, at the position that most accurately describes your feelings. You may place the line anywhere along the vertical scale.*

You will be rating the appropriateness of alerts in different driving situations. How appropriate do you think that alert was?

Appropriate refers to how suitable the alert was under the driving conditions. Did you understand the alert without being too startled?

You will be rating on a scale of 1 to 5.

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

DESCRIPTIONS OF THE RATING SCALES

After each set of tasks, you will be asked to make several subjective ratings, defined as follows.

The "Ease of Performing the Primary Driving Task" refers to the mental and control effort, and attention, it took to do the main driving task of steering and speed control while also doing the secondary task. How difficult was it to accomplish the goal of the main driving task, which was to keep the car in the center of the lane at a constant speed?

The "Sense of Discomfort (or Risk) Performing the Primary Driving Task" refers to your own feeling of mental and situational discomfort while driving. During the driving task, how much did you feel insecure, unsafe, stressed, and apprehensive; versus secure, safe, relaxed, and unconcerned. Did you feel like you were in control of the situation at all times? Note that any physical discomfort you felt should not be included in this rating.

The "Ease of Performing the In-Vehicle Task" refers to the mental and control effort, and attention, it took to perform the in-vehicle task while driving. How well did you accomplish the goals of the in-vehicle task while also operating the car? This includes the period from the first to the last interaction with the task.

The "Overall Mental Workload" refers to how much mental attention and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.). "Overall" refers to the combination of the primary driving task and the in-vehicle task. Was the overall mental effort easy or demanding, simple or complex? Was it easy to divide your attention between the 2 tasks, and to do both tasks at the same time?

Rating Scales for CWIM 167-5

1 / 5

Participant: ______

Group: ______

Road: 1 (Auditory / Haptic)

(Tonal / Verbal)

The following ratings should be given after each drive.

Ease of Performing the Driving Task

- Effortless
- Easy
- Fairly Easy
- Moderately Difficult
- Difficult
- Very Difficult
- Impossible

Sense of Discomfort (or Risk) Performing the Driving Task

- None
- A Little
- Some
- Moderate
- Much
- Extreme

Ease of Performing the in-vehicle Tasks

- Effortless
- Easy
- Fairly Easy
- Moderately Difficult
- Difficult
- Very Difficult
- Impossible

Overall Mental Workload

- None
- Very Low
- Low
- Moderate
- High
- Very High
- Impossible, cannot do it

Rating Scales for CWIM 167-5

Participant: ______

2 / 5

Group: ______

Road: 1 (Auditory / Haptic)

(Tonal / Verbal)

The following ratings should be given after each drive.

Appropriate refers to how suitable the alert was under the driving conditions. Did you understand the alert without being too startled?

Curve Ahead Alert

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

Construction Ahead Alert

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

Traffic Alert

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

FCW Alert

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

Rating Scales for CWIM 167-5

Participant: ______

3 / 5

Group: ______

Road: 2 (Auditory / Haptic)

(Tonal / Verbal)

The following ratings should be given after each drive.

Ease of Performing the Driving Task

- Effortless
- Easy
- Fairly Easy
- Moderately Difficult
- Difficult
- Very Difficult
- Impossible

Sense of Discomfort (or Risk) Performing the Driving Task

- None
- A Little
- Some
- Moderate
- Much
- Extreme

Ease of Performing the in-vehicle Tasks

- Effortless
- Easy
- Fairly Easy
- Moderately Difficult
- Difficult
- Very Difficult
- Impossible

Overall Mental Workload

- None
- Very Low
- Low
- Moderate
- High
- Very High
- Impossible, cannot do it

Rating Scales for CWIM 167-5

4 / 5

Participant: ______

Group: ______

Road: 2 (Auditory / Haptic)

The following ratings should be given after each drive. (Tonal / Verbal)

Appropriate refers to how suitable the alert was under the driving conditions. Did you understand the alert without being too startled?

Curve Ahead Alert

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

Construction Ahead Alert

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

Traffic Alert

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

FCW Alert

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

Rating Scales for CWIM 167-5

Participant: ______

Group: ______

Road: ______

The following ratings should be given at the end of the study.

---

1. During your drives, did you experience situations where more than one alert occured nearly at the same time? Where you received an auditory alert promptly followed by a second auditory alert? If yes, continue. If no, skip to question 2.

☐ Yes ☐ No

1a. Appropriate refers to how suitable the alert was under the driving conditions. Did you understand the alert without being too startled?

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

1b. How confusing were the alerts? Were they presented in a way that was easy to understand and clearly interpreted?

Extremely NOT Understandable	Somewhat Understandable	Neutral	Understandable	Extremely Understandable
1	2	3	4	5

2. During your drives, did you experience situations where more than one alert occured nearly at the same time? Where you received an auditory alert promptly followed by a second haptic alert? If yes, answer the next rating question. If no, skip the next rating question.

☐ Yes ☐ No

2a. Appropriate refers to how suitable the alert was under the driving conditions. Did you understand the alert without being too startled?

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

2b. How confusing were the alerts? Were they presented in a way that was easy to understand and clearly interpreted?

Extremely NOT Understandable	Somewhat Understandable	Neutral	Understandable	Extremely Understandable
1	2	3	4	5

SSQ - POST EXPOSURE SYMPTOM CHECKLIST

Date: Participant #: Study: 167-5

Please 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.	Headache	None	Slight	Moderate	Severe
4.	Eyestrain	None	Slight	Moderate	Severe
5.	Difficulty focusing	None	Slight	Moderate	Severe
6.	Increased salivation	None	Slight	Moderate	Severe
7.	Sweating	None	Slight	Moderate	Severe
8.	Nausea	None	Slight	Moderate	Severe
9.	Difficulty concentrating	None	Slight	Moderate	Severe
10.	Fullness of the head	None	Slight	Moderate	Severe
11.	Blurred vision	None	Slight	Moderate	Severe
12.	Dizziness (eyes open)	None	Slight	Moderate	Severe
13.	Dizziness (eyes closed)	None	Slight	Moderate	Severe
14.	Vertigo*	None	Slight	Moderate	Severe
15.	Stomach awareness**	None	Slight	Moderate	Severe
16.	Burping	None	Slight	Moderate	Severe

* Vertigo is experienced as loss of orientation with respect to vertical upright.
** Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

IMPORTANT: Please inform the Research Assistant if you feel any "Moderate" or "Severe" symptoms.

POSSIBLE QUESTIONS PARTICIPANTS COULD ASK, AND ANSWERS TO BE GIVEN

1. How did I do? This study is to examine drivers' behavior. There were no measures to determine how you did.

2. The simulator did not seem realistic or correct? Thank you for your feedback. We will consider your comments. Remember, this is a simulator and some difference with the real-world is to be expected.

3. Who is this study sponsor? US Department of Transportation.

4. Will there be a way to see the results from this study? There will be a report to our customer but ID of SSN is confidential and protected. To be determined by the customer.

5. Will there be future similar studies? If interested, we can put your name down if future studies come up.

POST STUDY INSTRUCTIONS

1. Indicate to the participant that he/she should wait/rest for at least 20 min. before leaving DRI. Offer additional time to rest if the participant indicates any discomfort or fatigue. If necessary, offer to arrange alternative transportation.

2. IMPORTANT: Remind the participant that the driving in the simulator should not necessarily reflect in any way how he/she should drive back on the road. The handling of the driving simulator may not be the same as their own car. The participant needs to continue to drive in a safe manner.

3. Ask if it would be okay for someone to contact him/her at a later time to make sure everything is okay.

HONORARIUM RECORD

I, ______________________________ received $____200__________ check from

Print Name (Full Legal Name) Amount

Dynamic Research, Inc. for my participation as a research subject on

_________________.

Date

Social Security _________-__________-_______

NOTE: All personal information will be kept confidential. Your SSN will only be used in the event that you receive more than $600 from DRI in one calendar year. If this happens, DRI will send you a 1099 form for tax purposes.

____ _________________

Sign Here Date

Internal use only:

Job #: 167-5

Task #: 15F00

Check # _________ (AIB)

SIMULATOR INCIDENT REPORT

Date ________________ Time ________________ Location Full Motion Simulator (Torrance) _____

Participant number ______________ Participant name _____________________________

Research assistant __________________________ Simulator operator ___________________________

DRI staff or others present____

Project name 167-5 ____ Configuration number _________ Run number ________ Runs comp.__________

Road name or description ____

Brief description of occurrence ____

____

Subject comments or complaints ____

____

Injuries? (yes/no) _________ Describe ____

Medical assistance provided? __________ By whom?____

Describe ____

Other comments ____

Prepared by _____________________________ Date _________________ Time ______________

APPENDIX C

Scenario Specification

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

C.1 ROADWAY

The roadway consisted of straights and curves on rural streets with the occasional intersection (Figure C1). The main road is 2 lanes with a single lane going in each direction. Light traffic was present at times with opposing traffic at the rate of about 1 car every 60 sec. The length of the main road was approximately 26 mi. The posted speed limit was mostly 55 mph, with one lane going in each direction. The experimental drive was approximately 25 min in duration. Events occurred in every drive in the same order but appeared to be in a different order to participants when starting at different locations. In addition to the main starting point, the road contained several alternative starting points to aid counterbalancing. The various starting points also aided when there was a need to reset the simulator or other unexpected event. The driver was placed on the road closer to where they were before the reset or unexpected event rather than starting from the beginning.

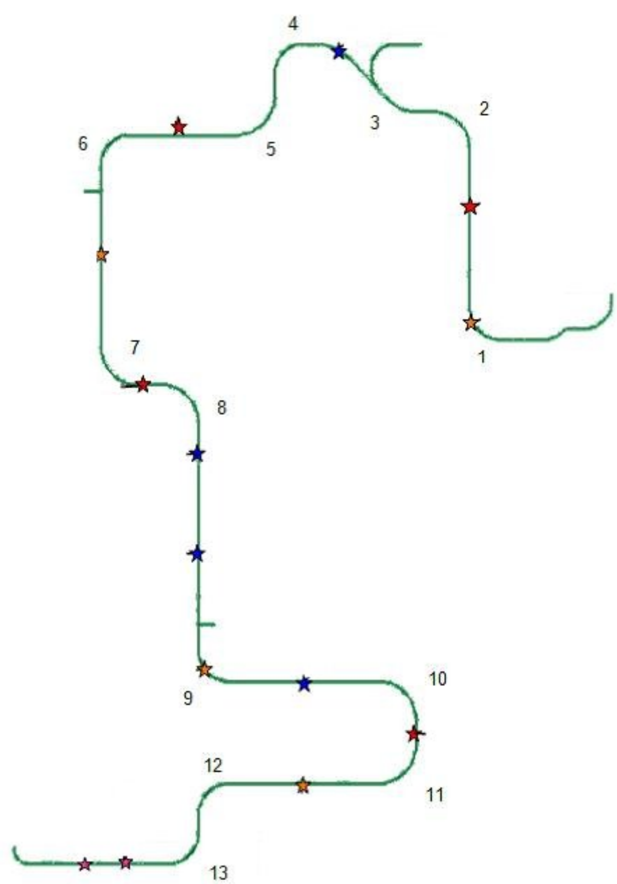


Figure C1. Graphics Roadway

Scenarios were triggered through tripwires or markers along the road. When the Subject Vehicle (SV) traveled over a tripwire, a series of events will occur. Tripwires were also set up for data collection purposes.

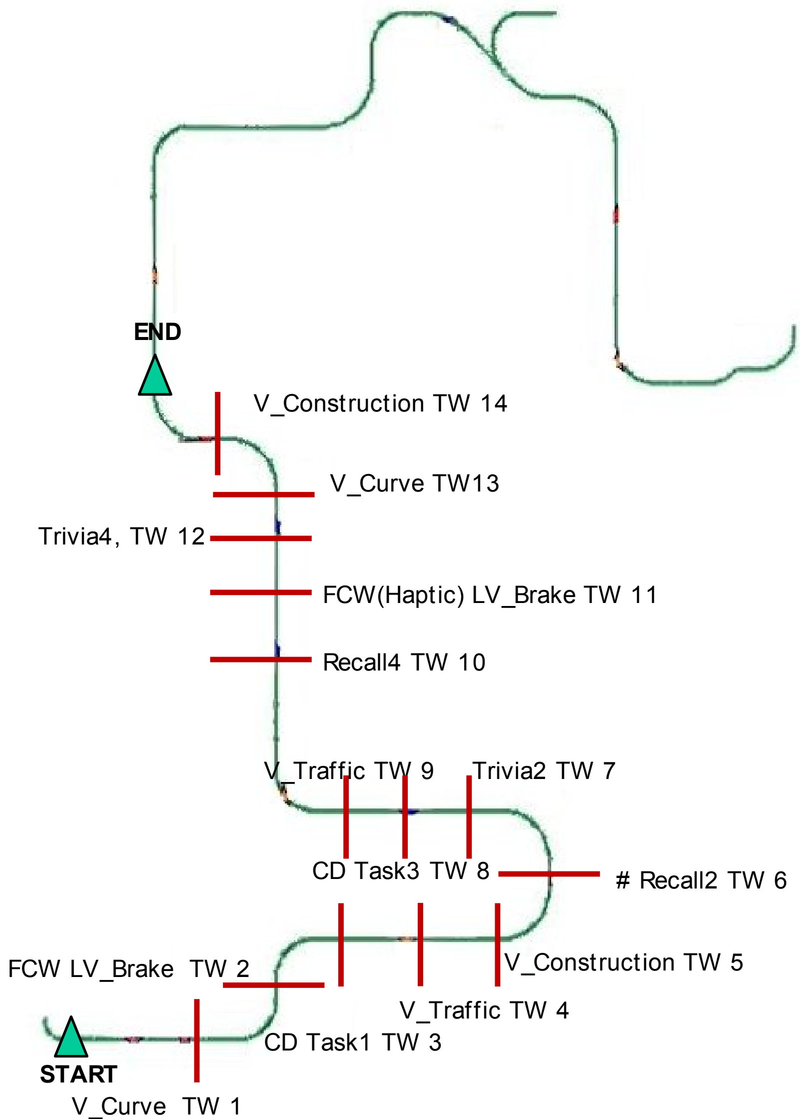


Figure C2. Warm-up Road for Group 1

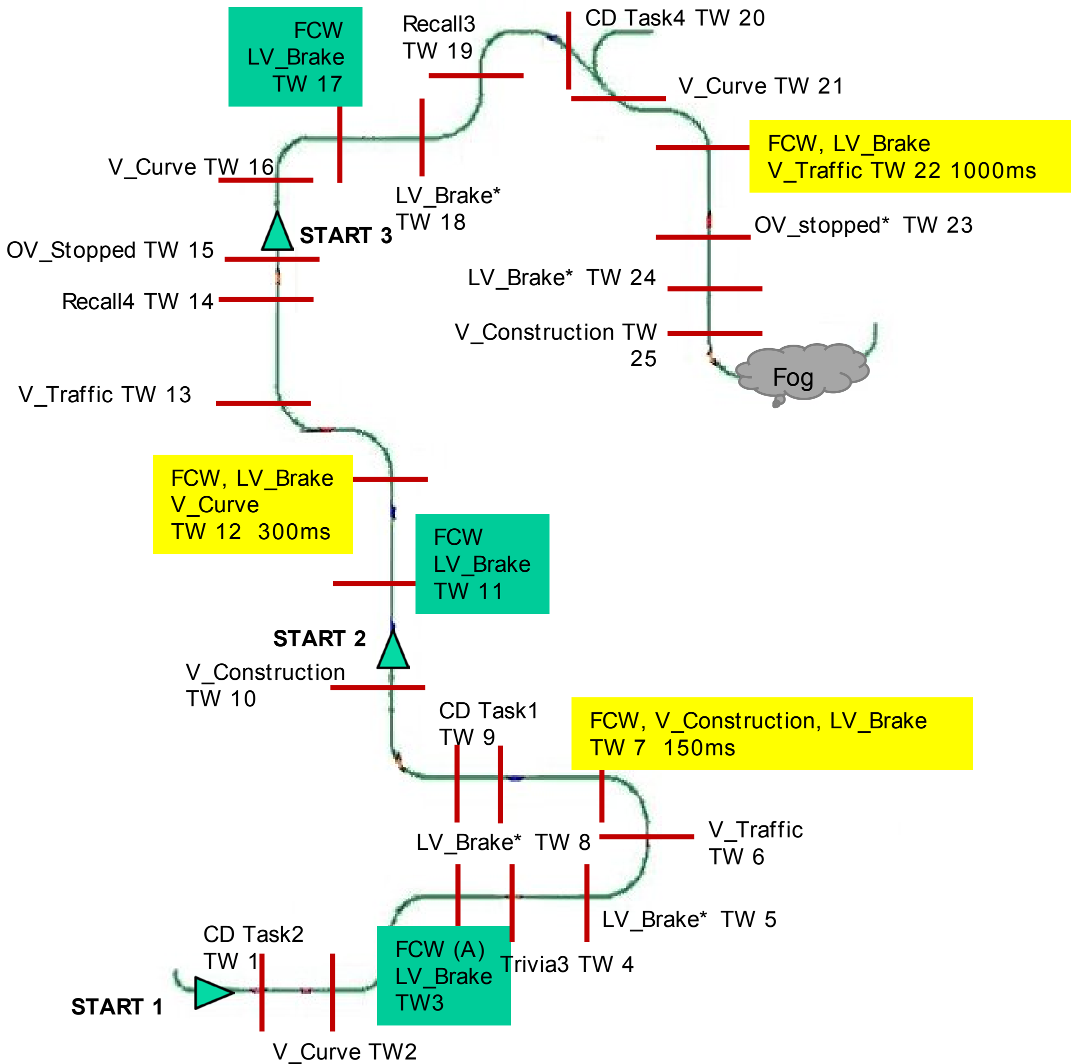


Figure C3. Road 1 for Group 1

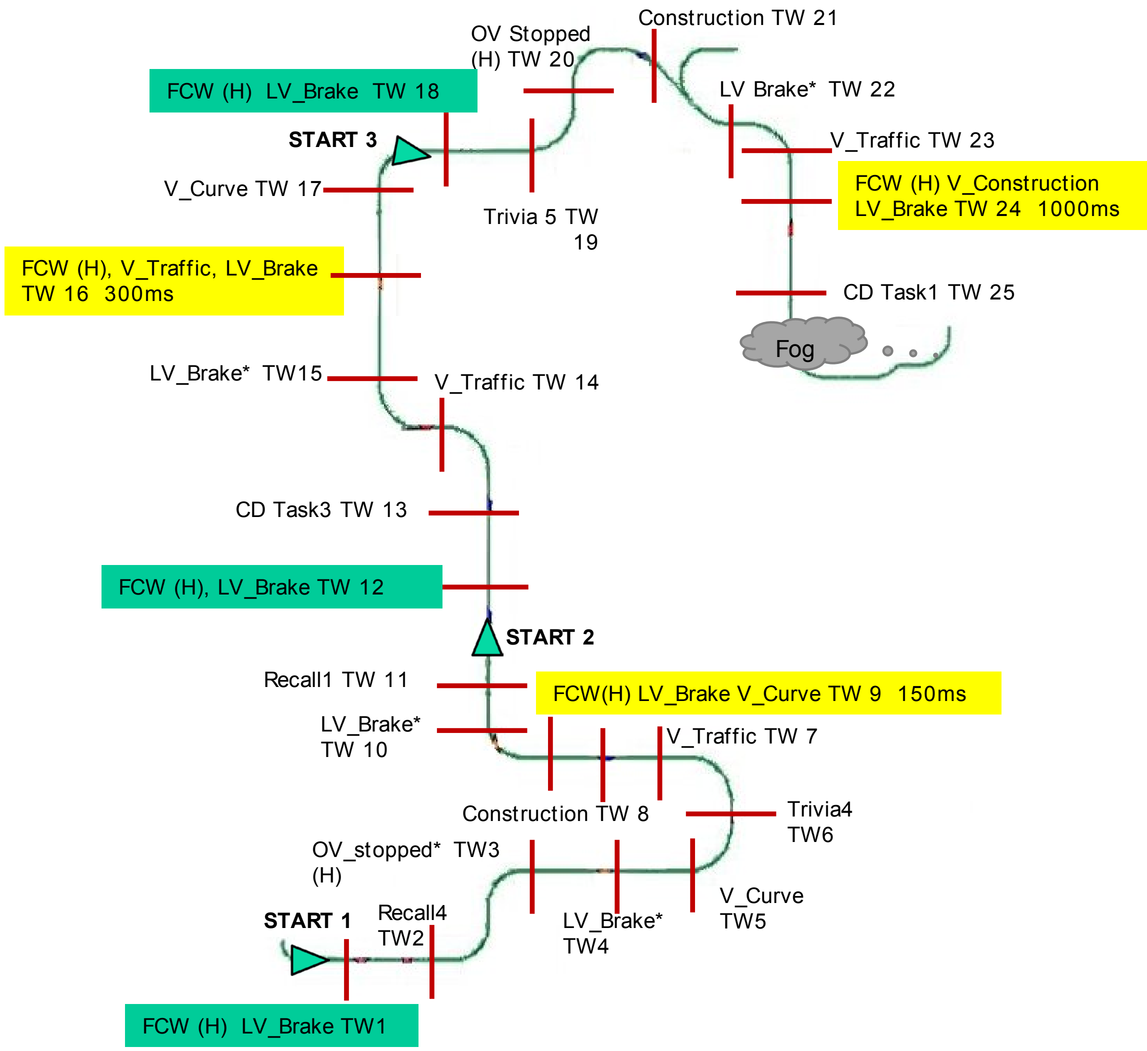


Figure C4. Road 2 for Group 1

C.2 FORWARD COLLISION WARNING SPECIFICATIONS

The Forward Collision Warning (FCW) system had two modes or ways to inform the driver that it was activated: audio alert and haptic braking pulse. The mode was set for each participant's drive using a configuration file and could not be changed during the drive. The mode determined whether the participant heard an audio alert or received a haptic braking pulse.

C.2.1 FCW-Auditory

Auditory alerts called the driver's attention to a conflict event. The audio alert used was a beeping tone with a period of 400 ms, a 50% duty cycle, for a total length of 4 sec.

C.2.2 FCW-Haptic

The specification for the active system brake pulse was accomplished by pulling the simulator platform back approximately 4.8 inches in 0.2 seconds. After 0.2 seconds, the platform is set back to zero. This offset went over whatever maneuver the participant was currently performing to ensure it was felt.

C.2.3 FCW Alert Threshold

Although the distance gauge was based on a TTC of 2.5 sec, the FCW system used was not based on TTC. The FCW system issued an alert concurrently with the lead vehicle performing the critical braking maneuver. This meant that the FCW system was 100% guaranteed to issue its alert before the subject could detect or react to the lead vehicle braking maneuver. This was done to help eliminate early braking responses to critical lead vehicle braking events.

C.3 LEAD VEHICLE EVENTS

C.3.1. Lead Braking Critical Vehicle

The SV was traveling at 55 mph on a straight and level road following a LV that was also traveling at 55 mph when the LV suddenly decelerated to 25 mph. See Figure C5.

Figure C5. Lead Vehicle Braking Event

C.3.2 False Alarm (Stopped vehicle on shoulder)

The SV encountered a stopped vehicle along the right shoulder, which was not a threat but was close enough to trigger the FCW alarm. See Figure C7.

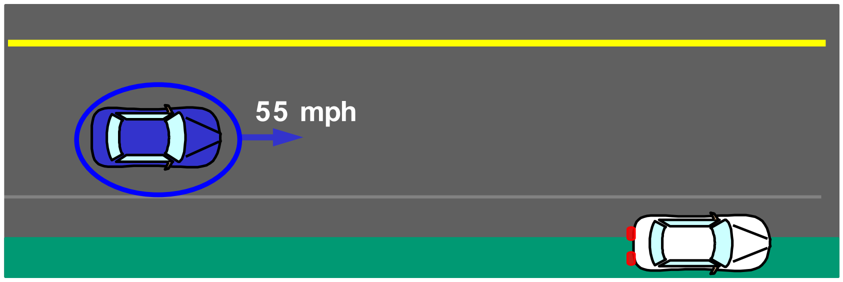


Figure C6. False Alarm Event (Stopped Vehicle)

C.3.4 Following Distance Display

The headway distance or following distance was displayed using a simulated analog headway display, which gave the driver feedback on how they should adjust their speed to meet the needs of the study (Figure C7). The display was located just under the speedometer on the right hand side (Figure C8). A color indicator was used where the display showed:

- Green: when the driver was at the target following distance
- Red: when the driver was too close to the LV the needle would move to the right red zone (i.e., going too fast), and would move to the left red zone if the driver was too far from the LV (i.e., going too slow). An acceptable range was set between a 2 and 2.5 sec time-headway.

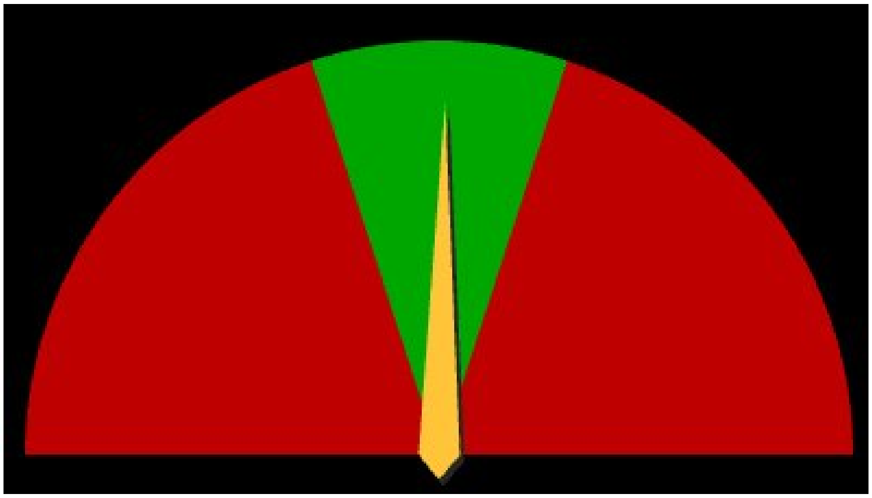


Figure C7. Following Distance Display

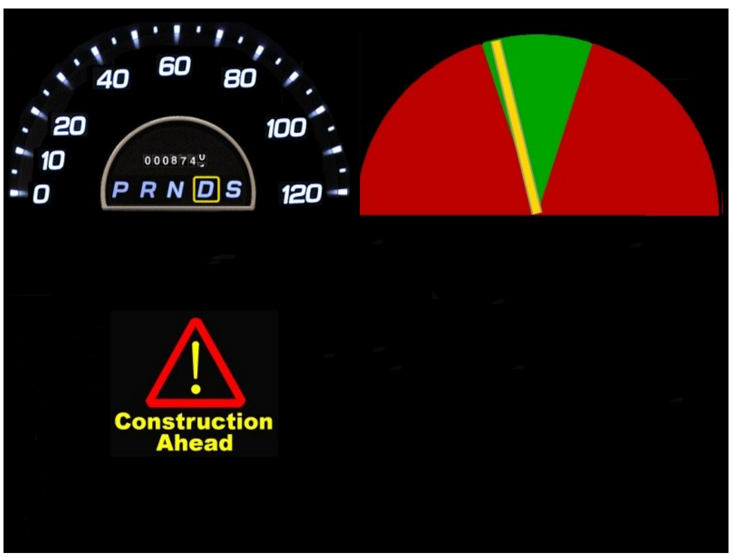


Figure C8. Dashboard Displays

C.4 EARLY ALERTS

At times the early alerts were activated before an FCW alert at varying Stimulus Onset Asynchrony or SOA time periods of either 150 ms, 300 ms, or 1000 ms. The SOA time period began at the start of the early alert and ended at the start of the FCW alerts, as described in Figure C9. Alerts were displayed just under the speedometer in the dashboard on the left hand side, see Figure C8.

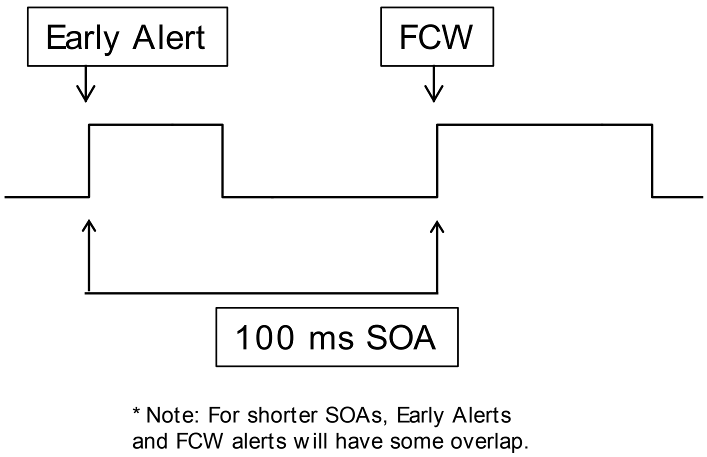


Figure C9. SOA Time Period

C.4.1 Early Alerts

All tonal early alerts used the same auditory tone. All verbal alerts were messages spoken aloud. Both the tonal and verbal alerts were the same duration.

The following SA alerts were used for this study:

- Slow traffic ahead alert 

- Curve speed alert 

- Construction ahead alert 

All early alerts occurred in realistic situations, for example, the traffic alert was always followed by a cluster of vehicles in front of the vehicle to mimic a traffic congested zone. The curve ahead alert occurred before entering into a curve on the road, and the construction alert was triggered before approaching a construction zone on the opposing traffic side. The reason the construction zone was placed on the opposing side was to prevent the participant from slowing their traveling speed and changing their headway distance, especially before an FCW event.

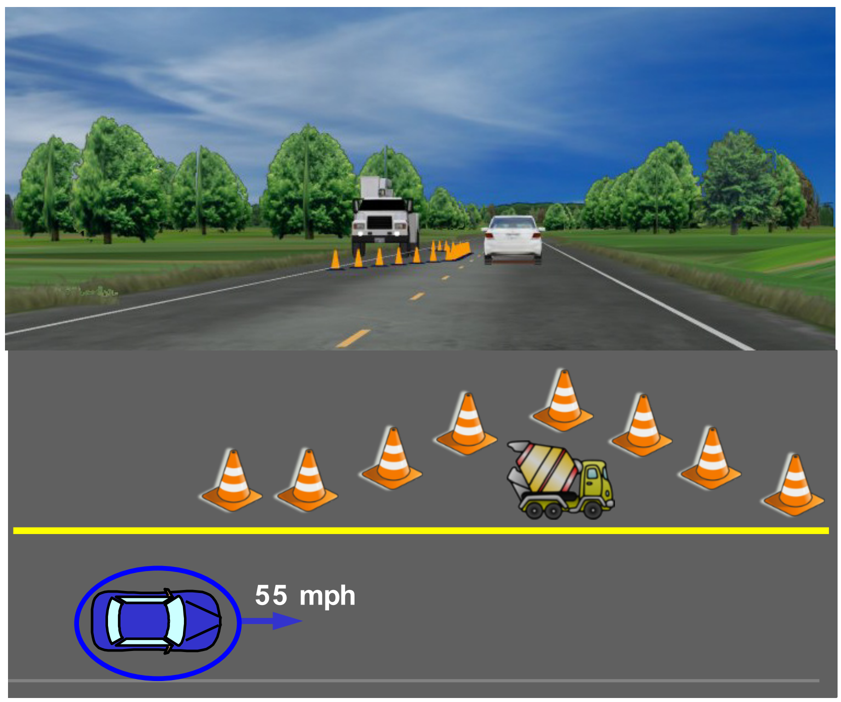


Figure C10. Sample Construction Zone

C.5 DISTRACTOR TASKS

Within each session, three distraction task events were presented. The distractor tasks were not associated with any planned FCW events but were a ruse or secondary distractor tasks.

C.5.1 Number Recall Task

A sequence of five digits were displayed on a small LCD screen and the participant was asked to recite. The display was mounted in the center console. There were a total of four different 5-digit sequences as described in Table C1.

Table C1. Number recall task list

Task	Sequence
1	8-3-6-5-6
2	4-5-9-6-7
3	1-6-0-2-1
4	8-2-4-1-2

C.5.2 CD Task

The CD task required that participants select a CD from a group of CDs stored in the cab on the driver's overhead sun visor, place it into the radio CD slot, and then advance it to a particular track before returning it to the storage location. The task lasted at least 10 sec and required several glances away from the roadway. Approximately 2000 ft of roadway was required to support this event with the instruction message requiring 1200 ft and 1200 ft to respond.

Table C2. CD task list

Artist	Track
Neil Diamond	2
Neil Diamond	7
Whitney Houston	9
Whitney Houston	10

C.5.3 Trivia Task

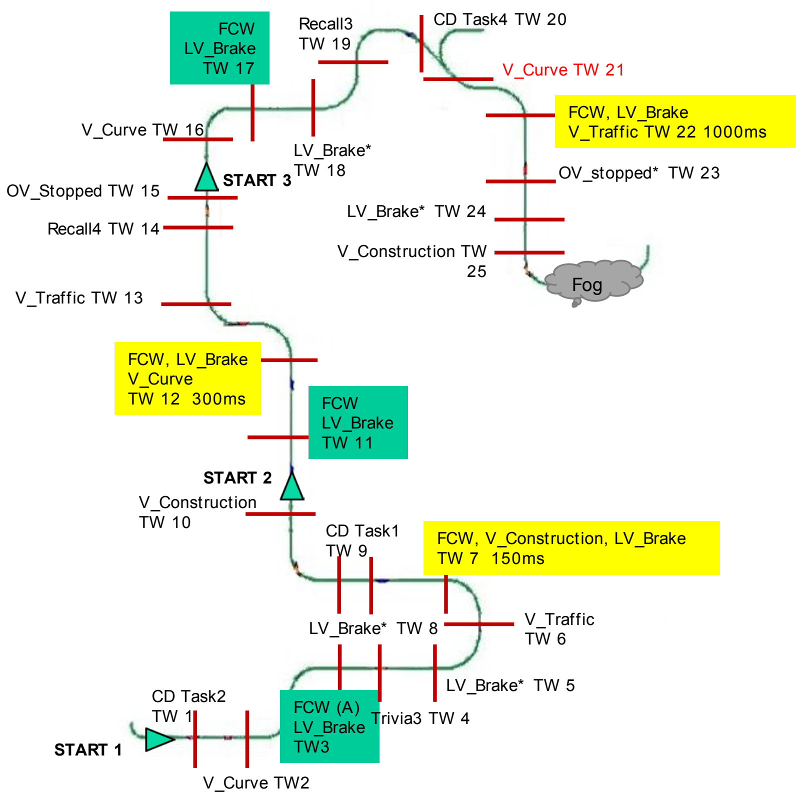
The trivia task required that the driver select the correct answer on a small LCD monitor after listening to a trivia question. Approximately 2000 ft of road was required to support this event with the instruction message requiring 1200 ft and 1200 ft to respond. There were no specific measures associated with this task.

Trivia questions include:

- "What famous document contains the sentence: we hold these truths to be self-evident; that all men are created equal" Answer: Declaration of Independence
- "What color does acid turn when applied to litmus paper" Answer: Red
- "Who blinks more - men or women?" Answer: Women
- "What is the largest freshwater lake in the world?" Answer: Lake Superior
- Which of the following animals cannot jump? Answer: Elephant

C.6 SCENARIO SEQUENCE

All scenarios were triggered to occur at specific times along the road. Below is an example timeline or runlog, which outlines the order in which scenarios occurred during a Group 1 drive.



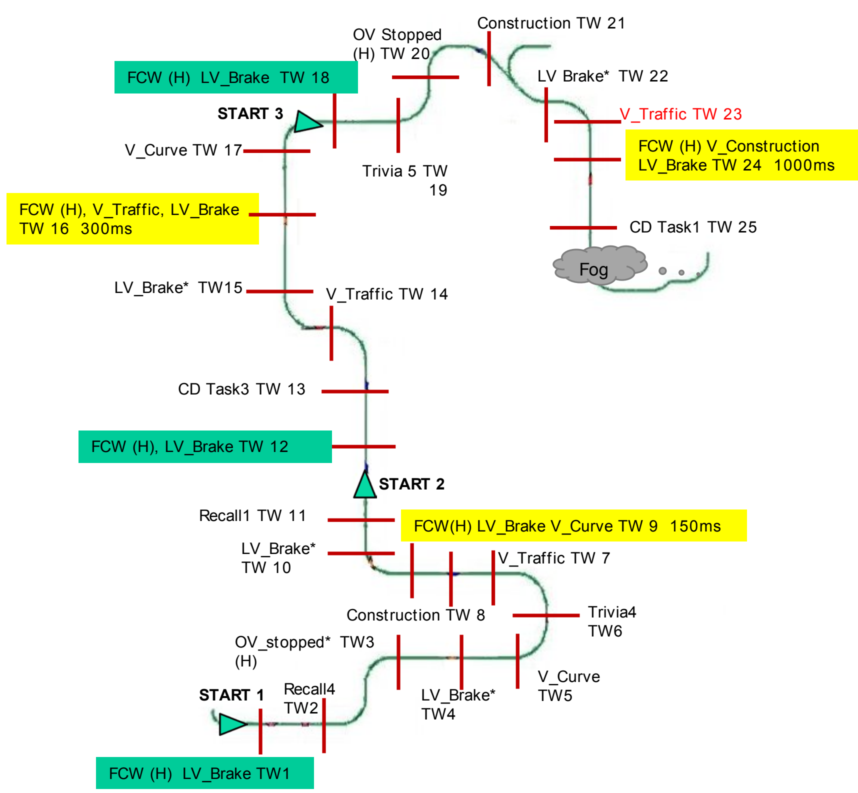


Figure C11. Sample Runlogs for roads 1 and 2

C.7 EVENT SPECIFICATIONS

This section details events and secondary tasks.

C.7.1 Lead Vehicle Events

LEAD VEHICLE CRTICIAL BRAKING	
RATIONALE	This portion of the scenario triggers the FCW alert.
ROAD NETWORK REQUIREMENTS	Straight, level road
PREPARATION	Tripwires labeled LV_Brake activate scenario.
START CONDITIONS	SV traveling approximately 55 mph on straight, level road following the LV.
ACTUAL EVENT	LV suddenly decelerates (at a value of .5 G) and slows to 25 mph.
END CONDITIONS	The LV gradually accelerates back to 55 mph. As the LV starts to move, the participant begins to follow the LV trying to maintain the appropriate headway.
PERFORMANCE MEASURES	Driver response time (braking/steering), minimum distance to lead vehicle, time of accelerator release, maximum deceleration or brake force

FALSE ALARM (STOPPED VEHICLE)	
RATIONALE	This portion of the scenario falsely triggers the FCW alert.
ROAD NETWORK REQUIREMENTS	Straight, level road
PREPARATION	Tripwires labeled LV_Stopped activate scenario.
START CONDITIONS	SV traveling approximately 55 mph on straight, level road following LV.
ACTUAL EVENT	SV encounters a vehicle parked on the right shoulder when the FCW alert is falsely activated.
END CONDITIONS	The SV continues driving in the current path.
PERFORMANCE MEASURES	None

FOLLOWING DISTANCE	
RATIONALE	To ensure the SV is at the correct distance when scenarios are activated.
ROAD NETWORK REQUIREMENTS	Highway
PREPARATION	LV; Analog headway display
START CONDITIONS	LV in front of SV with a starting distance of 181.5 ft.
ACTUAL EVENT	Driver must try to stay close to the target distance (between 2 and 2.5 sec time headway) by using analog headway display. The color indicator shows when driver is too close or too far (in red), and at an acceptable range from LV (in green).
END CONDITIONS	The display is on continuously.
PERFORMANCE MEASURES	Continuous headway distance to lead vehicle.

C.7.3 Early Alerts

EARLY ALERTS	
RATIONALE	Alerts are used for SOA purpose.
ROAD NETWORK REQUIREMENTS	None
PREPARATION	Tripwires labeled Traffic, Construction and Curve activate this scenario.
START CONDITIONS	Alert may be triggered on its own in null events or when SOA is 150, 300, or 1000 ms from FCW in critical events.
ACTUAL EVENT	Participant is driving along the road when an alert in the form of an icon appears and tone (T)/verbal (V) alert sounds. Alerts were triggered in a realistic environment. The Traffic Ahead alert was triggered before approaching a cluster of vehicles mimicking traffic in front of the lead vehicle. The Construction Ahead was triggered before approaching a construction zone located in the opposing side of traffic. The Curve Ahead alert appeared before approaching a curve on the road.
DRIVER RESPONSE	Driver should respond to the alert by verbally stating what they thought the alert was.
CLEANUP	None
PERFORMANCE MEASURES	Continuous headway distance to lead vehicle.

C.7.4 Distractor Tasks

NUMBER RECALL	
RATIONALE	Tasks are ruse to mask the true purpose of the study.
ROAD NETWORK REQUIREMENTS	Straight, level road
PREPARATION	Tripwires labeled Recall activate this scenario.
START CONDITIONS	The SV drives over the tripwire that initiates this task.
ACTUAL EVENT	Participant is given a verbal command and the number sequence of numbers is displayed on the LCD located in the center console. After all numbers are displayed, the driver is asked to verbally recite the number sequence.
END CONDITIONS	The participant tries to complete the secondary task while continuing to drive. After the task is over, driver tries to focus on maintaining headway distance.
PERFORMANCE MEASURES	Errors in number recall. Eye glance data during task.

CD TASK	
RATIONALE	Task is used as a ruse to mask the true purpose of the study.
ROAD NETWORK REQUIREMENTS	Straight, level road
PREPARATION	CDs are placed in a holder attached to driver’s sun visor.
START CONDITIONS	Tripwires labeled CD task activate this scenario.
ACTUAL EVENT	Participant is given the verbal command “CD task” followed by the CD artist and track number. Participant finds the CD located in the sun visor, puts CD into radio, forwards to correct track and puts the CD back to its storage place after hearing the first few seconds of the correct track.
END CONDITIONS	Participant places CD back to sun visor and returns to monitors their headway distance to LV.
PERFORMANCE MEASURES	Error is selecting correct CD or track number

TRIVIA TASK	
RATIONALE	Task is used as a ruse to mask the true purpose of the study.
ROAD NETWORK REQUIREMENTS	Straight, level road
PREPARATION	Tripwires labeled Trivia task activate this scenario.
START CONDITIONS	The subject vehicle drives over the tripwire that initiates this task.
ACTUAL EVENT	Participant is given a verbal command "Trivia Question" followed by the question. A short list of possible answers to the question is then displayed on a small LCD screen located in the center console where the participant is asked to select the correct answer.
END CONDITIONS	Participant selects the correct answer on the LCD screen.
PERFORMANCE MEASURES	Error in selecting the correct answer.

APPENDIX D

Data Cleaning

D.1. DATA CLEANING

Prior to data analysis, the data was reviewed to ensure that only valid data were included (see Sec 2.8.1).

a. Data filtering due to participant behaviors

   Data were filtered out of the analyzed data set if the following criteria or conditions occurred:

   - Participant braked early during a critical event.
     - Any braking occurred less than 5 sec prior to a critical or baseline alert event
     - If more than 2 braking occurrences per road session
     - If more than 2 “red” zones per road session
   - Participant was not pressing on the accelerator at the onset of lead vehicle braking. This would fail to produce an Accelerator Response and Movement time.
   - Outlier data or participant falls out of the norm compared to other participants in the study (2 standard deviations from the mean).
   - Participant driver failed to follow instructions (e.g., failed to maintain speed, ignored following distance, did not try to perform distraction tasks, etc.)
   - Participant did not understand the event and performed unexpected driving maneuvers (e.g., came to a complete stop, veered off road, waited for instruction from the Research Assistant, etc.).
   - Participant was distracted by something other than items planned during the event (e.g., talked during event, answered phone, drinking water, experiencing motion or simulator sickness, etc.)
   - Driver failed to set off the FCW alerts by either braking too soon, stopping before the event occurs, swerving before entering the FCW alert zone, etc.
   - Participant failed to complete the study for various reasons.

b. Data filtering due to event failures.

   An event was considered invalid if one of the following event failures occurred:

   - FCW Haptic:
     - If an event failed to initiate the haptic warning.
   - FCW Audio:

  - If an audio alert failed or was accompanied by other audio alerts that were not part of the event.
  - The incorrect audio was played.
  - The audio file failed to play at the correct sound level.

- Early alert

  - Failed to occur when planned.
  - Failed to play correct audio state (tone versus verbal).
  - Was not accompanied by an alert icon.
  - The incorrect audio file was played.
  - The audio file failed to play at the correct sound level.

APPENDIX E

ADDITIONAL RESULTS

E.1 ACCELERATOR REACTION TIME

Table E-1 summarizes the number of samples (N) by event type. Collecting a value for Accelerator Reaction presented a few difficulties when participants had their foot off the accelerator prior to a critical event. In those cases, an Accelerator Reaction value was not collected. Although Accelerator Reaction values were sometimes missing, Total Response time was used to capture those missing fractions of time. The following graph contains the means and standard errors for Accelerator Reaction by critical event type.

Table E-1. Accelerator Reaction Count (N)

Accelerator Reaction (Verbal)	N	Accelerator Reaction (Tonal)	N
Audio FCW	17	Audio FCW	16
Haptic FCW	15	Haptic FCW	17
Audio FCW 150 ms	16	Audio FCW 150 ms	16
Audio FCW 300 ms	14	Audio FCW 300 ms	15
Audio FCW 1000 ms	10	Audio FCW 1000 ms	13
Haptic FCW 150 ms	15	Haptic FCW 150 ms	15
Haptic FCW 300 ms	16	Haptic FCW 300 ms	18
Haptic FCW 1000 ms	11	Haptic FCW 1000 ms	9
Max Number	18	Max Number	18

*Note: Missing Perception times are due to participant having their foot off of the accelerator prior to the event. This is mostly due to their adjusting speed prior to the event.

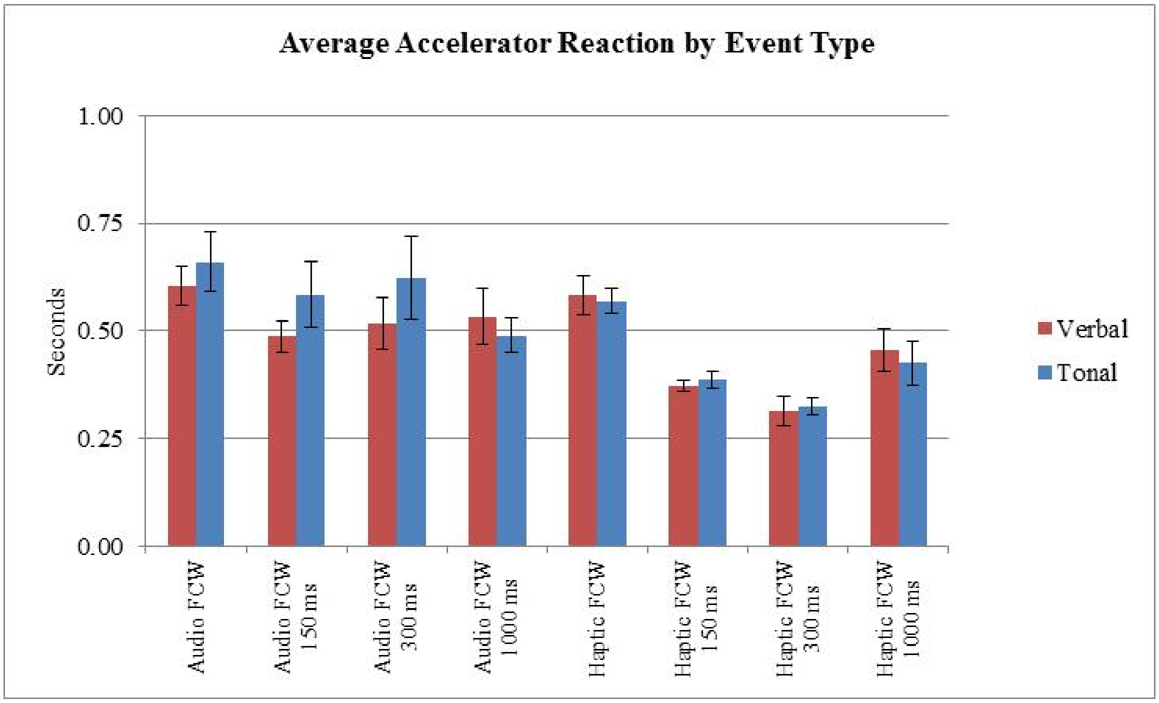


Figure E-1. Accelerator Reaction Time Means and Standard Errors

There were no statistical differences within the Verbal group for Accelerator Reaction time, but there were differences within the Tonal Early Alert group for FCW type ($p = 0.029$) where Haptic FCW alert events resulted in shorter Accelerator Reaction times than Auditory FCW alert events.

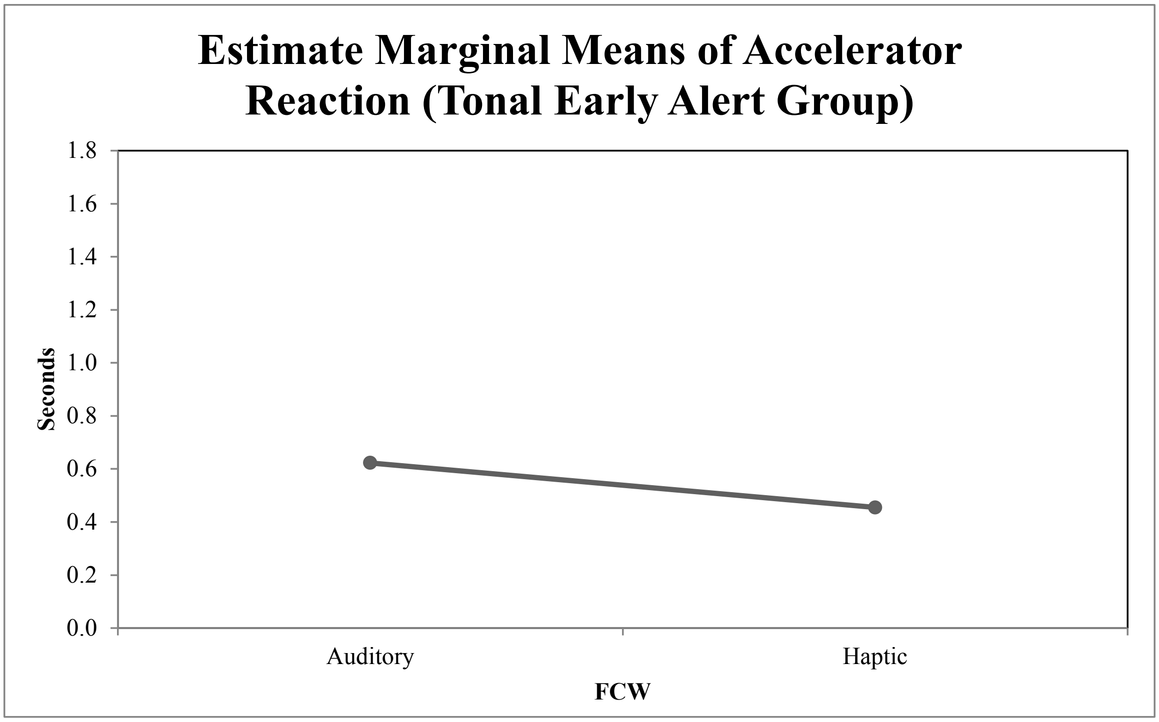


Figure E-2. FCW Marginal Means for Accelerator Reaction Time (Tonal Group)

A repeated measures analysis revealed that there was a significant difference between the Auditory and Haptic FCW alert events (p = 0.018), such that Accelerator Reaction times were significantly shorter when the FCW was haptic than when it was auditory. There was also a significant interaction between FCW type and SOA (p = 0.031), where 150 ms and a 300 ms decreased Accelerator Reaction time but an SOA of 1000 ms with a Haptic FCW resulted in an increase of Accelerator reaction time. Accelerator Reaction time continued to decrease when 1000 ms SOA was paired with an Auditory FCW.

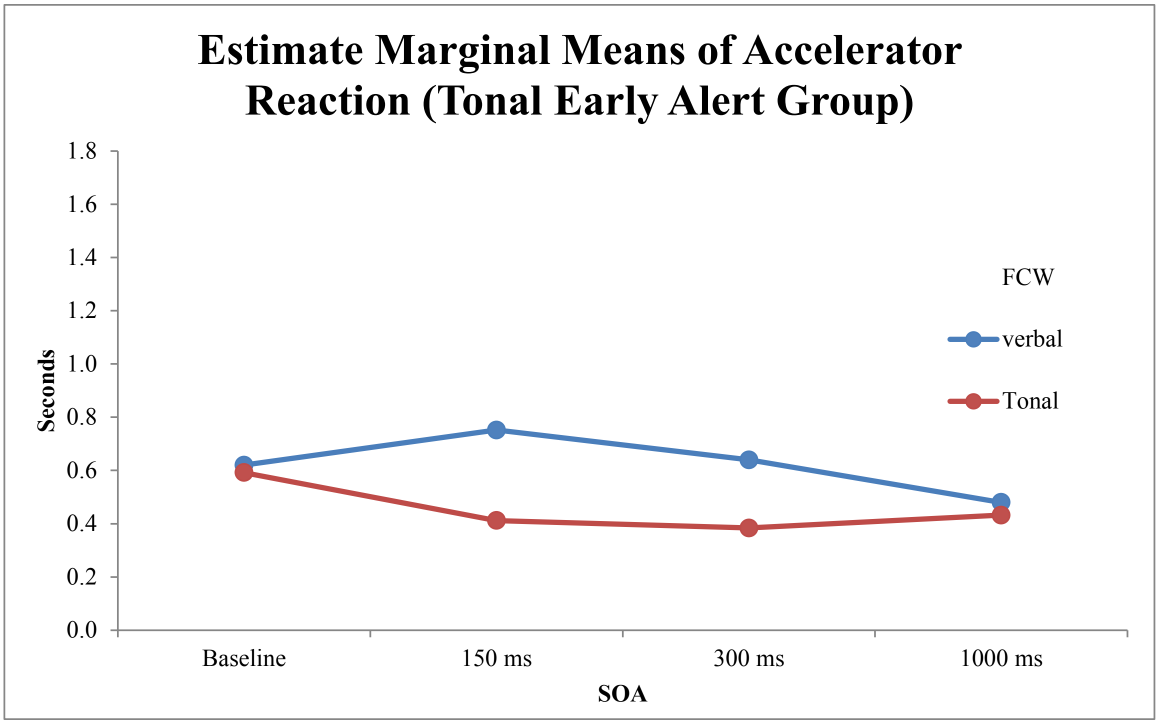


Figure E-3. FCW and SOA Marginal Means for Accelerator Reaction Time (Tonal Group)

Paired comparisons of Accelerator Reaction times show that when comparing Baseline events, significant differences exist between the Baseline Haptic FCW events and FCW with Verbal Early events with SOA of 150 and 300 ms. There are also significant differences between Auditory FCW Baseline events and Tonal Early Events with SOA of 1000 ms. Lastly, data show that All Tonal Early Alert events were significantly different from the Haptic FCW Baseline events.

Table E-2. t-Test for Accelerator Reaction Times When Compairing Baseline Events

Accelerator Reaction Ttests

Verbal							
Audio FCW	150 ms	300 ms	1000 ms	Haptic FCW	150 ms	300 ms	1000 ms
	0.052	0.249	0.390		0.000	0.000	0.070
Tonal							
Audio FCW	150 ms	300 ms	1000 ms	Haptic FCW	150 ms	300 ms	1000 ms
	0.461	0.746	0.042		0.000	0.000	0.031

E.1.1 Accelerator to Brake Movement Time

Table E-3 summarizes the total number of samples for each event type. Accelerator to Brake Movement also presented difficulties and were not captured if Accelerator Reaction values were missing. The following graph contains the means and standard errors by critical event for Accelerator to Brake Movement.

Table E-3. Accelerator to Brake Movement Time Count (N)

Accelerator to Brake Movement (Verbal)	N	Accelerator to Brake Movement (Tonal)	N
Audio FCW	17	Audio FCW	16
Haptic FCW	15	Haptic FCW	17
Audio FCW 150 ms	16	Audio FCW 150 ms	16
Audio FCW 300 ms	14	Audio FCW 300 ms	15
Audio FCW 1000 ms	10	Audio FCW 1000 ms	13
Haptic FCW 150 ms	15	Haptic FCW 150 ms	15
Haptic FCW 300 ms	16	Haptic FCW 300 ms	18
Haptic FCW 1000 ms	11	Haptic FCW 1000 ms	9
Max Number	18	Max Number	18

*Note: Missing Movement data is due to missing Perception data.

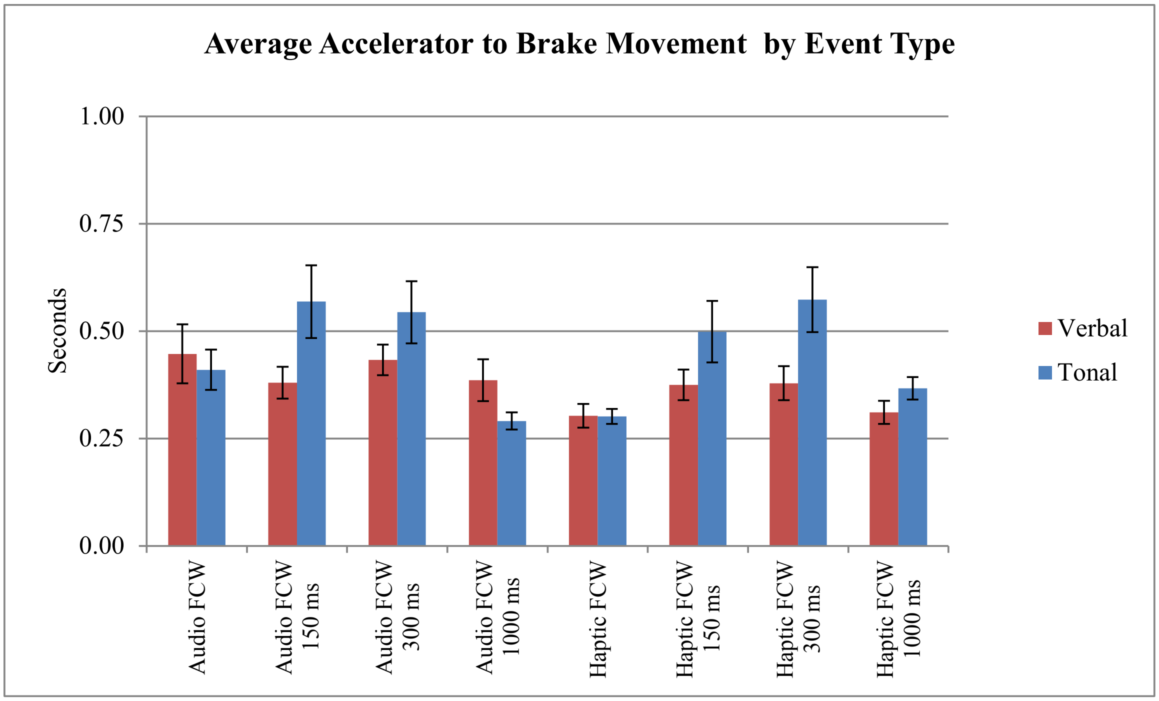


Figure E-4. Accelerator to Brake Movement Time Means and Standard Errors

E.1.2 Accelerator to Brake Movement Time Inferential Statistics

There was a marginal significant difference between Auditory and Haptic FCW ($p = 0.052$) for Accelerator to Brake Movement time in the Verbal Early Alert group where the Haptic FCW alert events resulted in significantly shorter Accelerator to Brake Movement times, than with the Auditory FCW alerts events.

There was also a significant difference between SOA times ($p = 0.039$) for Accelerator to Brake Movement times in the Tonal Early Alert group where the Baseline and SOA of 1000 ms resulted in significantly shorter Accelerator to Brake Movement times, than 150 ms or 300 ms SOA.

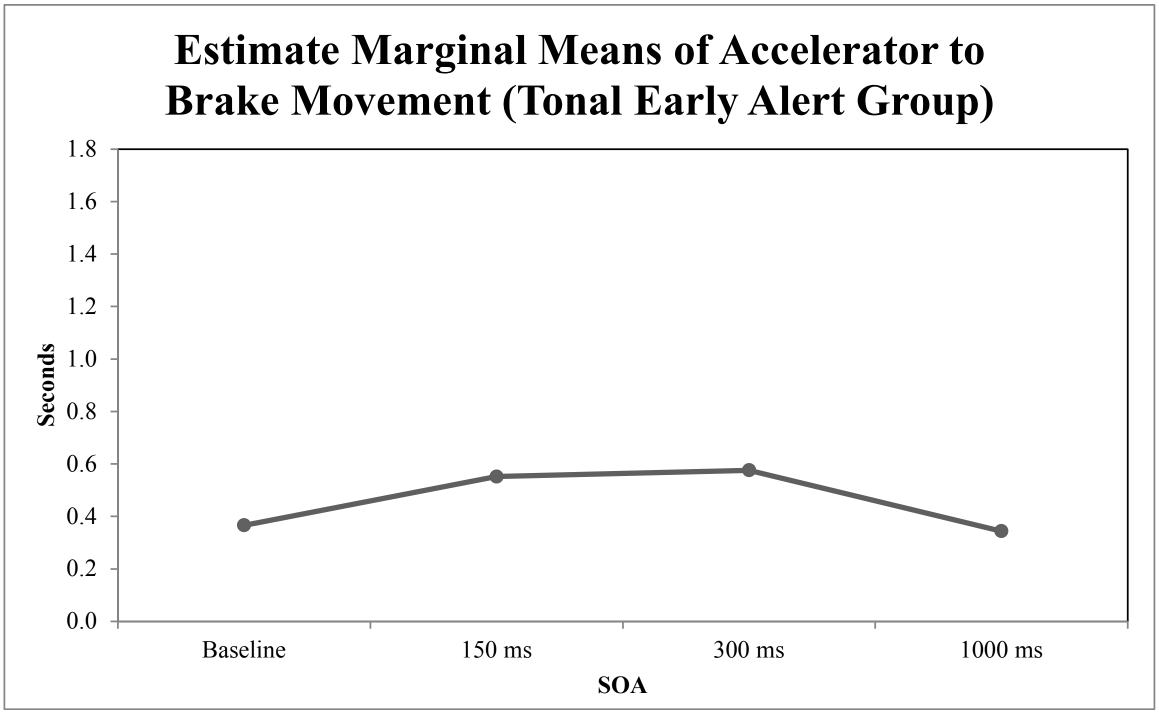


Figure E-5. SOA Marginal Means for Accelerator to Brake Movement Time (Tonal Group)

Paired comparison analysis on Accelerator to Brake Movement times between Baseline events and Tonal Early Alert events show that significant differences existed between the Haptic FCW Baseline and Tonal Early Alert events with an SOA of 1000 ms. There were also significant differences between Haptic FCW Baseline events and Tonal Early Alert events with SOA of 150 and 300 ms.

Table E-4. t-Test for Accelerator Reaction Times When Compairing Accelerator to Brake Movement Times

	Accelerator to Brake Movement Ttests			
Audio FCW	Audio FCW V 150 ms	0.40	Audio FCW T 150 ms	0.12
	Audio FCW V 300 ms	0.86	Audio FCW T 300 ms	0.13
	Audio FCW V 1000 ms	0.48	Audio FCW T 1000 ms	0.03
Haptic FCW	Haptic FCW V 150 ms	0.12	Haptic FCW T 150 ms	0.02
	Haptic FCW V 300 ms	0.13	Haptic FCW T 300 ms	0.00
	Haptic FCW V 1000 ms	0.83	Haptic FCW T 1000 ms	0.05

E.1.3 Max Brake Movement Time

Table E-5 summarizes the total number of samples per event type. Most events were accounted for, except those that contained early braking prior to a critical event. The following graph contains the means and standard errors by critical event for Max Brake Movement time.

Table E-5. Max Brake Movement Time Count (N)

Max Brake Movement (Verbal)	N	Max Brake Movement (Tonal)	N
Audio FCW	18	Audio FCW	18
Haptic FCW	18	Haptic FCW	18
Audio FCW 150 ms	18	Audio FCW 150 ms	18
Audio FCW 300 ms	18	Audio FCW 300 ms	18
Audio FCW 1000 ms	18	Audio FCW 1000 ms	17
Haptic FCW 150 ms	17	Haptic FCW 150 ms	18
Haptic FCW 300 ms	18	Haptic FCW 300 ms	18
Haptic FCW 1000 ms	17	Haptic FCW 1000 ms	16
Max Number	18	Max Number	18

*Note: Missing Brake Reaction data is due to early braking.

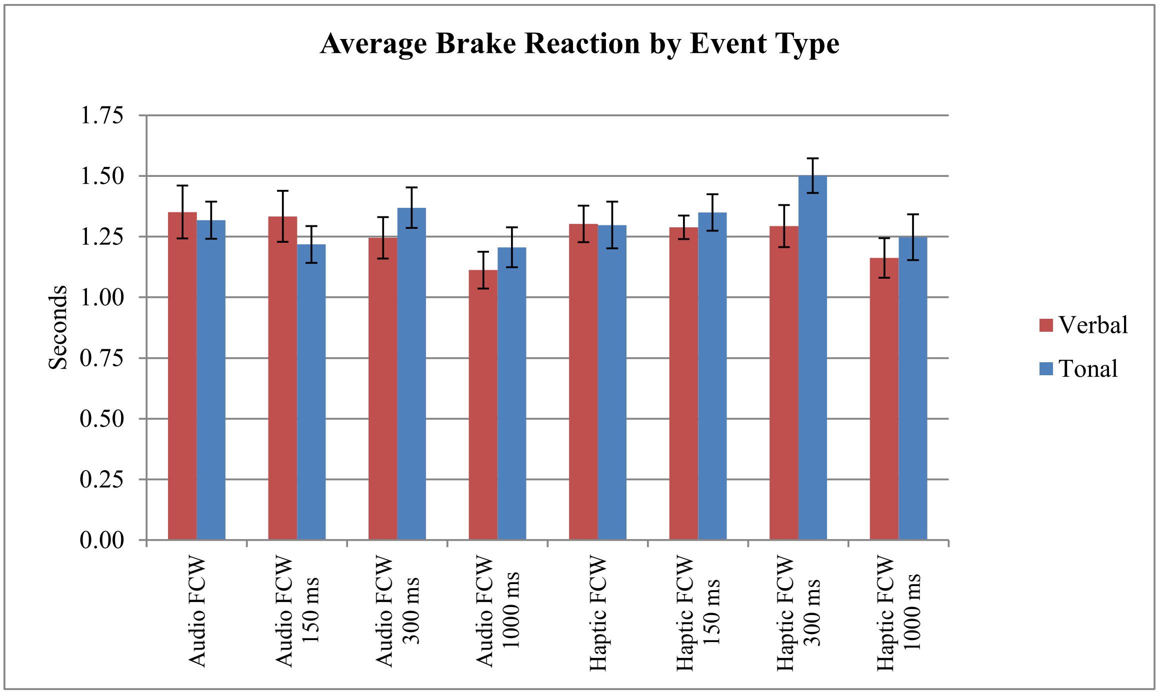


Figure E-6. Max Brake Movement Time Means and Standard Errors

There was a statistical difference in the Verbal Early Alert group for Max Brake Movement between SOA times ($p = 0.027$) where having any early alert resulted in shorter Max Brake Movement times, with 1000 ms SOA having the shortest Max Brake Movement time.

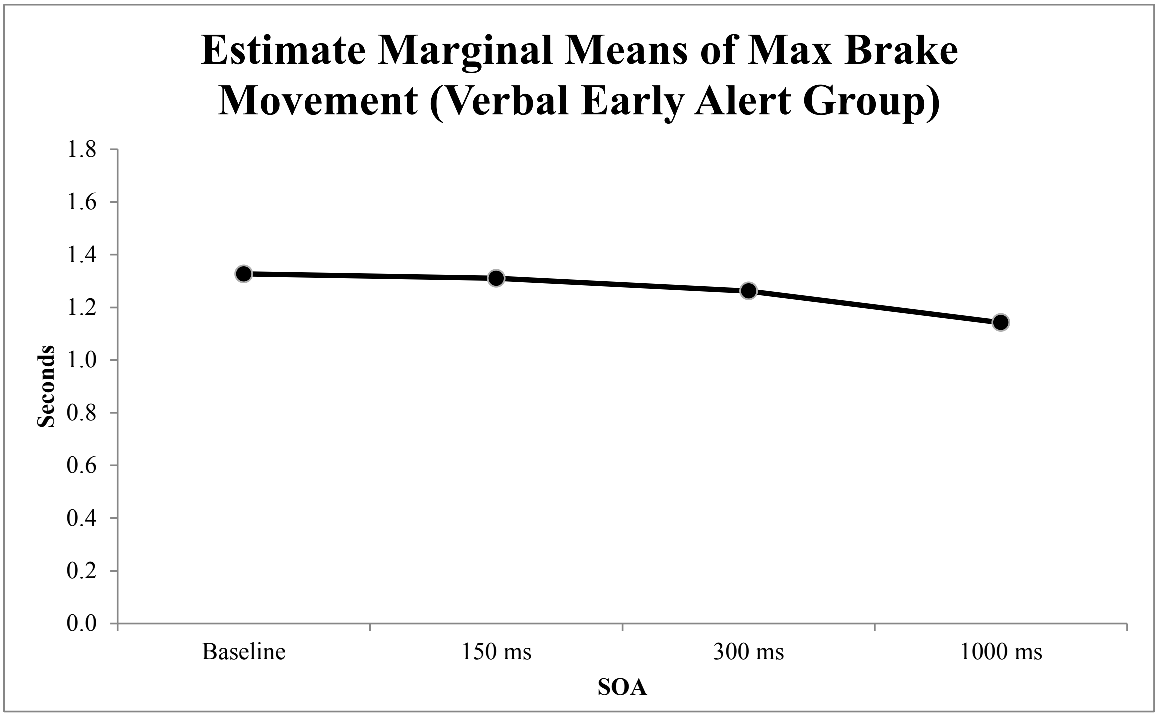


Figure E-7. SOA Marginal Means for Max Brake Movement Time (Verbal Group)

There was also a marginal statistical difference between SOAs (p = 0.046) for the Tonal Early Alert group where having a 300 ms SOA resulted in the largest Max Brake Movement times and a 1000 ms SOA resulted in having the shortest Max Brake Movement times.

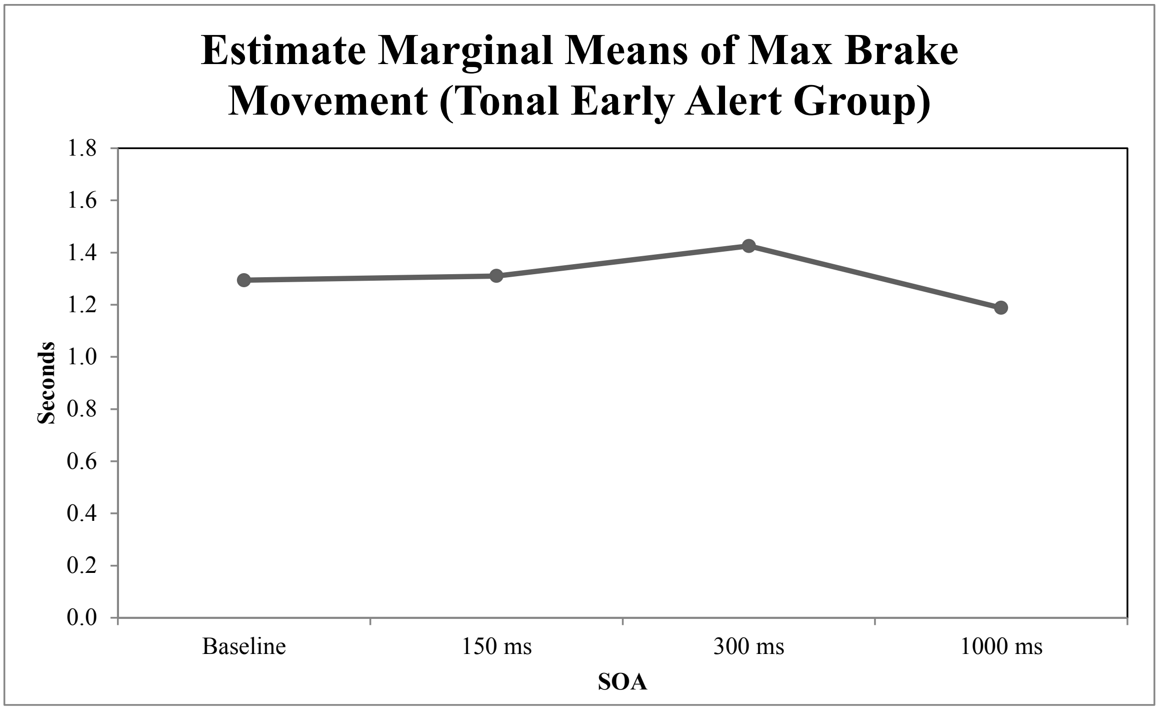


Figure E-8. SOA Marginal Means for Max Brake Movement Time (Tonal Group)

A repeated measures analysis revealed a statistical difference between SOA times on Max Brake Movement ($p = 0.003$) such that Max Brake Movement time increased as SOA increased but and decreased at 1000 ms SOA.

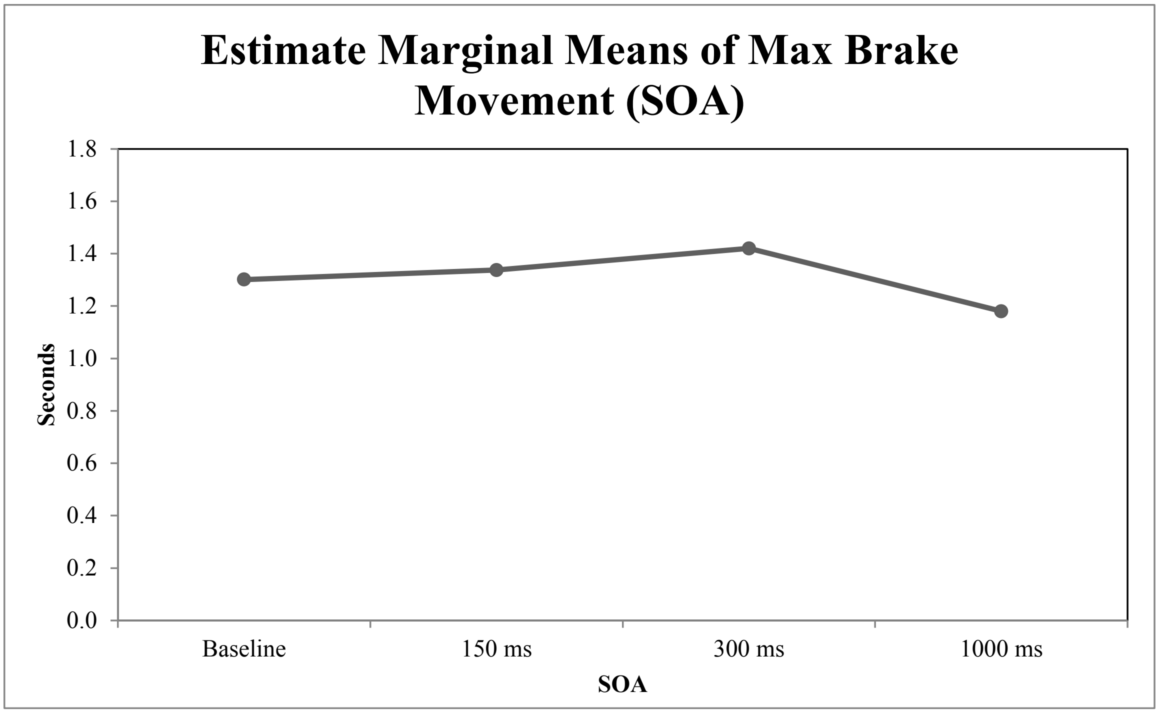


Figure E-9. SOA Marginal Means for Max Brake Movement Time (All Participants)

Paired comparisons revealed that there were no statistical differences between Baseline events and Verbal and Tonal Early Alert events for Max Brake Movement.

Table E-6. t-Tests for Paired Comparisons Between Baseline Events for Max Brake Movement Time

Max Brake Movement T-tests

<table>
<tr><td colspan="8">Verbal</td></tr>
<tr><td rowspan="2">Audio FCW</td><td>150 ms</td><td>300 ms</td><td>1000 ms</td><td rowspan="2">Haptic FCW</td><td>150 ms</td><td>300 ms</td><td>1000 ms</td></tr>
<tr><td>0.907</td><td>0.451</td><td>0.082</td><td>0.877</td><td>0.939</td><td>0.215</td></tr>
<tr><td colspan="8">Tonal</td></tr>
<tr><td rowspan="2">Audio FCW</td><td>150 ms</td><td>300 ms</td><td>1000 ms</td><td rowspan="2">Haptic FCW</td><td>150 ms</td><td>300 ms</td><td>1000 ms</td></tr>
<tr><td>0.359</td><td>0.655</td><td>0.328</td><td>0.672</td><td>0.100</td><td>0.711</td></tr>
</table>

E.2 ADDITIONAL RESULTS DISCUSSION AND CONCLUSIONS

Accelerator Reaction Time

Accelerator Reaction time was defined as the time in which the LV critical braking event was triggered to the time in which the participant released their foot off the accelerator. This measure proved to be difficult to acquire in instances where the participant had their foot off the accelerator before the LV braking event was triggered. Although measures were taken to minimize the number of times in which this occurred, it was still an unpredictable behavior that could not be avoided for this study. Closer investigation of these instances showed that drivers tended to take their foot off the accelerator to adjust their speed. Results for Accelerator Reaction time showed that having a Haptic FCW resulted in shorter Accelerator Reaction times than having an Auditory FCW. These results were true for both Verbal and Tonal Early Alert events. Results showed an interaction between FCW type and SOA in which Accelerator Reaction time increased for SOA times larger than 300 ms with a Haptic FCW but continued to decrease with an Auditory FCW. Because several Accelerator Reaction times were not captured, other measures are given heavier considered in the final discussion.

Accelerator to Brake Movement Time

Accelerator to Brake Movement time was defined as the time it took the participant to move their released accelerator foot to the brake pedal in response to a LV braking event. When Accelerator Reaction time was missing, Movement was also not available by definition. As expected, Accelerator to Brake Movement time results were similar to Accelerator Reaction time results in which having a Haptic FCW resulted in shorter or shorter Accelerator to Brake Movement times than having an Auditory FCW. Accelerator to Brake Movement data also revealed that Accelerator to Brake Movement times were shortest when Tonal Early Alert events were combined with an SOA of 1000 ms. This result is consistent with research by Wiese and Lee. Again, due to several missing Accelerator to Brake Movement times, other measures will provide a more analysis in the final discussion.

Max Brake Movement Time

Max Brake Movement time was defined as the time it took participants to go from initial braking to maximum braking during a LV braking critical event. Data revealed that for both Verbal and Tonal Early Alert events, and SOA of 1000 ms resulted in the shortest Max Brake Movement times.

Driver-Vehicle Interfaces for Advanced Crash Warning Systems: Research on Evaluation Methods and Warning Signals

Appendix F

Driving Simulator Results For Research on the Safety Implications Of Psychological Refractory Period For Advance Collision Warning System and Early Safety-Related Alerts for the Distracted Driver

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

REVISION HISTORY

Version	Date	Notes
DRI-TR-13-10	2013-07-26	First draft
	2013-07-29	Added Conclusions
	2013-07-30	Deleted Extended Total Response Time
DRI-TR-13-10-1	2013-09-04	Respond to Westat comments. Updated glance results
DRI-TR-13-10-2	2014-01-27	Respond to NHTSA comments

ABBREVIATIONS USED IN THIS DOCUMENT

ACWS	Advanced Collision Warning System
CWIM	Crash Warning Interface Metrics
DD	Distracted Driver
DRI	Dynamic Research, Inc.
DVI	Driver Vehicle Interface
EA	Early Alert
IP	Instrument Panel
LV	Lead Vehicle
NHTSA	National Highway Traffic Safety Administration
PRP	Psychological Refractory Period
RA	Research Assistant
SOA	Stimulus Onset Asynchrony
SV	Subject Vehicle
TTC	Time to Collision

1. INTRODUCTION

In-vehicle technologies are becoming more popular and vehicles are now being equipped with various warning systems, safety features, and entertainment systems. Although the design of each system is taken into consideration to ensure each performs as intended, little research addresses the integration of these systems and how they may affect the driver's intended response. Time-critical or urgent warning systems such as those designed to avoid collisions, lane departures, and other potentially critical situations may be in competition with the alerts and notifications of less urgent systems such as those designed for notification purposes. If tasks share the same perceptual and response mode, then resource competition is greater. Therefore, two auditory alerts have greater resource competition than systems that differ in perceptual mode, such as an auditory alert and a haptic alert (Wickens 1984, 2002, Haigney and Westerman 2001). Just as important is the coordination and timing of alerts and how one might affect the driver's response time to another. Wiese and Lee (2004) addressed the issue in terms of the Psychological refractory period or PRP effect, which refers to the delayed response a person has to a second stimulus when the temporal proximity or period between it and an initial stimulus is short. Wiese and Lee performed two studies where they varied the onset time between two alerts to examine which of the two times, a 300 ms stimulus onset asynchrony (SOA) or random non-concurrent onsets, caused less temporal conflict and had less of an effect on the driver's performance. They hypothesized that a less urgent event (an auditory email message alert) would interfere with a more urgent alert (auditory collision avoidance alert). In their first study, Wise and Lee triggered an email alert 300 ms before a collision warning alert and found that the email alert interfered with driver's response to the collision warnings. However, in a second study, Wiese and Lee triggered an email alert at 1000 ms prior to the collision warning and found the opposite effect had occurred; the onset of the email alert enhanced the response to the collision +warning by improving the braking process and inducing a faster accelerator pedal release.

A later study by Levy, Pashler, and Boer (2006) tested predictions of the central bottleneck hypothesis, which applies when the information processing stage of response selection limits dual-task performance by acting as a bottleneck, and predictions of hypotheses about interference from common stimulus and response modalities. Participants in the 2006 study were asked to perform two tasks simultaneously while performing a simulated driving task. A choice task was used where participants responded either manually or vocally to the number of times an auditory or visual stimulus occurred. The second task required participants to brake as soon as they observed the lead vehicle brake lights. The SOA, which is the time between the onsets of the task stimuli, varied between 150, 350, and 1200 ms. Although the choice task was considered to be an easy task, the braking task still suffered from dual-task interference. Comparison of reaction times at 0 and 350 ms SOA indicated a braking delay effect of more than 16 ft for a vehicle traveling at 65 mph. Brake reaction times increased as the SOA was reduced which showed signs of PRP effect. However, contrasting the Wiese and Lee study, the 1200 ms SOA participants had slower brake reaction times than those with 350 ms SOA but not slower than those with 0 or 150 ms SOA. This may be due to the fact that participants were less prepared to brake having gotten used to shorter SOAs.

Similar studies have examined the effects of a secondary task or distractor task on driver braking reaction times by varying the SOA. A series of studies by Lee, et al. (2002), varied the initial headway of the participant vehicle to a lead vehicle, initial forward speed, and different levels of rear-end collision avoidance system alerts. In the first study of the series, a rear-end collision avoidance system was triggered at three different alert algorithm thresholds, none, late, and early detection. Results showed that an early alert provided the greatest benefit and led to earlier release of the accelerator pedal and more gradual braking. The current study took this and chose to look at SOA times of 150, 300, and 100 ms to determine if reaction time would change depending on SOA timing.

The overall goal of the previous or phase 1 crash warning interface metrics (CWIM) PRP study (DRI-TR-13-01, 2013) was to evaluate various onset time intervals between less urgent safety-related alerts (early alerts or EA) and forward collision warning system (FCW) to more fully define the magnitude of the PRP. It also had the objective to determine if the results would be similar to those in past studies such as those found in the first study by Wiese and Lee, and study by Hibberd et al. (2010) where shorter SOA times resulted in slower brake reaction times. In contrast, longer SOA times (1000 ms) may result in brake reaction times that are not negatively affected by EA. Safety-related EA include non-verbal (tonal) and verbal auditory alerts. In addition, the study hoped to determine if there would be similar results as those found past research where alerts with similar perceptual modes will interfere with one another more than alerts with different perceptual modes (Wickens 1984, 2002, Haigney and Westerman 2001). In other words, would pairing haptic FCW alert events with auditory EA (both tonal and verbal) result in quicker braking times than when auditory FCW alert events are paired with auditory EAs?

In the phase 1 of the CWIM PRP effort, participants were exposed to either verbal or tonal less urgent EA in combination with both auditory and haptic FCW alerts. The SOA between both alerts was varied by 150, 300, or 1000 ms. In some instances, drivers were exposed to a single (FCW) alert, and other times they were exposed to an EA followed by an FCW alert before experiencing a critical event in the form of a lead vehicle (LV) braking event. Drivers were not intentionally distracted when alerts were set off.

The phase 1 CWIM PRP study found that having a non-urgent safety related EA during a LV braking event was a benefit most of the time, compared to not having an EA present. The only times this was not the case was when a tonal EA was presented at 150 ms SOA. This may suggest that the EA served as a type of pre-alert or pre-cue for participants in this study. If considering an FCW system in a vehicle, these results tend to support a haptic FCW over an auditory FCW in producing quicker response times and longer minimum distances during LV braking events. When combining an FCW system with an earlier non-urgent safety related alert, the results from the first phase of CWIM suggest that a combination of haptic FCW and verbal EA would enhance response time and thus improve braking response. The findings from past research found that alerts with similar perception modes would interfere. For SOA interval times, these results tended to support previous research from Wiese and Lee, and Hibberd, that shorter SOA times may hinder brake response time as opposed to larger SOA times, such as 1000 ms, which may in fact enhance response time.

In the phase 2 PRP experiment, there was a key methodological difference from the phase 1 experimental method. Drivers in phase 2 were engaged in a distractor task during the PRP manipulations. For the phase 2 experiment, we examined how the temporal relationship of the EA to FCW onset can affect how distracted drivers (DD) respond to FCW. It is unclear how drivers' reaction times will differ when their attention is divided between two tasks (driving and the distractor task) at the onset of a critical event. Previous research by Hibberd et al (2010) found that the presentation of an in-vehicle task 350 ms before a braking event delayed braking 174 ms in contrast to 146 ms without an in-vehicle task and resulted in a 5.45 m increase in stopping distance. Therefore, this study hypothesizes that when presenting an in-vehicle task prior to a critical braking event, it will cause a delay in total reaction and braking reaction times, along with shortened distance between the subject vehicle (SV) and LV.

2. EXPERIMENTAL SETUP

2.1. DRIVING SIMULATOR

The Dynamic Research, Inc., (DRI) motion base driving simulator was used to accomplish the driving evaluations (Figure 1). The DRI driving simulator is a research grade motion base driving simulator. It has a dynamically realistic, moving base with 6 degree of freedom hexapod motion, "driver-in-the-loop" research device. It has a 180 degree forward field of view, a fully instrumented car cab with a control force steering loader, and surround-sound audio system where the speakers are located against the right and left A-pillars of the cab. Cameras were mounted to record the steering by the driver, the forward view of the simulator roadway, the overhead view of the simulator roadway, and the foot movements of the participant while driving.

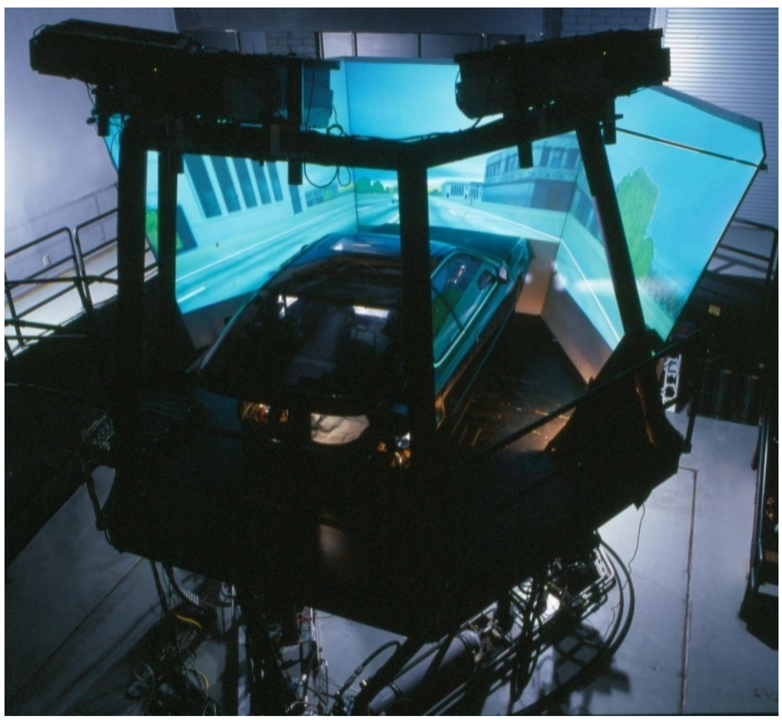


Figure 1. DRI Motion Based Simulator

2.2. PARTICIPANTS

A total of 36 typical drivers were used in this evaluation. Participants were between ages of 35 and 55 years old with an average age of 47 years old and a standard deviation of 5.7 years. All participants were in generally good health. An equal number of males and females were recruited that had a minimum of 10,000 miles of driving per year and a driver's license for at least two years. Participants also had corrected 20/40 vision, were not color blind, were able to hear all alerts, and did not have any other limitations that may impair their driving. Participants could not have participated in the previous CWIM PRP experiments. Four participants were replaced because they failed to complete the study or were eliminated for responding to the alert prior to the distraction task.

2.3. INDEPENDENT VARIABLES

The objective of this study was to evaluate various onset time intervals between less urgent safety-related alerts and a FCW, for the DD situation, to more fully define the magnitude of the PRP using the following independent variables.

- LV braking events (1 types)
- SOA times (3 intervals)
- EA types (2 alert types)
- FCW modes (2 configurations)

Independent variable descriptions are listed below. The study used similar variables as used by the phase 1 CWIM PRP effort in order to provide consistency.

2.3.1 FCW modes

The following FCW alert modes were adopted from the phase 1 CWIM PRP study conducted for NHTSA in 2012:

- Auditory FCW alert: A pulsing tone with a period of 400 ms, a 50% duty cycle, and a total length of four sec. The auditory alert used by past PRP efforts was used in the current study.
- Haptic FCW alert: A simulated vehicle brake pulse with the driving simulator platform moving back 4.8 in in 0.2 sec and set back to zero in 0.2 sec.

The FCW alert was issued when the participant driver passed over a driving simulator scenario tripwire, at that point the LV begins the critical braking event (see 2.3.4).

2.3.2 EA types

Two non-urgent safety-related EA types were used, with 3 alerts for each alert type (see B.4.1 for additional alert descriptions):

- Verbal: “traffic ahead”, “curve ahead”, and “construction ahead”
- Tonal: non-verbal tone (the same tone was used for all early alerts)

A visual icon always accompanied each alert. The same visual icon was used for each paired verbal and tonal alerts. The EA icon was also displayed on the IP, as seen in Figure 3. Drivers were asked to adjust their seats and steering wheels to ensure they could clearly see all items displayed in the IP. The icon helped drivers identify EA for both the audio and tonal conditions.

- Slow traffic ahead alert 

- Curve speed alert 

- Construction ahead alert 

2.3.3 SOA times

The following list of SOAs from the phase 1 CWIM PRP study between the EA and the FCW were used for the current study:

- 150 ms
- 300 ms
- 1000 ms

The results from short intervals of 150 and 300 ms will provide a better understanding of the possible interfering effects. The 1000 ms condition will provide possible confirmation of either no negative effect or benefit to the FCW response behavior.

2.3.4 LV braking task

One type of braking event was used.

LV critical braking event

The SV was traveling at approximately 55 mph on a straight and level road following a LV that was also traveling at 55 mph when the LV suddenly decelerated, 0.82 sec prior to the number task audio instruction, to 25 mph at a rate of 0.5 G.

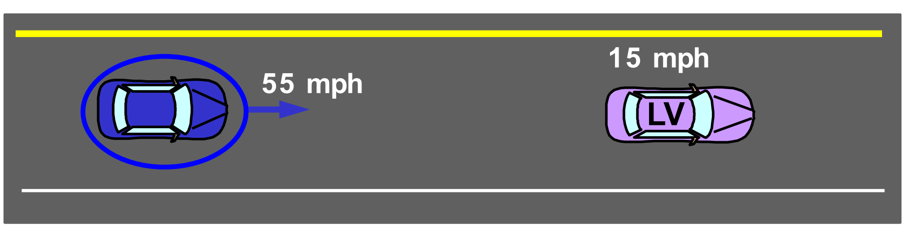


Figure 2. Example Lead Vehicle Critical Braking Event

2.3.5 Headway distance gauge

The headway distance or following distance to the LV was displayed using a simulated analog headway display located in the instrument panel (IP), which gave the driver feedback on how they should adjust their speed to meet the needs of the study to maintain headway between 2-2.5 sec (Figure 3). Additional details are provided in Appendix B (Scenario Specification).

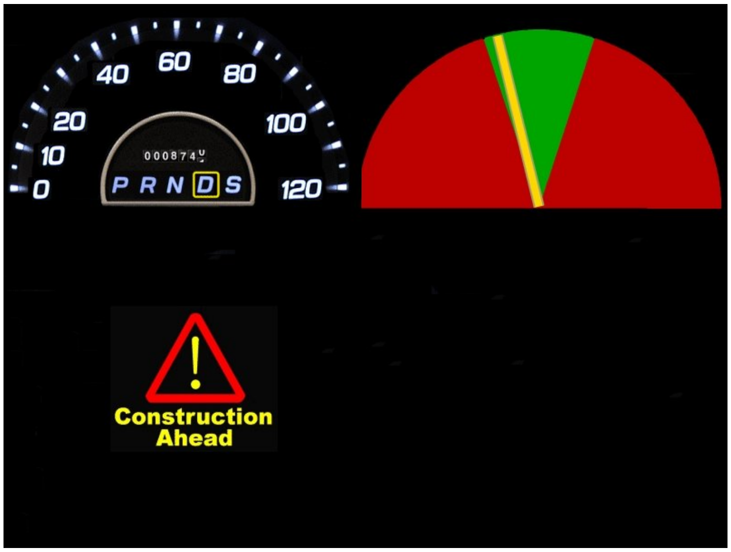


Figure 3. Headway Display Gauge (Upper Right); Early Alert Icon (Lower Left)

2.4. TEST PLAN

The driving simulator evaluation varied the FCW modality (auditory, haptic) across blocks of trials. The experimental design also varied the interval between the EA and FCW onset within subjects. The experimental design varied the type (verbal, tonal) of the EA between subjects.

A total of 36 driver participants were included in the driving simulator evaluation. The order of the EA and FCW alerts were counterbalanced with the critical braking events in order to minimize learning effects. Seventy six percent of events in each road were null distractor tasks and alerts events in order to minimize an association of braking events paired with a particular alert type. Participants were randomly assigned to one of the two main EA Type groups (verbal and tonal) with 18 participants per group. A within-subjects experimental design was used in each of the EA Types. With 2 FCW (auditory and haptic) modes and 3 SOA intervals, resulting in 6 counterbalanced configurations within each EA type group. In addition, each participant drove a warm-up road to become familiar with the driving simulator and then drove the actual road. The specific road conditions depended on the group the participant was placed in. After the warm-up road participants were familiar with all alerts and tasks. The no alert baseline1 (LV critical braking, no FCW and no EA) was presented at the end of the warm-up road. The baseline1 event needed to be a complete surprise to participants; therefore it was placed at the end of the warm-up road which is before participants had any prior exposure to any LV critical braking events, and was therefore completely unexpected. The baseline2 event (LV critical braking, auditory FCW or haptic FCW without any EA) was placed as the first condition after baseline1, and with 3 occurrences per road . Table 1 summarizes the order of the blocks in which critical events were presented depending on the EA Type group assignment.

Table 1. Participant Groups

Group 1	Verbal EA type by order of presentation								
	N/A	Auditory FCW				Haptic FCW			
SOA	Baseline1	Baseline2	150 ms	300 ms	1000 ms	Baseline2	150 ms	300 ms	1000 ms
1A	1	2	3	4	5	6	7	8	9
1B	1	2	5	3	4	6	9	7	8
1C	1	2	4	5	3	6	8	9	7
1D	1	6	7	8	9	2	3	4	5
1E	1	6	9	7	8	2	5	3	4
1F	1	6	8	9	7	2	4	5	3

Group 2	Tonal EA type by order of presentation								
	N/A	Auditory FCW				Haptic FCW			
SOA	Baseline1	Baseline2	150 ms	300 ms	1000 ms	Baseline2	150 ms	300 ms	1000 ms
2A	1	2	3	4	5	6	7	8	9
2B	1	2	5	3	4	6	9	7	8
2C	1	2	4	5	3	6	8	9	7
2D	1	6	7	8	9	2	3	4	5
2E	1	6	9	7	8	2	5	3	4
2F	1	6	8	9	7	2	4	5	3

2.5. DISTRACTOR TASK

A number task distractor task was paired with critical and non-critical events. During a critical event, an LV braking event occurred while the participant tried to complete a number task Number tasks were paired with critical events only 25 percent of the time. During a non-critical event, no LV braking events were presented while participants completed a number task. The task required that participants verbally repeat a sequence of five digits displayed on an LCD screen. The task remained mounted in the center console on the right of the driver seat as in the previous Phase 1 PRP study (when no distractor task was timed to occur during the LV event). The main goal of the distractor task was to have the driver look away from the forward roadway scene so as to not visually detect the onset of the LV critical braking event. A total of sixteen different 5 digit sequences were used. This task was synced with the LV braking event to ensure that participants looked away from the road during the duration of the critical task (see B.5). The number task started 1.6 sec after the number task pre-recorded auditory instruction or cue was given. The number task command lasted a total of 0.82 sec and it took the computer 0.75 sec to activate the task which gave participants 1.6 sec to orient (pay attention) to the task display. A previous study by Sugimoto and Sauer (2005) found that a mean reaction time for participants to respond to a warning is 0.82 sec. This same reaction time was used to trigger a distraction task prior to an advanced crash avoidance technologies (ACAT) warning in a study by Van Auken et al. (2011). The current study gave participants sufficient time to react to the number task cue. Each of the 5 numbers was displayed for 0.5 seconds on the LCD screen. The number task also appeared on its own (without EA or FCW alerts) 67 % of the time in order to prevent participants from predicting critical events.

2.6. DATA COLLECTION

2.6.1. Objective Data

The objective simulator data collected was saved as an ASCII text format, which made it easy to manipulate using Matlab, SPSS, and Excel. Objective data collected by the driving simulator was recorded at 25 samples per sec and included:

- Subject and lead vehicle forward speed
- Subject and lead vehicle x and y position
- Lateral lane position
- Longitudinal acceleration
- Lateral acceleration
- Yaw rate
- Path angle
- Steering wheel angle
- Steering wheel torque
- Accelerator pedal position
- Brake pedal pressure
- Headway distance to LV
- Event channel (trip wires, triggers, EA start time, FCW start time etc.)
- LV braking task
- Accelerator reaction time
- Braking movement time
- Warning condition
- Time-to-collision
- Collision outcome
- Relative velocity at collision

Also, in-cab video recordings included the participant's face, forward view, accelerator and brake pedals, steering wheel, and overhead view. Figure 4. Shows a example of recorded video image. The upper left quadrant contained the participant's face, the upper left contained the forward view and pedals, the lower left quadrant contained the overhead view, and lower right quadrant contained the over the shoulder view.

Figure 4. Sample Video Recording Setup

2.6.2. Subjective data

The subjective ratings were collected at the end of each drive and reduced using a continuous rating scale. Subjective measures included the following:

- Ease of performing the driving task
- Sense of discomfort (or risk) performing the primary driving task
- Ease of performing the secondary entry task
- Overall mental workload

All subjective data were compiled into an Excel worksheet and analyzed. The definitions of each of the rating questions are included in Appendix A

2.6.3. Eye glance data

Eye glance behavior data were extracted using video reduction techniques. The specifics on data reduction areas of interest are described in Figure 5 and included the forward roadway, instrument panel, number distractor task (LCD monitor), and other locations (looking anywhere else). The locations of interest had the approximate viewing angles when measured using an average male with 50th percentile height in the driver seat. The visual warning icons located in the instrument panel are at approximately 25 deg down vertically from the forward scene. The LCD monitor that displays the secondary task is at approximately 40 deg horizontally from the forward scene.

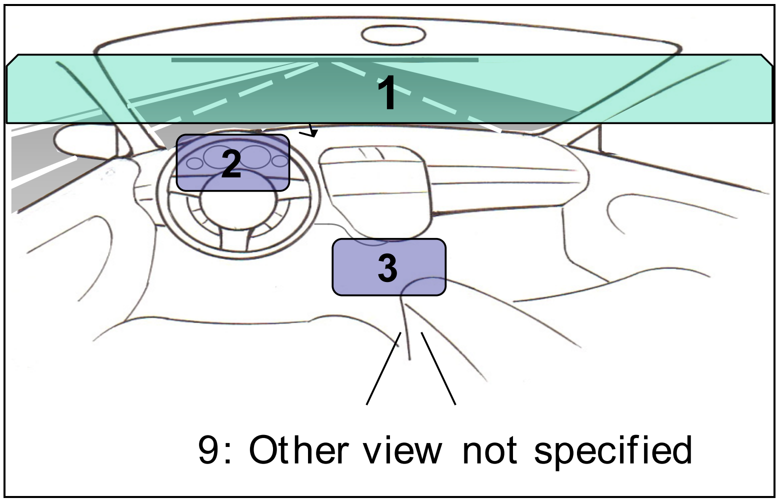


Figure 5. Eye Glance Areas of Interest

Eye glance data was extracted for a set amount of time for each type of event. Eye glance reduction started at the end of the distractor task audio cue and continued for 2.85 sec, which is at the EA activation, and in some events at the FCW alert (and LV braking activation). Figure 6 summarizes the various eye glance reduction windows for each event type.

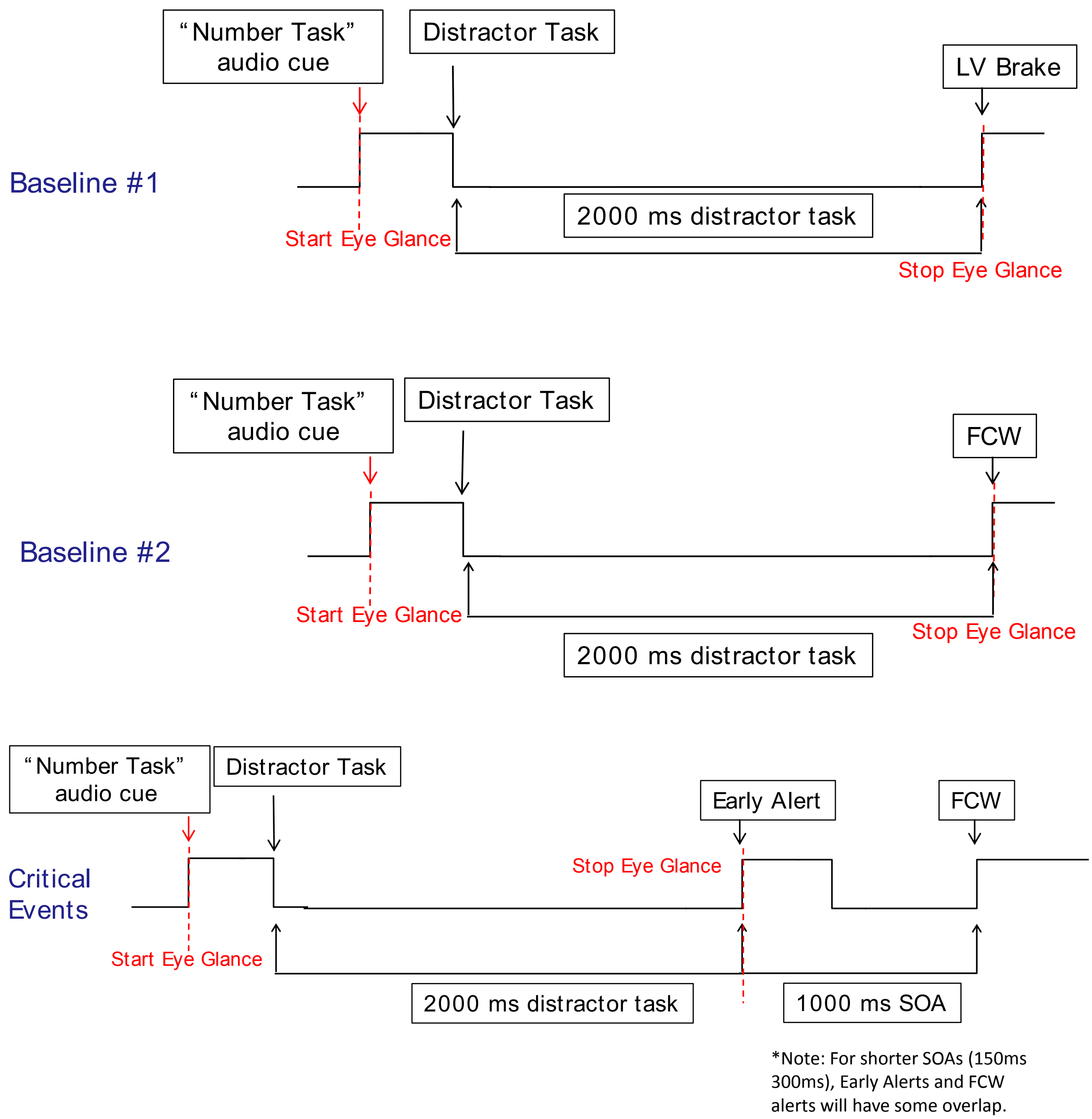


Figure 6. Eye Glance Reduction Window

3. RESULTS

3.1. OBJECTIVE RESULTS

3.1.1 Measures

The performance measures included the following:

- Accelerator reaction time, which was defined as the time in which the LV started braking to when the participant responded to the event by releasing their foot from the accelerator pedal. An accelerator reaction was defined as anything more than 1% throttle position movement. Unfortunately this value was not attained, for participants who had their foot off the accelerator pedal during this time frame and resulted in blank values.
- Accelerator to brake movement time, which was defined as the time it took the participant's foot to go from the released accelerator pedal to the brake pedal. A brake press was defined as anything greater than 1.0 kgf in brake pressure. Again, for participants who had their foot off the accelerator pedal during the time frame, this value was not attained.
- Total response time, which was defined as the start of the LV braking event to the end of accelerator to brake movement.
- Max brake movement time, which was defined as the time it took the participant to go from start of braking to maximum braking.
- Distance, which was defined as the minimum distance between the SV and the LV.

Figure 7 outlines each performance measure by time.

Figure 7 also lists the alerts and how they would interact with number task and the various measures. Figure 7 depicts one possible event type in which the number task and the FCW are combined with an SOA of 1000 ms. In this combination, the two alerts would not overlap but in an event in which and FCW is combined with a much shorter SOA, such as an SOA of 150 ms, the two variables would be overlapping one another in this figure.

Although five main performance measures were examined in this study, only two were of high importance to the study, total response time and distance.

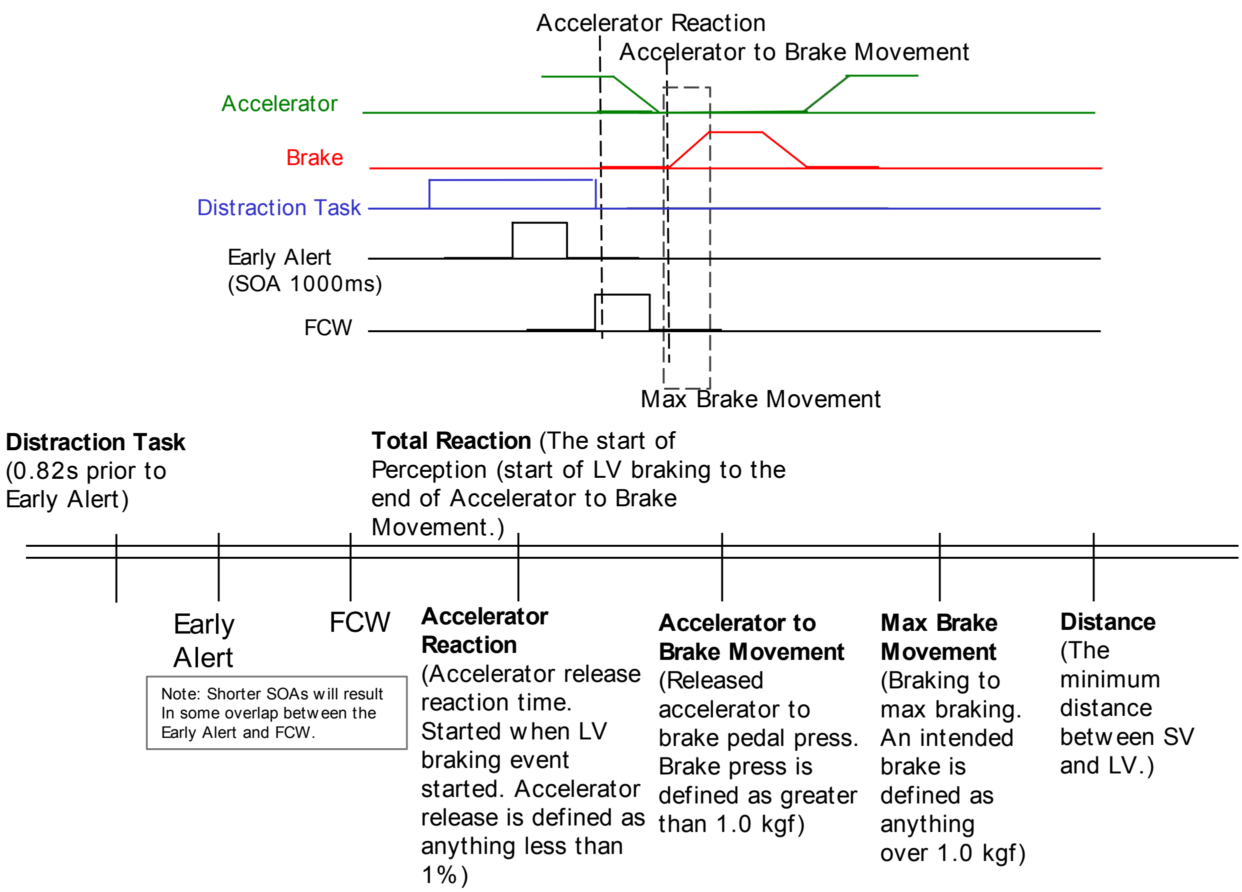


Figure 7. Timeline and Definitions of Measures

3.1.2 Data analysis window

The data analysis window is the same one used in the Phase 1 CWIM PRP study. It starts when the LV starts to brake or when the FCW alert starts to when the participant starts to brake (end of accelerator to brake movement).

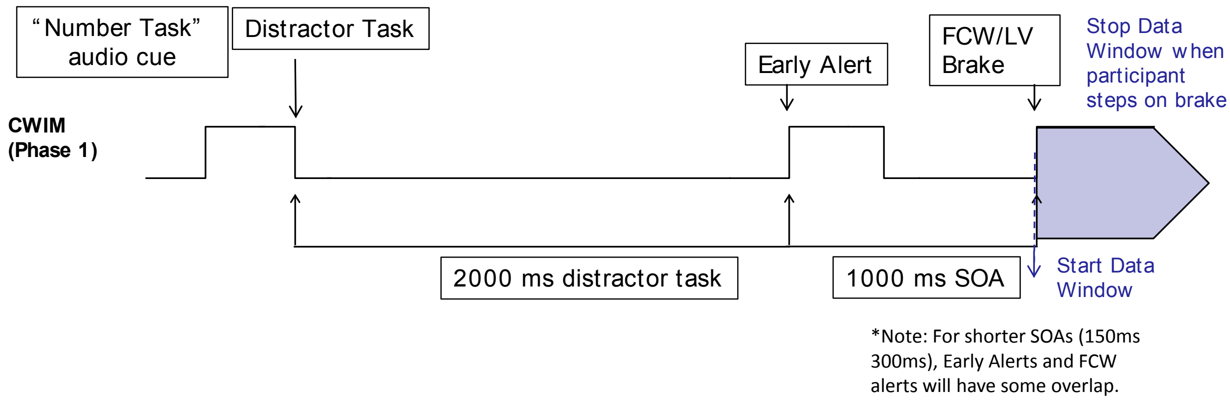


Figure 8. Phase 1 Data Analysis Window

3.1.3 Data analysis

In this phase of CWIM PRP study, the dataset was split by the between-subjects factor (tonal and verbal) after performing a one-way ANOVA to determine if any main effects between the two groups existed. Analysis were consistent with those done in phase 1 of CWIM. Although further analysis could have been performed, time and budget did not allow were an issue for both phases. A one-way ANOVA did not reveal any main effects between the two groups. Each group was then analyzed using a repeated measures analysis to determine whether there were any main effects or interactions within each group. A significant value of $p < 0.05$ with Greenhouse-Geisser Epsilon was used. Paired Sample t-tests were further performed to help possibly explain significances found in the previous analysis.

3.1.4 Total response time

Table 2 summarizes the number of samples per event type. The missing values are not due to incomplete drives, but by early braking instances. Figure 9 shows the means and standard errors by event type.

Table 2. Total Response Time Count (N)

Total Response (Verbal)	N	Total Response (Tonal)	N
Audio FCW	18	Audio FCW	18
Haptic FCW	18	Haptic FCW	18
Audio FCW 150 ms	17	Audio FCW 150 ms	16
Audio FCW 300 ms	17	Audio FCW 300 ms	14
Audio FCW 1000 ms	15	Audio FCW 1000 ms	14
Haptic FCW 150 ms	18	Haptic FCW 150 ms	18
Haptic FCW 300 ms	18	Haptic FCW 300 ms	18
Haptic FCW 1000 ms	15	Haptic FCW 1000 ms	17
Max Number	18	Max Number	18

*Note: Missing Total Reaction Time data is due to early braking or red zone over 50%.

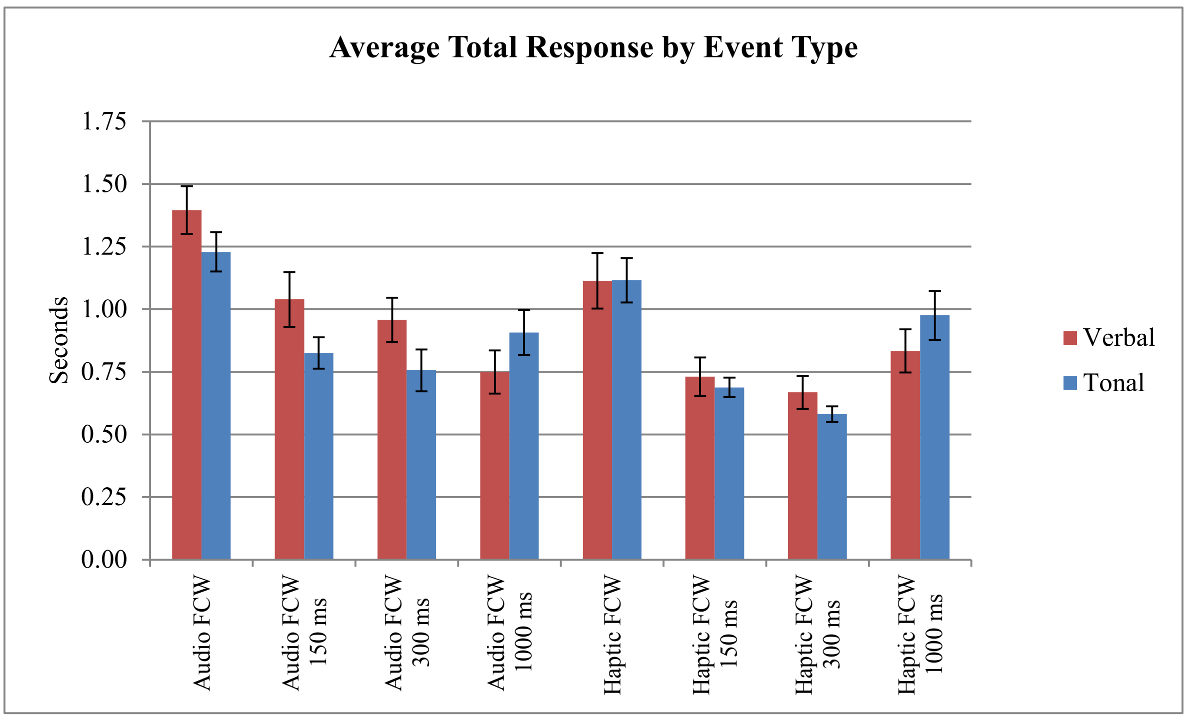


Figure 9. Total Response Time Means and Standard Errors

There was significant difference between auditory and haptic FCW on total response time ($p = 0.035$) such that haptic FCW alerts produced shorter total response times (Figure 10). There was also a significant difference between SOA times ($p < 0.0005$) whereas SOA increased, total response time decreased with an increase in 1000 ms SOA (Figure 11).

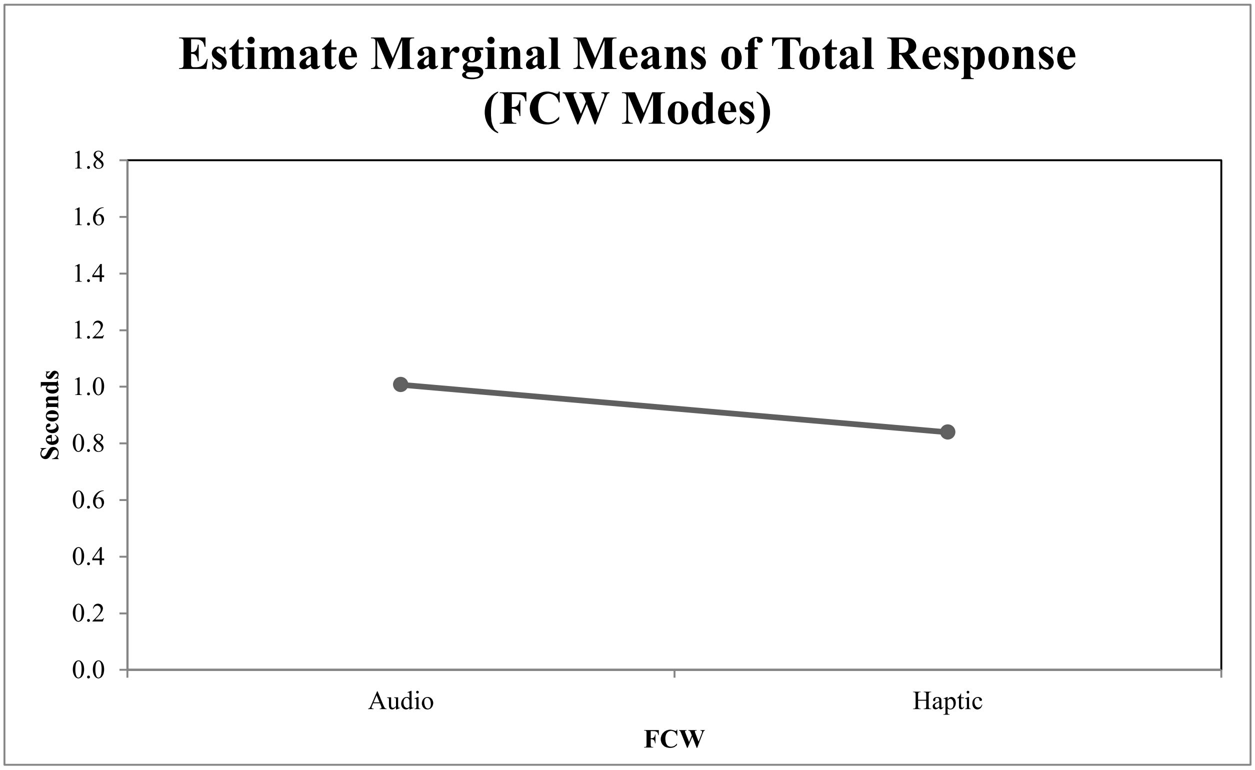


Figure 10. FCW Marginal Means for Total Response Time

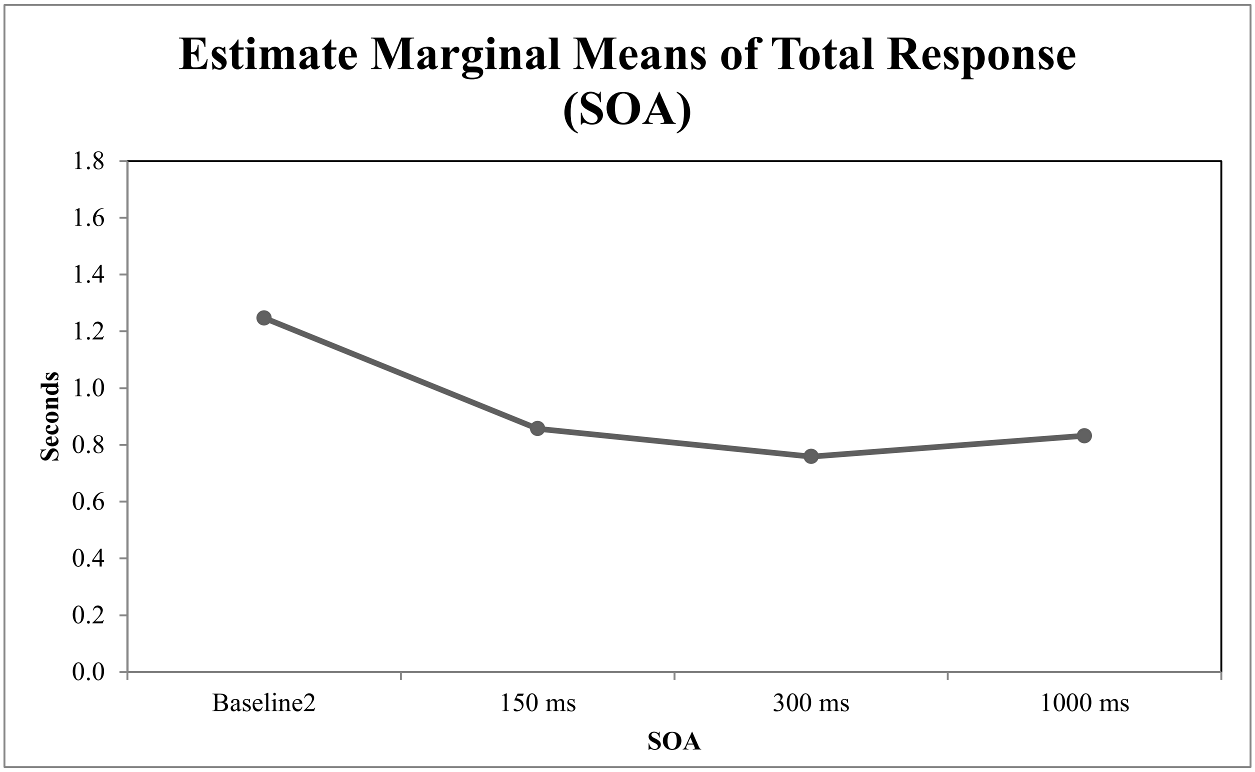
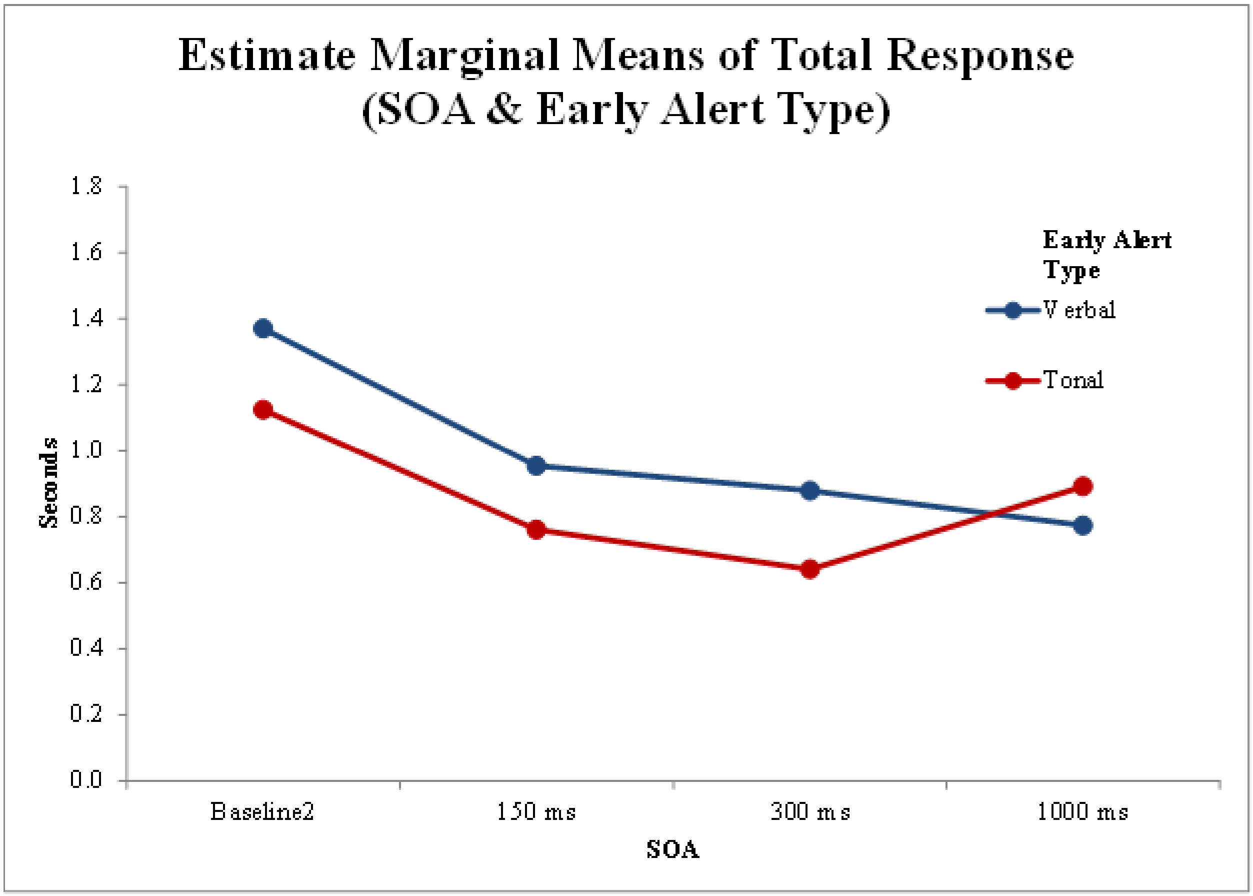


Figure 11. SOA Marginal Means for Total Response Time

There was an interaction between SOA and EA type ($p = 0.016$) where for tonal EA, as SOA increases, total response time decreases with an increase at 1000 ms for tonal EA. In contrast, for verbal EA, as SOA increases, total response time decreased slightly (Figure 12 and Figure 13). There was also an interaction between FCW and SOA ($p = 0.004$) where for haptic FCW, total response time had an increase at 1000 ms but for auditory FCW, total response time decreased slightly with every SOA increase (Figure 14 and Figure 15).


Estimate Marginal Means of Total Response
(SOA & Early Alert Type)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Seconds
Early Alert Type
Verbal
Tonal
Baseline2
150 ms
300 ms
1000 ms
SOA

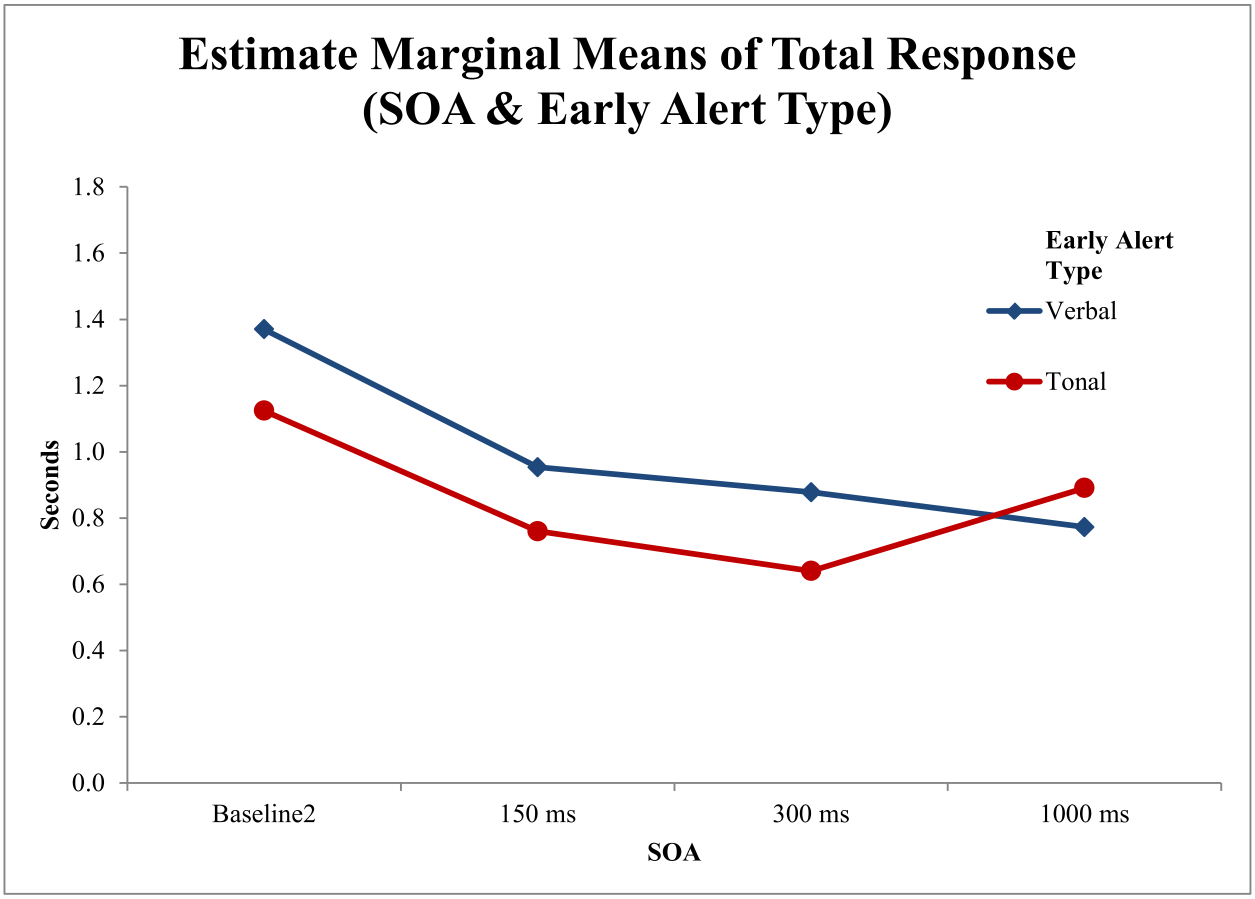


Figure 12. SOA and Early Alert Type Marginal Means for Total Response Time

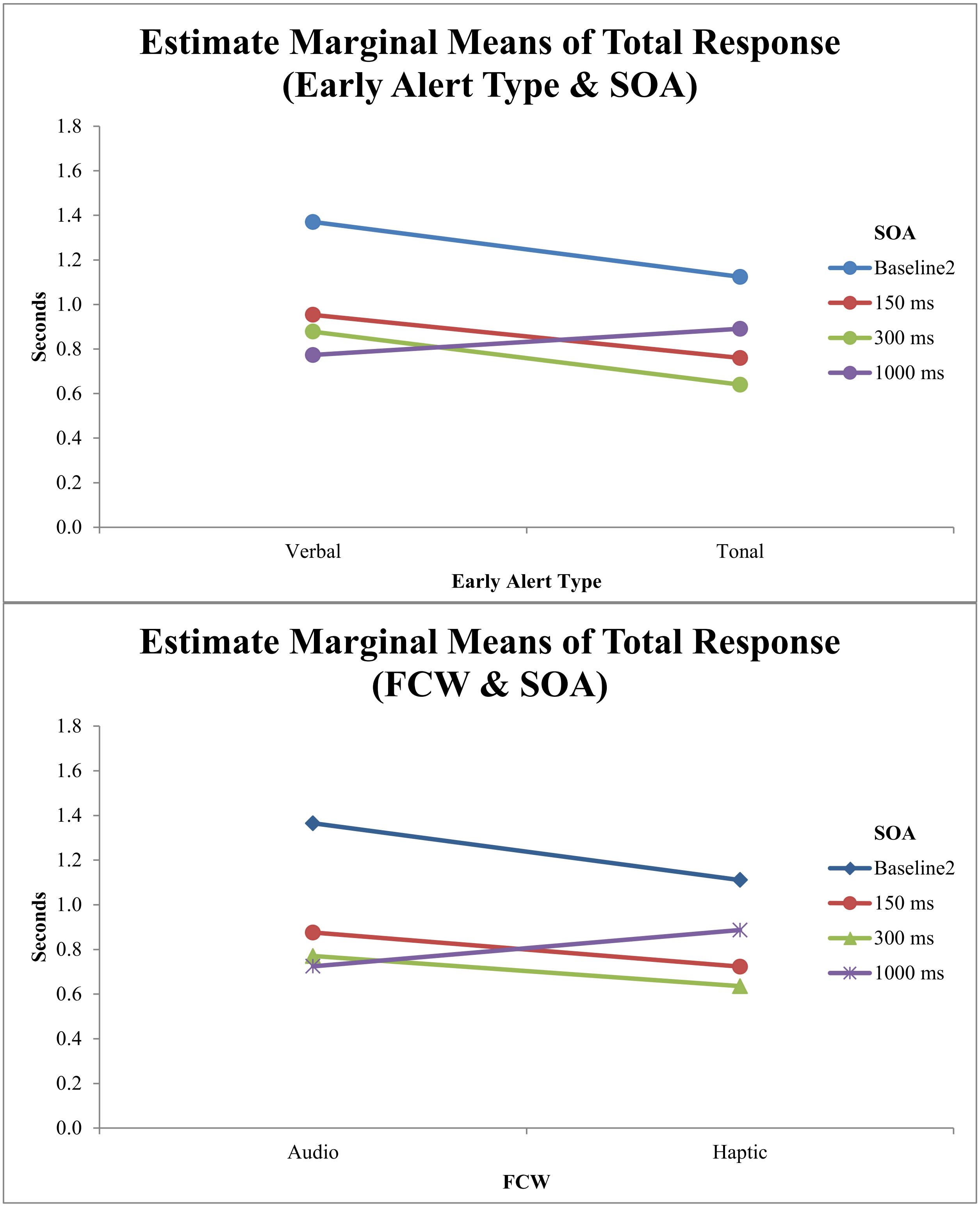
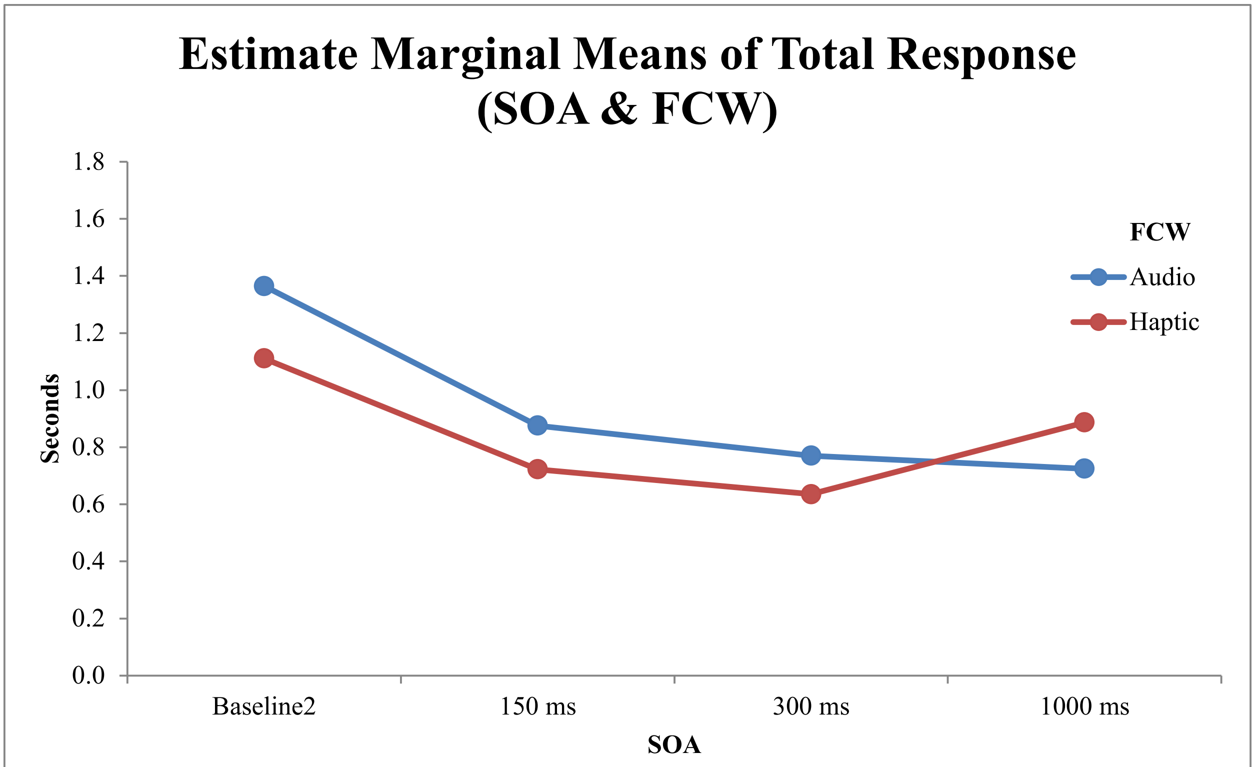


Figure 13. Early Alert Mode and SOA Marginal Means for Total Response Time



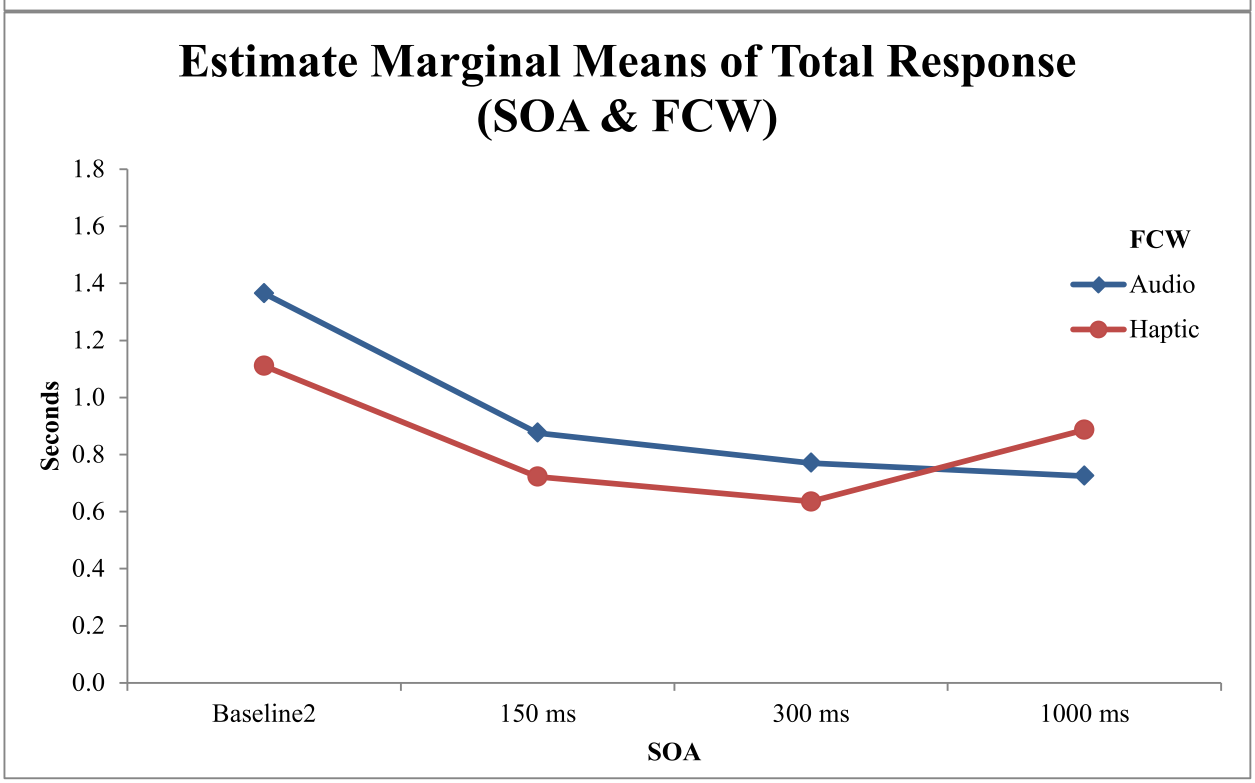
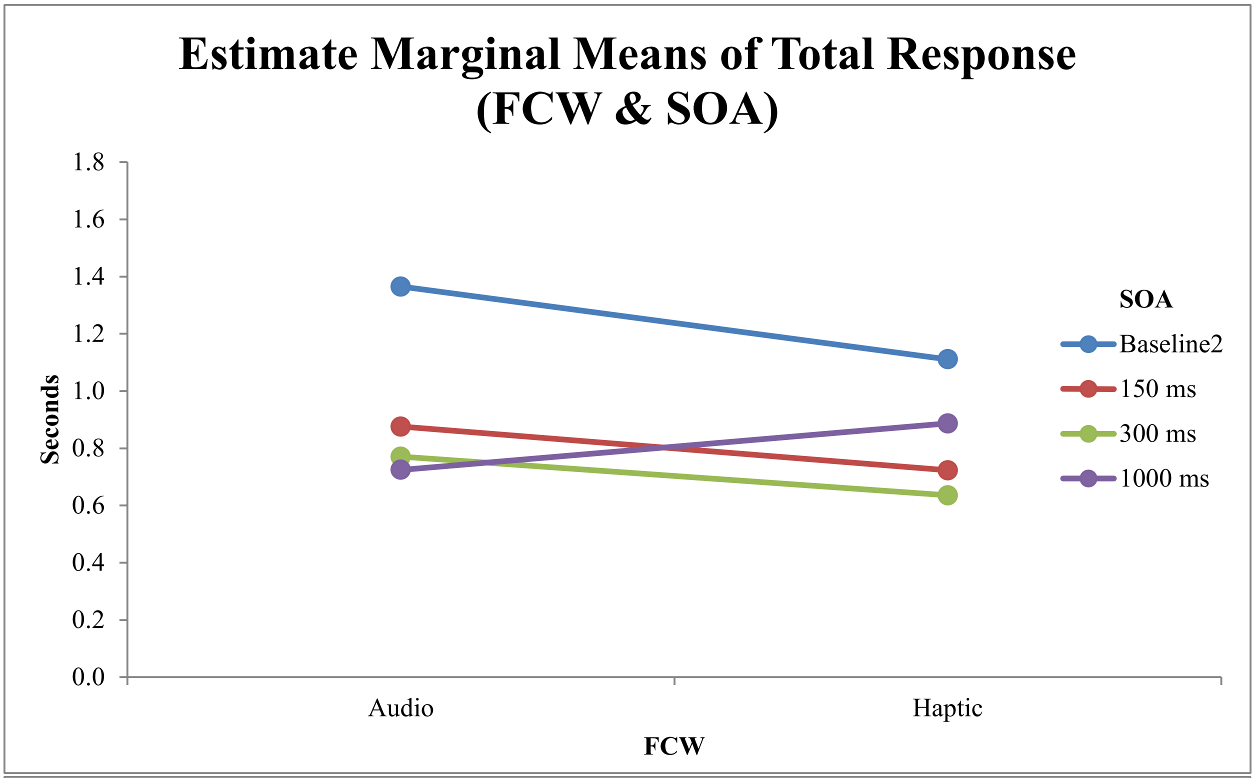


Figure 14. SOA and FCW Marginal Means for Total Response Time



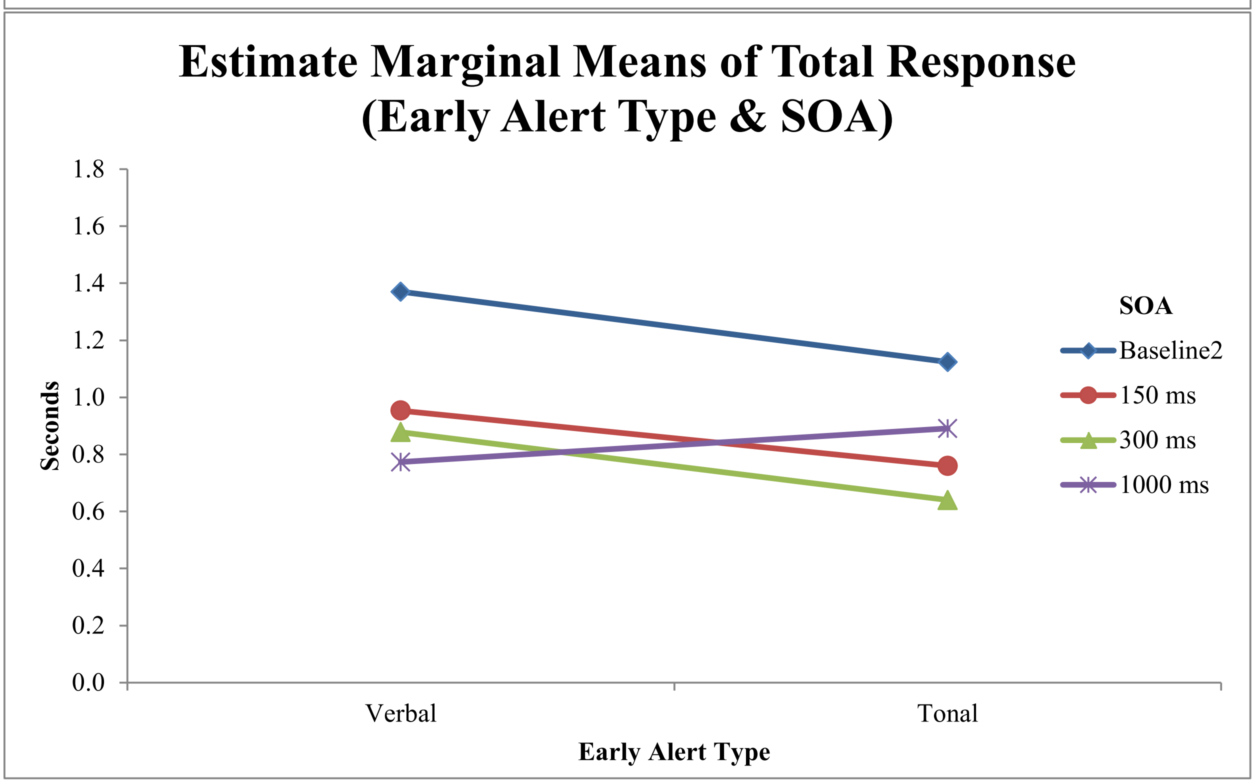


Figure 15. FCW and SOA Marginal Means for Total Response Time

Paired comparisons for verbal total response times showed a significant difference between both auditory and haptic baseline2 events and events with an SOA of 150, 300, and 1000 ms. There were also significant differences for tonal events between auditory FCW baseline2 events and events with an SOA of 150, 300, and 1000 ms. But also a significant difference for haptic FCW baselines2 and events with an SOA of 150 and 300 ms. See Table 3.

Table 3. t-Tests Paired Comparisons between Baseline Events for Total Response Times

Total Response T-tests

Verbal							
Audio FCW (Baseline2)	150 ms	300 ms	1000 ms	Haptic FCW (Baseline2)	150 ms	300 ms	1000 ms
	0.019	0.002	0.000		0.008	0.002	0.055
Tonal							
Audio FCW (Baseline2)	150 ms	300 ms	1000 ms	Haptic FCW (Baseline2)	150 ms	300 ms	1000 ms
	0.000	0.000	0.012		0.000	0.000	0.296

3.1.5 Distance

When looking at the number of collisions during baseline events, the baseline1 events which were critical LV braking events without any alerts resulted in the most number of collisions (72%). That number was greatly reduced for baseline2 events which were events with an FCW alert during a critical LV braking event. Three collisions (8%) were observed for the audio FCW events while five collisions (14%) were observed for the haptic FCW events (Table 4). It should be noted that all baseline1 events occurred during the warm-up road for each participant while the Baseline2 events occurred during actual study drives.

Table 4. Collision Summary

Event Type	Collisions
No FCW Alert (Baseline1)	26
Audio FCW (Baseline2)	3
Haptic FCW (Baseline2)	5
Audio FCW Verbal 150 ms	1
Audio FCW Verbal 300 ms	1
Audio FCW Verbal 1000 ms	1

Table 5 summarizes the total amount of valid data per event type for the minimum distance analysis. The values not accounted for are due to early braking instances and other reasons outlined in Appendix D on data cleaning of the phase 1 CWIM report.

Table 5. Distance Count (N)

Distance (Verbal)	N	Distance (Tonal)	N
Audio FCW	18	Audio FCW	18
Haptic FCW	18	Haptic FCW	18
Audio FCW 150 ms	17	Audio FCW 150 ms	16
Audio FCW 300 ms	18	Audio FCW 300 ms	17
Audio FCW 1000 ms	17	Audio FCW 1000 ms	17
Haptic FCW 150 ms	18	Haptic FCW 150 ms	18
Haptic FCW 300 ms	18	Haptic FCW 300 ms	18
Haptic FCW 1000 ms	17	Haptic FCW 1000 ms	18
Max Number	18	Max Number	18

*Note: Missing Total Reaction Time data is due to early braking or red zone over 50%.

Figure 16 shows the means and standard errors by critical event for distance.

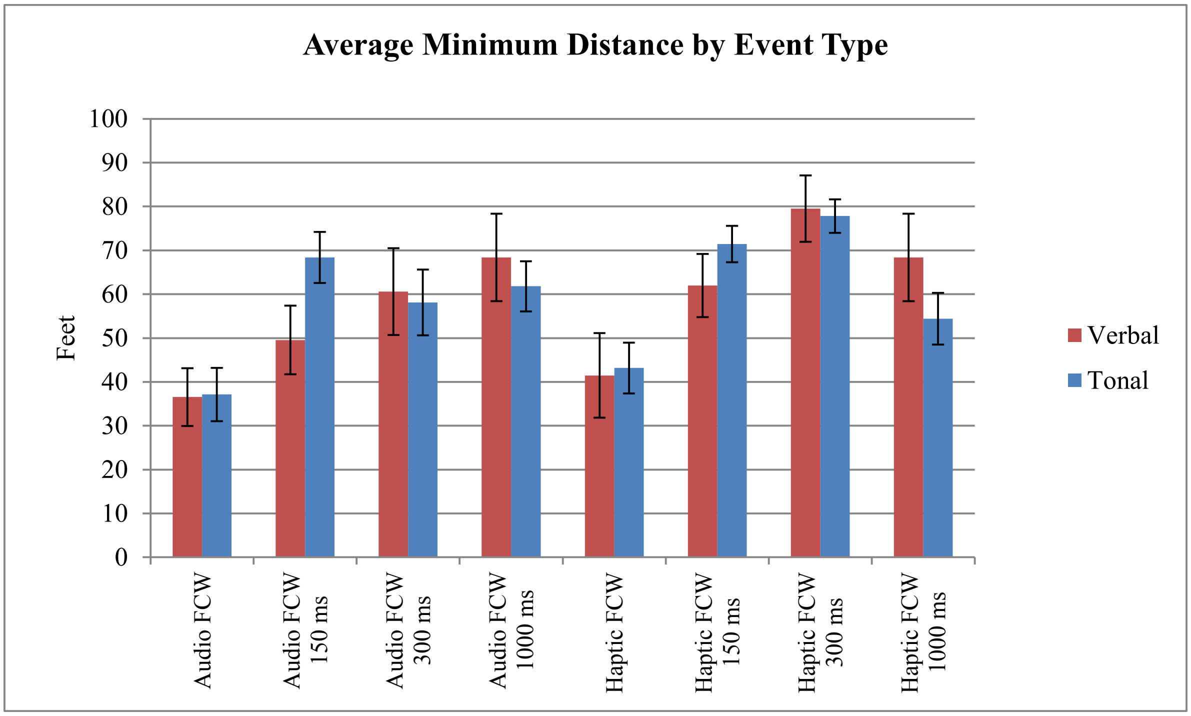


Figure 16. Distance Means and Standard Errors

A repeated measures analysis found that there was a significant difference between auditory and haptic FCW ($p = 0.005$) where haptic FCW resulted in longer minimum distances between the SV and LV (Figure 17). There was also a significant difference between SOA times ($p = 0.000$) whereas SOA increased, distance also increased with an decrease in 1000 ms SOA (Figure 18).

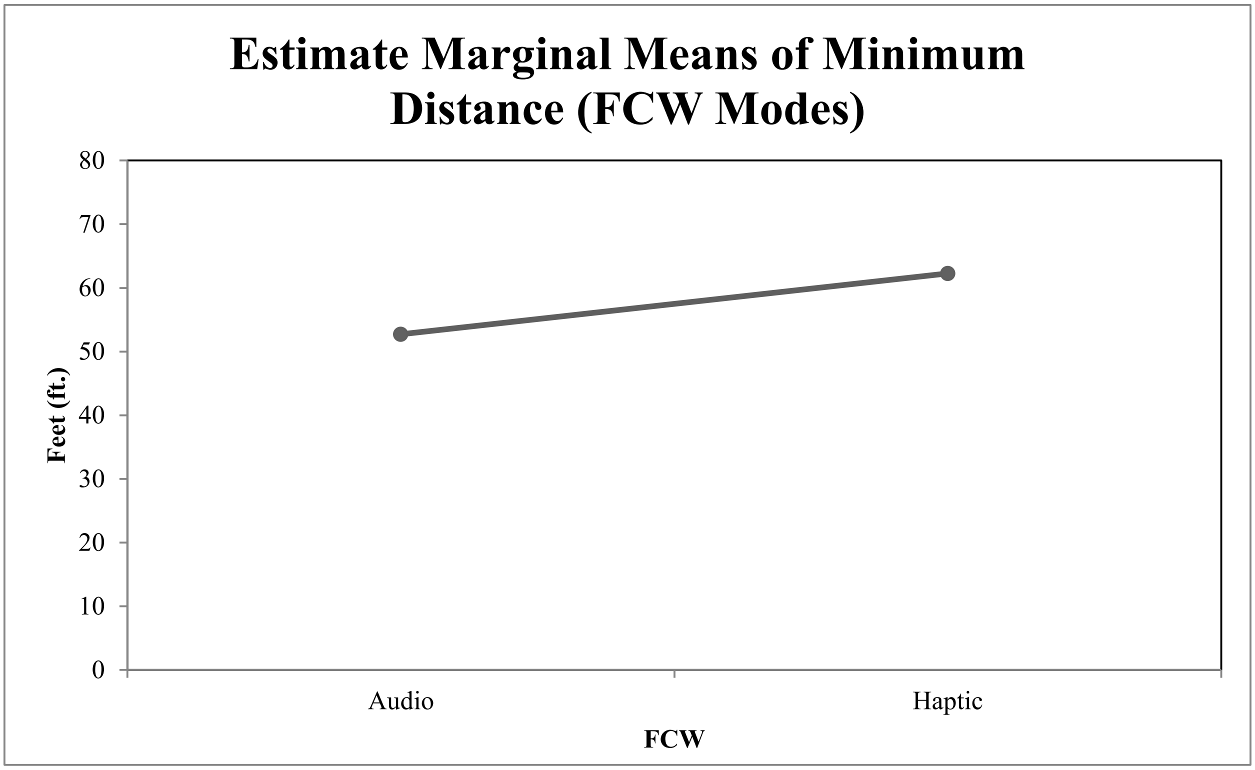


Figure 17. FCW Marginal Means for Distance

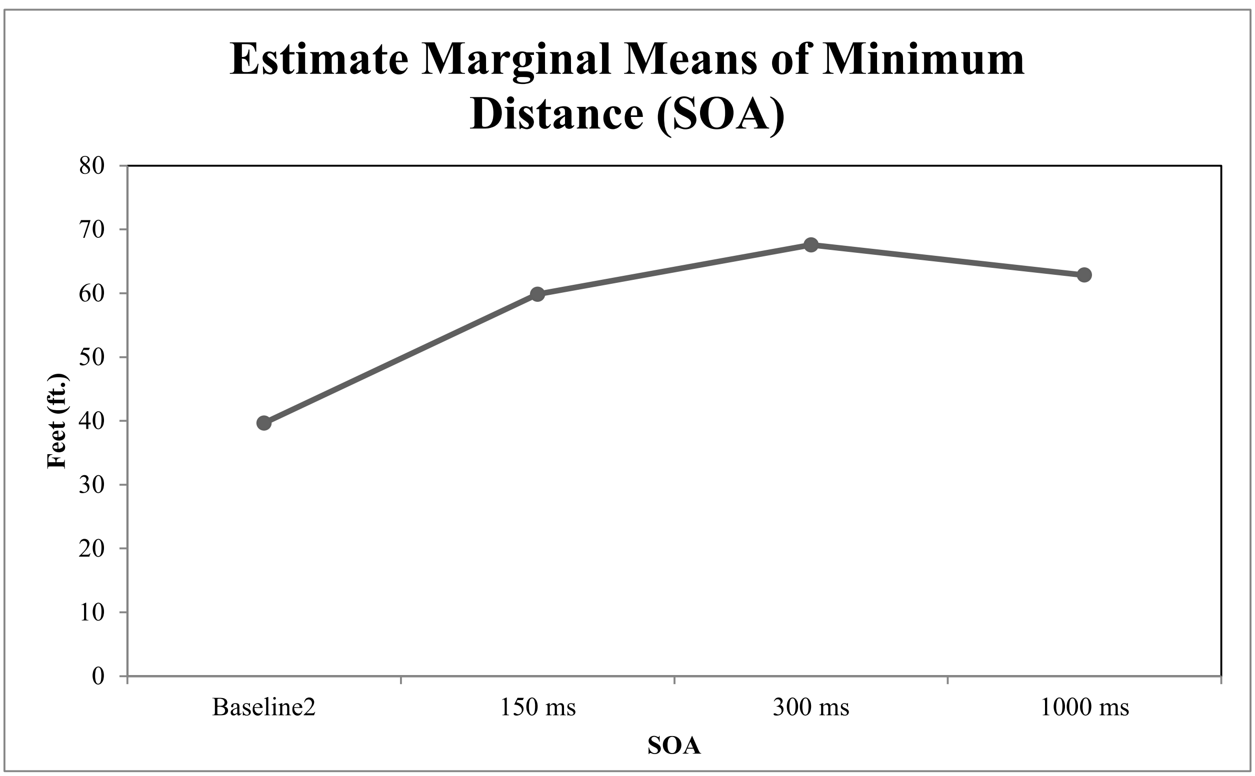


Figure 18. SOA Marginal Means for Distance

There was an interaction between SOA and EA type ($p = 0.043$), where for verbal EA, distance increased as SOA increased, and leveled at 1000 ms. But for tonal EA distance increases as SOA increases from baseline to 150 ms, but with a sharp decrease in distance for alerts with SOA of 1000 ms (Figure 19 and Figure 20). There was also an interaction between SOA and FCW type where for the audio FCW, Distance increased as SOA increased, but for haptic FCW, distance increase as SOA increased, with a decrease in distance at 1000 ms (Figure 21 and Figure 22).

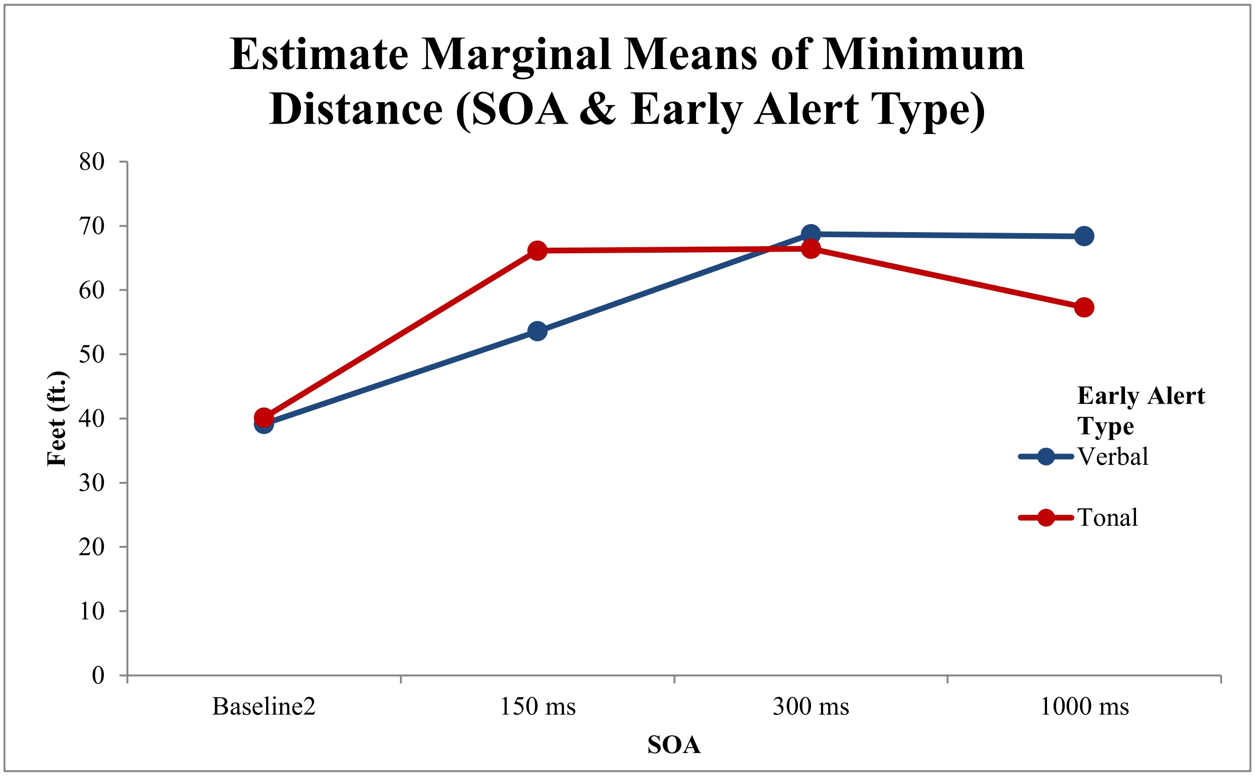


Figure 19. SOA and Early Alert Type Marginal Means for Distance

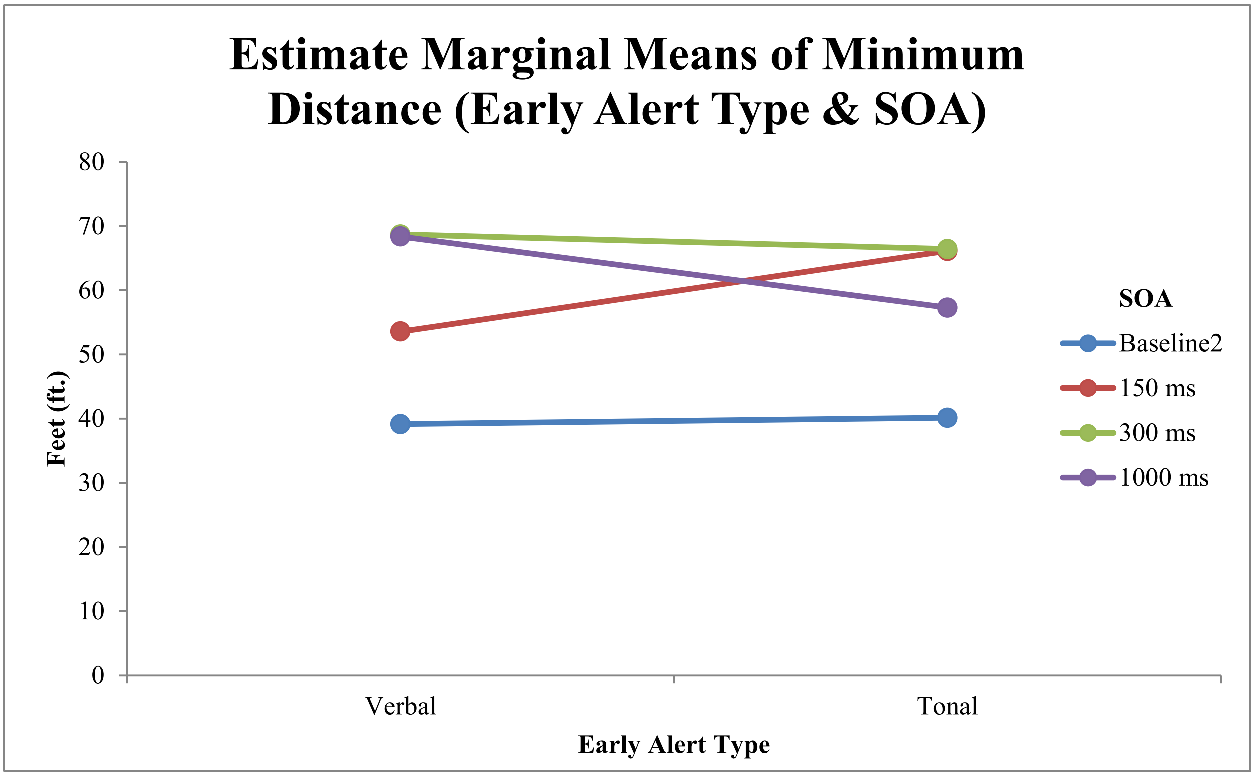


Figure 20. Early Alert Type and SOA Marginal Means for Distance

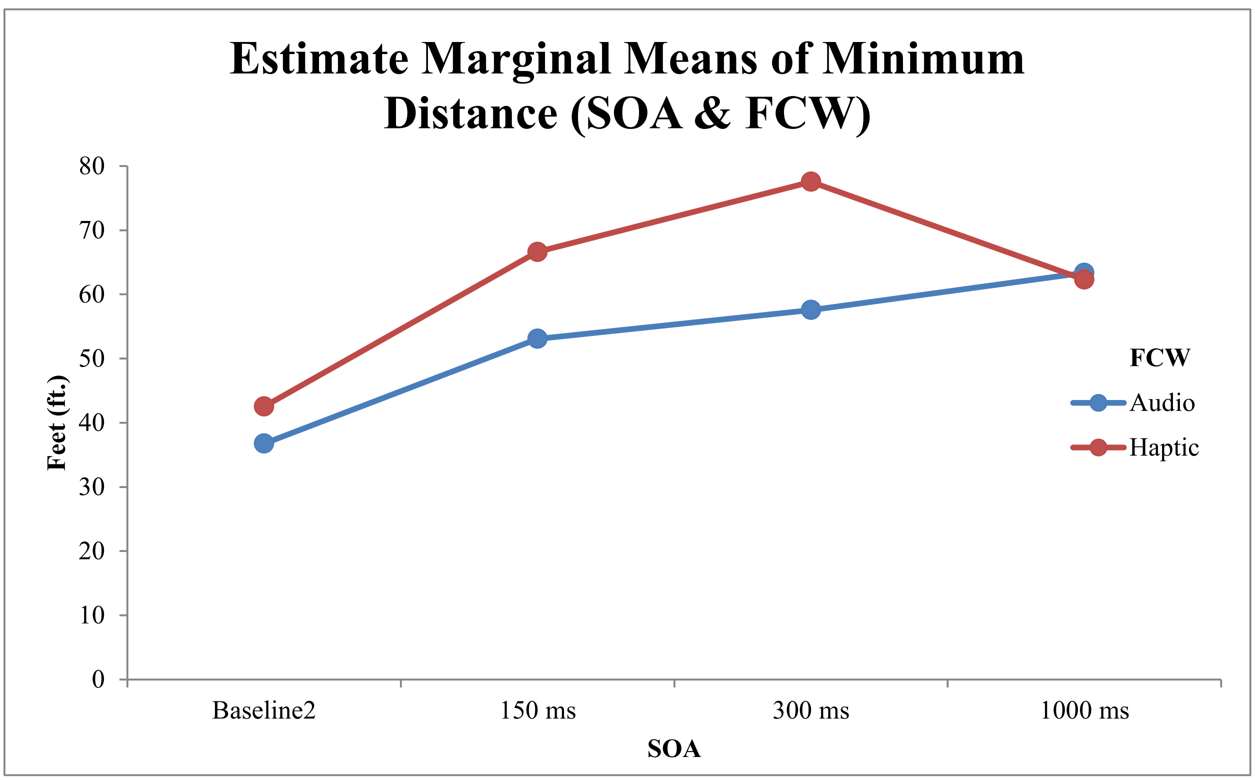


Figure 21. SOA and FCW Marginal Means for Distance

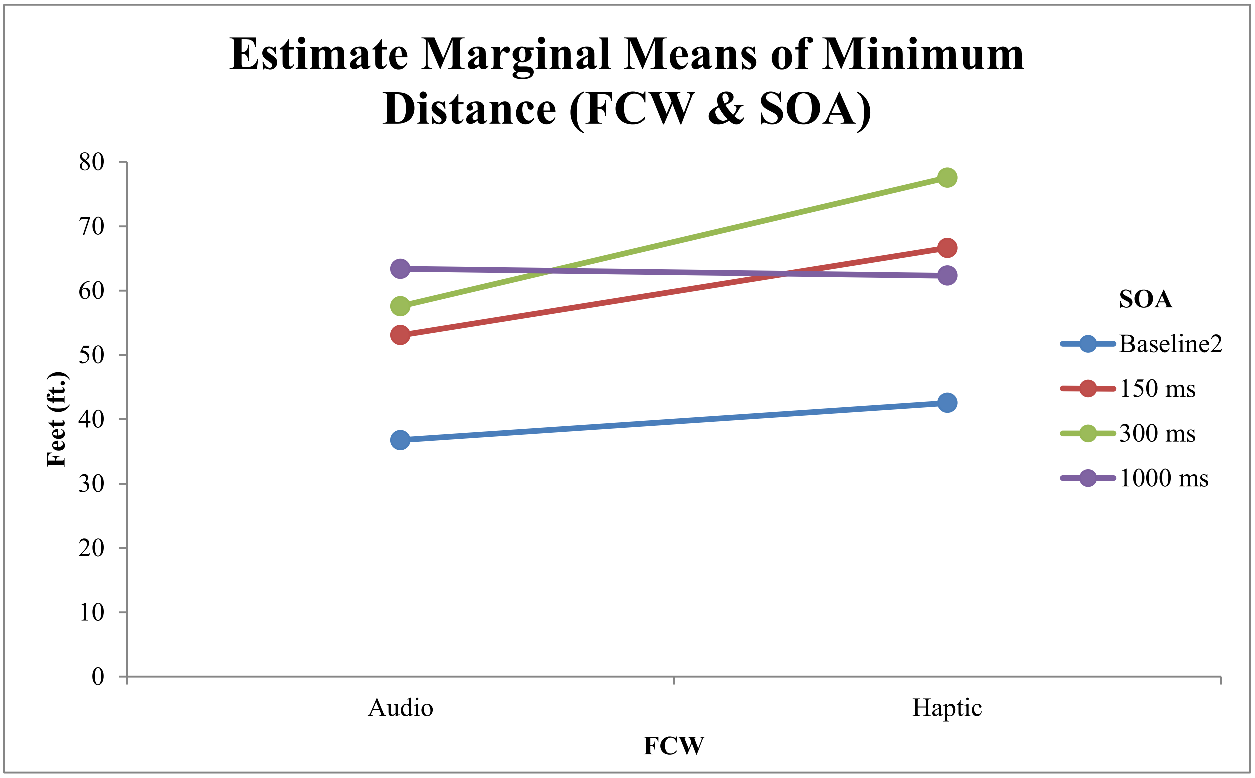


Figure 22. FCW and SOA Marginal Means for Distance

Paired comparisons of verbal events revealed that there were statistical differences between auditory baseline2 events and events with an SOA of 1000 ms. There was also a significant difference between haptic baseline2 events and events with an SOA of 300 ms for distance. When comparing tonal EA events, there were statistical differences between event with auditory FCW baseline2 and events with SOA of 150, 300, 1000 ms. When comparing haptic FCW events there was a statistical difference between the haptic FCW baseline2 events and events with an SOA of 150 and 300 ms (Table 6).

Table 6. t-Tests for Paired Comparisons Between Baseline Events for Minimum Distance

Distance T-tests

Verbal							
Audio FCW (Baseline2)	150 ms	300 ms	1000 ms	Haptic FCW (Baseline2)	150 ms	300 ms	1000 ms
	0.212	0.052	0.013		0.098	0.004	0.061
Tonal							
Audio FCW (Baseline2)	150 ms	300 ms	1000 ms	Haptic FCW (Baseline2)	150 ms	300 ms	1000 ms
	0.001	0.030	0.006		0.000	0.000	0.121

3.2 EYE GLANCE RESULTS

3.2.1 Number task eye glance results

A number task was used as a distractor task for this study. Based on the eye glance results, most participants did not focus or fixate completely on the distractor task LCD for the 2.85 sec duration of the task. The distractor task was interrupted two seconds in by the first alert. During the baseline1 events, participants tended to spend more time looking at the LCD monitor during the distractor task. For baseline2 events which contained a FCW alert, participants tended to look away from the LCD monitor during the distraction task.

3.2.2 Eye glance reduction windows

Data coding eye glances for all events were completed the same way. Eye glance started at the end of the distractor task audio cue and was interrupted at 2 seconds by the start of FCW (and LV braking) or the EA (see Figure 6).

Figure 23 to Figure 24 show various single glance times (SGT), and Figure 25 to Figure 26 show the total glance tmes (TGT). Although participants were told that accuracy of the number task was important, and reminded during the study, they still tended to look up at the road during the number task. Because the baseline1 event was located in the warm-up road, participants tended to be more focused on the LCD monitor during this event, than any other event that followed. It is likely after having experienced a LV braking event in the baseline1 event, most participants tended to look up more during the baseline2 and critical events in anticipation of a LV braking event. More than half of number distraction tasks were not paired with LV braking critical events, but participants may have tended to anticipate a LV braking event. Both TGT and SGT to the road were similar for both the auditory and haptic FCW.

Before any alert, participants spent most of their time looking down at the LCD monitor which displayed the distractor task, but did occasionally look up at the road while performing the task. Although participants tended to look up during the first 2.85 sec after the distractor audio cue, they were still engaged in the task since participants still accurately identified the numbers from the number task 74 % of the time. All critical events were set up so that prior to the 2.85 sec there was nothing happening in the forward scene. For example, the LV braked only at the same time at the onset of the FCW alert. This means there was no indication that the LV would be braking during the time between the distractor audio cue and through the EA. When looking at SGT, participants tended to spend on average between 1.2 and 1.5 sec on the LCD monitor. When looking at the TGT, on average, participants spent between 1.6 and 1.8 sec looking at the LCD monitor. Note that the total time between the distractor task and the onset of an alert, or end of the number task, was 2.0 sec.

In order to better understand if the eye glance behavior changed from the first FCW critical event, and those that followed. Eye glance for baseline 2 events where an FCW alert was used revealed that overall, eye glance behavior stayed consistent. When looking at SGT, participants spent on average 0.7-1.5 sec looking at the LCD monitor, and also spent on average between 0.4-0.7 sec looking forward. Behavior for the first critical event and all other critical events resulted in similar results where participant were engaged in the distractor task, but periodically looked to the forward road during the first 2.85 sec of the critical event.

In order to determine if participant drivers were looking or engaged in the distractor task, eye glance on FCW onset was reviewed. It was found that 92% with auditory FCW, had their eyes on the LCD monitor upon FCW onset, and 81% of participant with haptic FCW had their eyes on the LCD monitor upon FCW onset. All other eye glances were to the road. When given an EA alert participants tended to verbally respond to the warning they thought was given. Participants did on occasion respond to the EA before receiving the FCW alert.

+

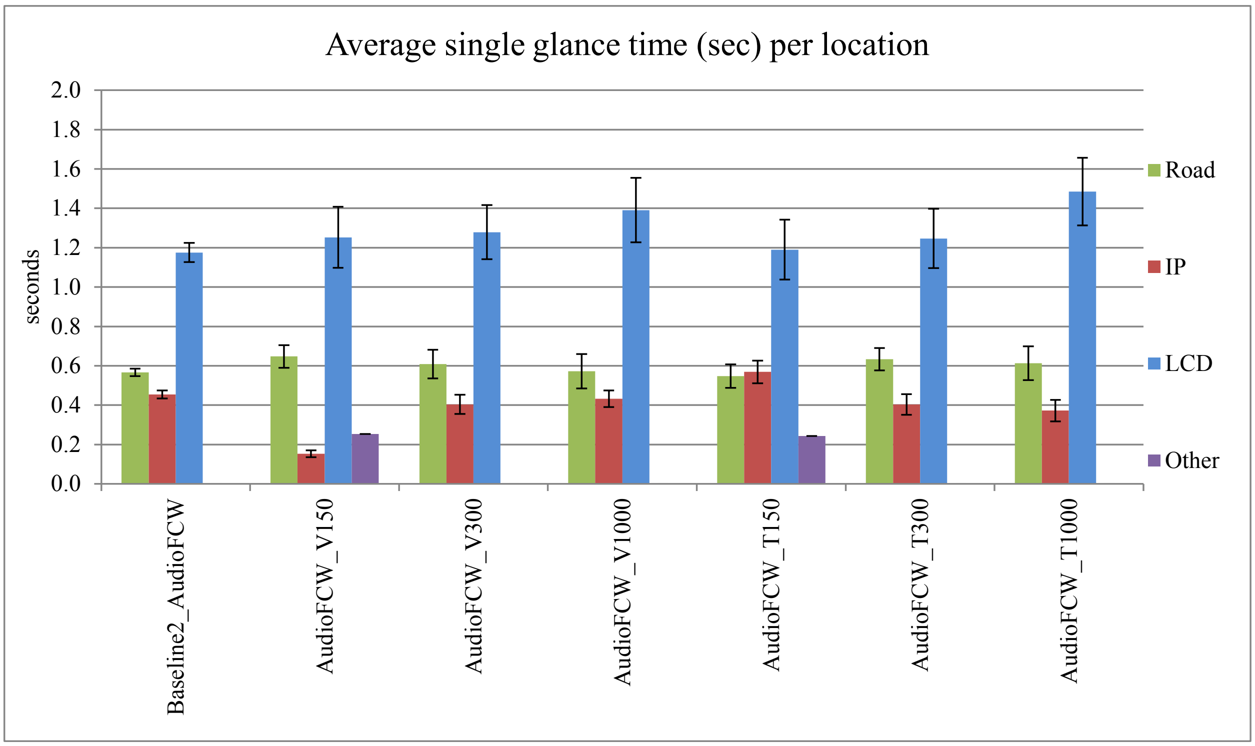


Figure 23. Average Single Glance Time for Audio FCW Critical Events by Location

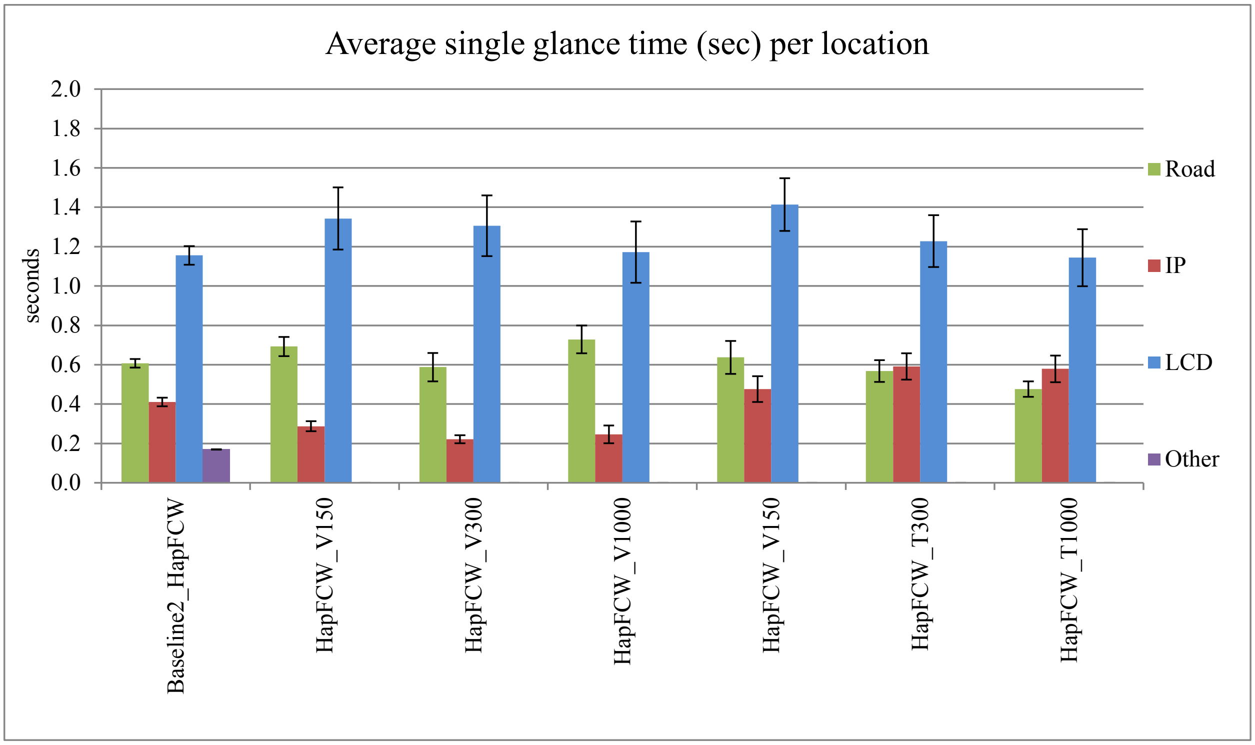


Figure 24. Average Single Glance Time for Haptic FCW Critical Events by Location

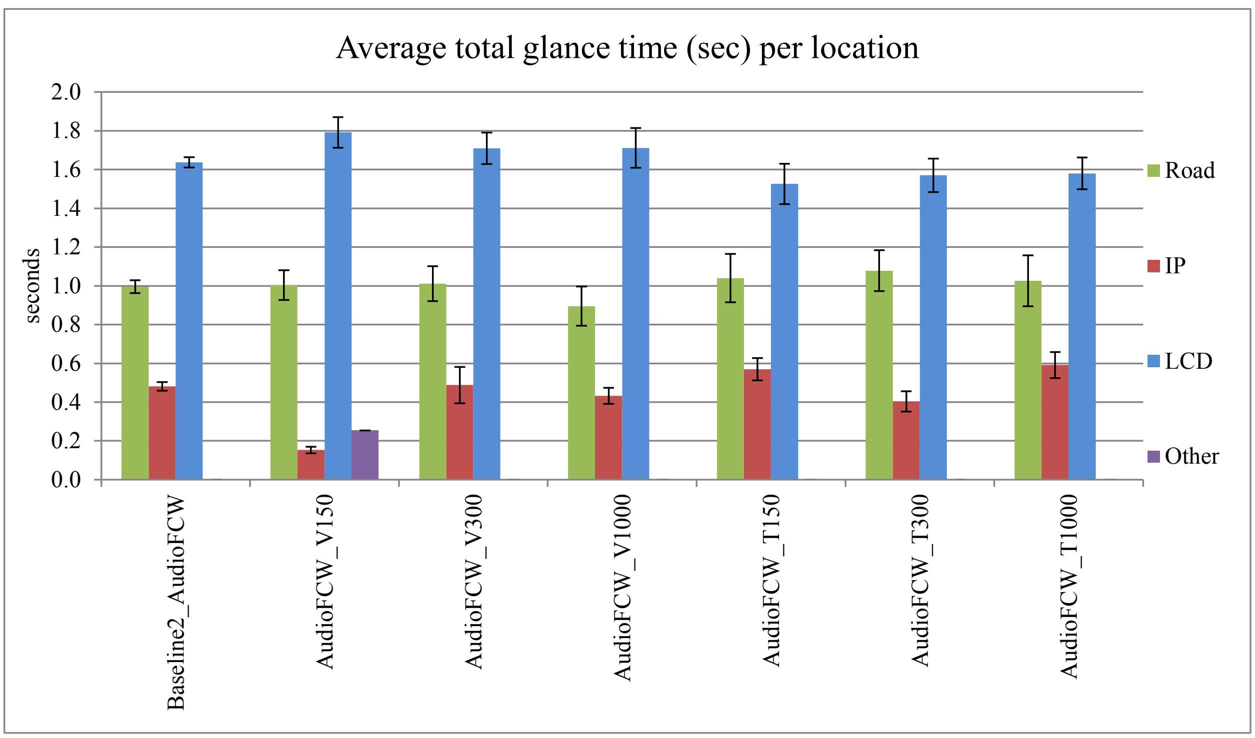


Figure 25. Average Total Glance Time for Audio FCW Critical Events by Location

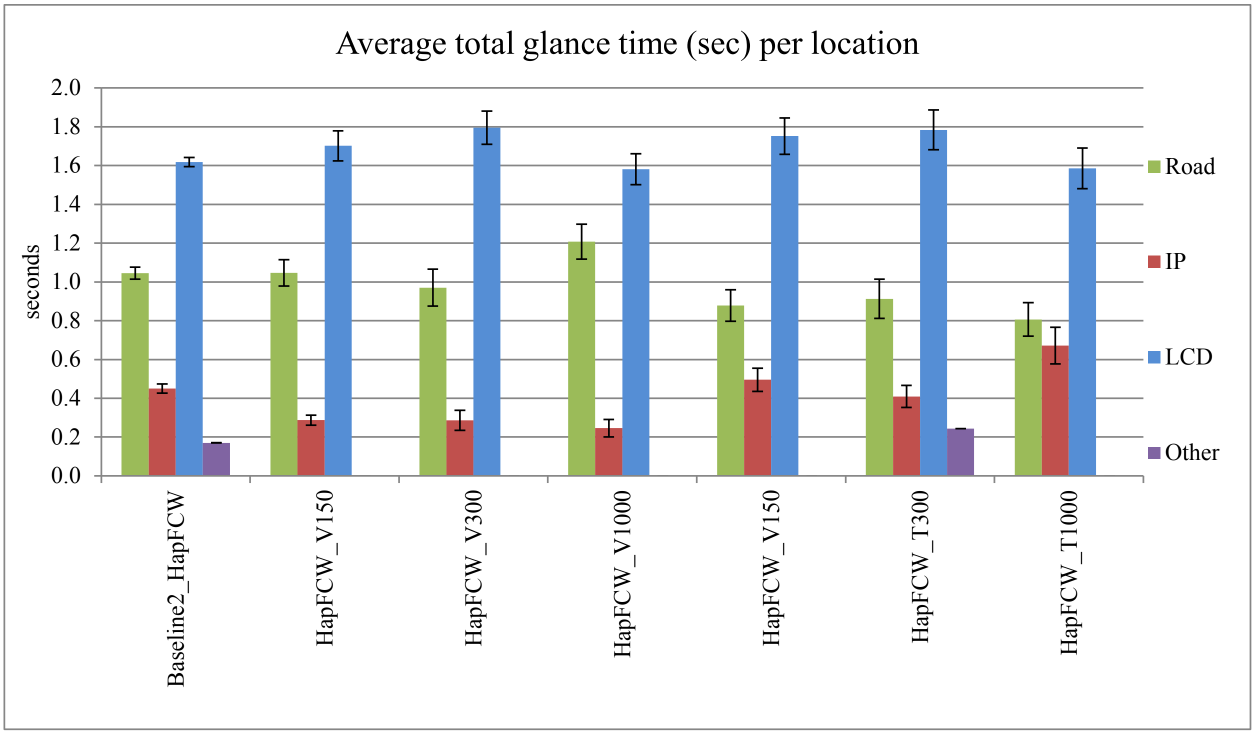


Figure 26. Average Total Glance Time for Haptic FCW Critical Events by Location

3.3 SUBJECTIVE RESULTS

Participant comparison subjective ratings on appropriateness, understandability, ease of performing the task, and overall mental workload were collected and analyzed. The following graphs represent counts, mean ratings and standard errors results.

On average, the Auditory FCW tonal participants and auditory FCW verbal participants noticed that two alerts were given during critical events similarly (Figure 27). On average, a few more participants in the verbal group noticed both alerts when EA was paired with haptic FCW alert, than when both alerts were auditory (Figure 28).

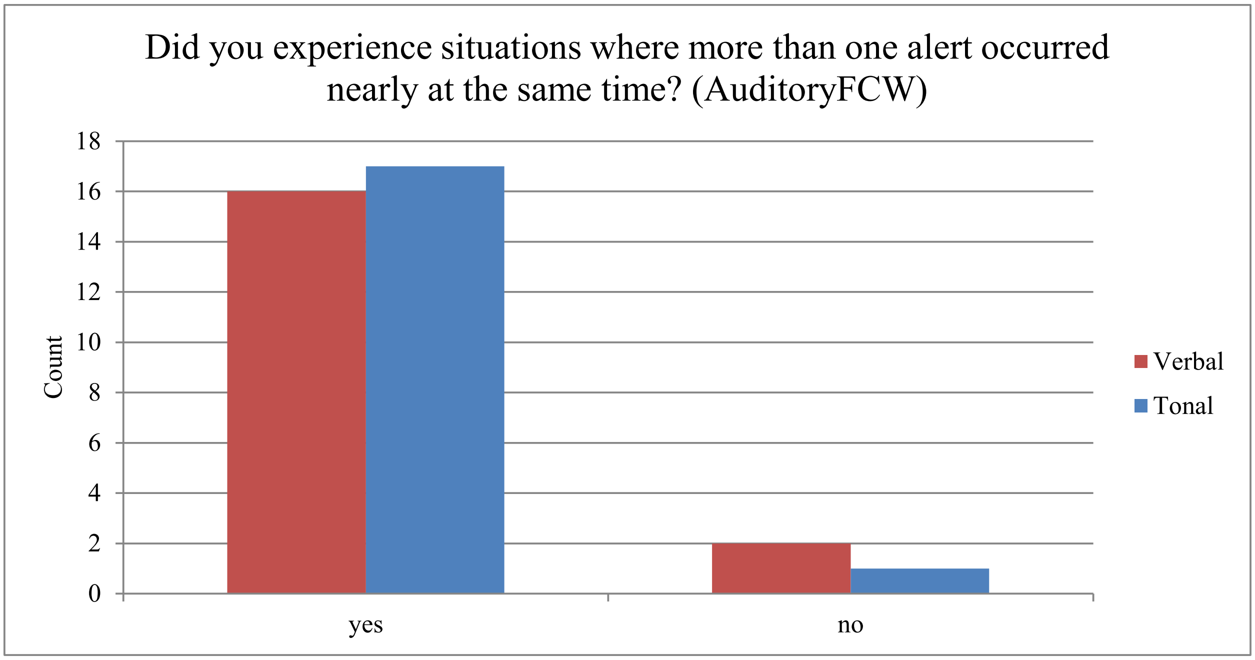


Figure 27. Number of Alerts Experienced (Auditory FCW)

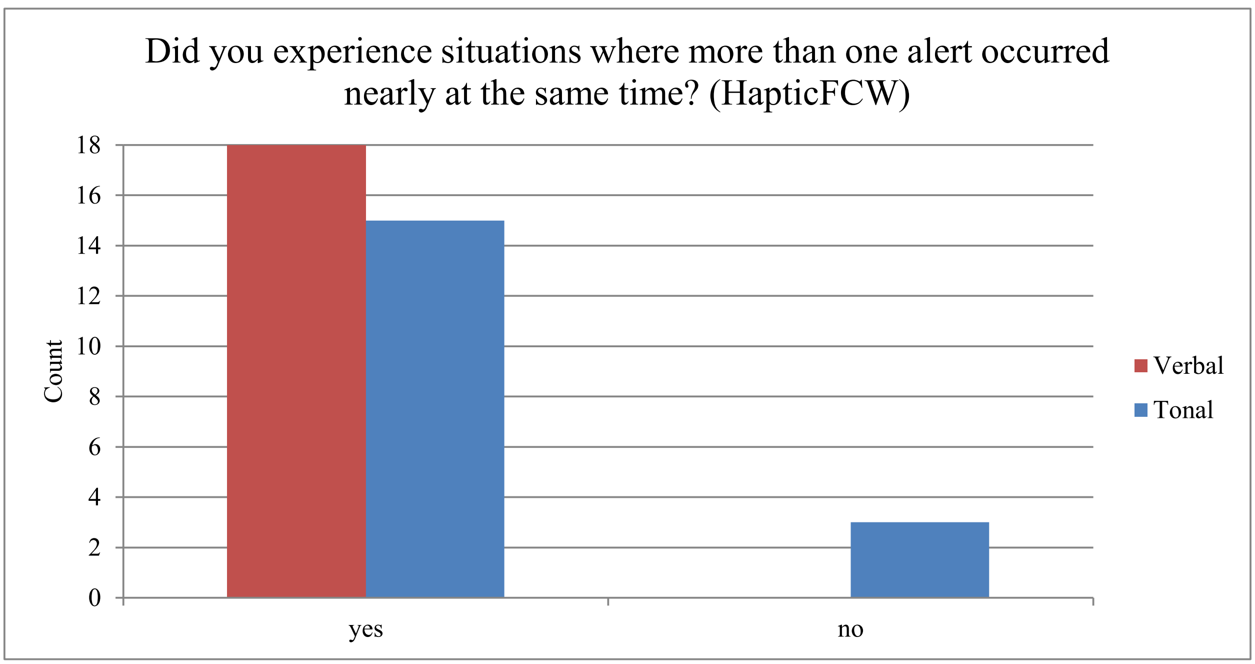


Figure 28. Number of Alerts Experienced (Haptic FCW)

Participants tended to rate the understandability of alerts better when EA were paired with the haptic FCW than when paired with the auditory FCW (Figure 29 and Figure 30).

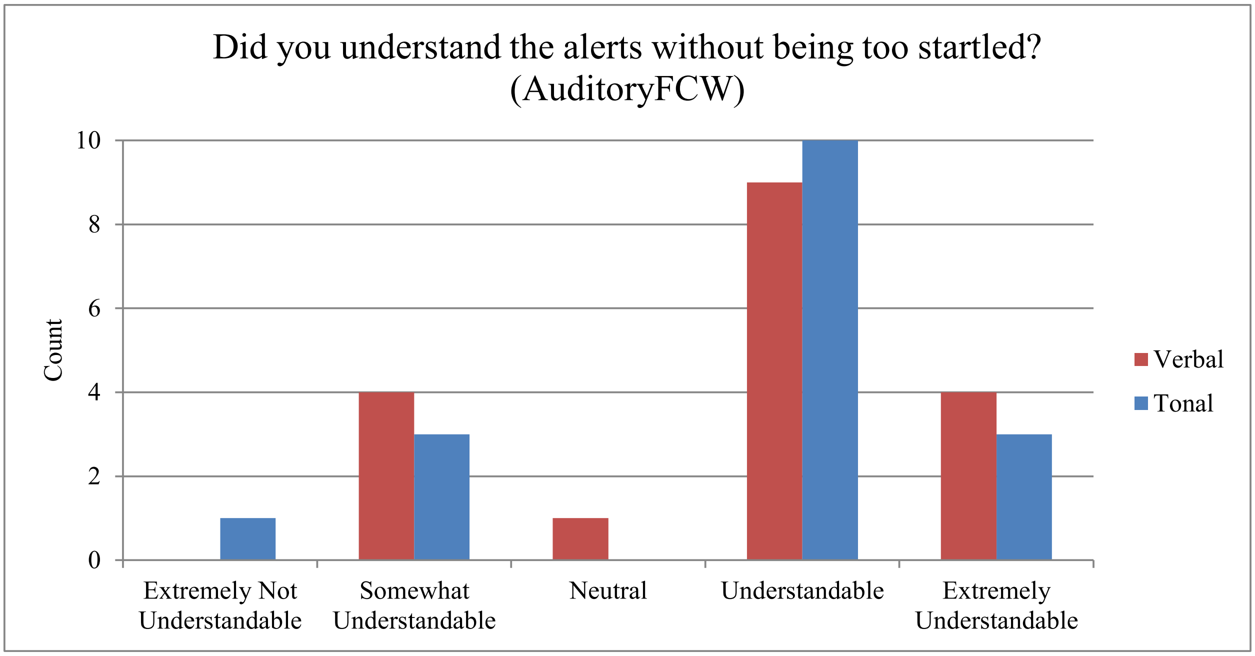


Figure 29. Understandability of Alerts (Auditory FCW)

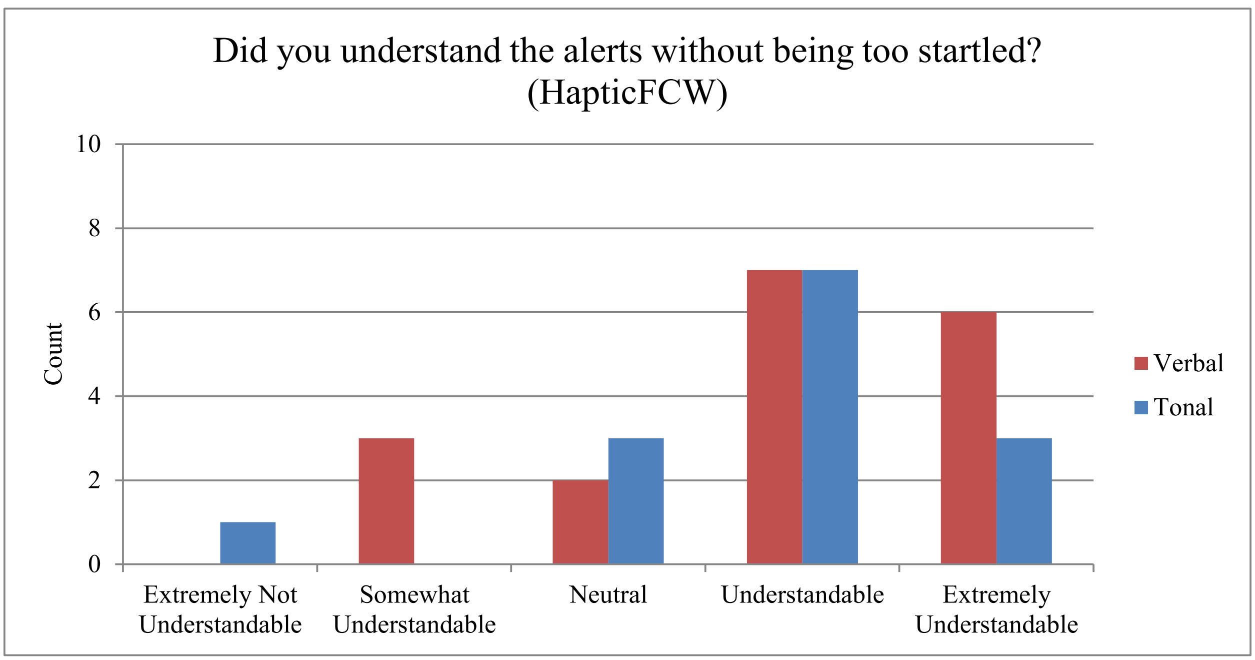


Figure 30. Understandability of Alerts (Auditory FCW)

More participants rated being slightly more confused by the pairing of the FCW and EA when both were auditory than when the FCW was haptic and EA was auditory (Figure 31 and Figure 32).

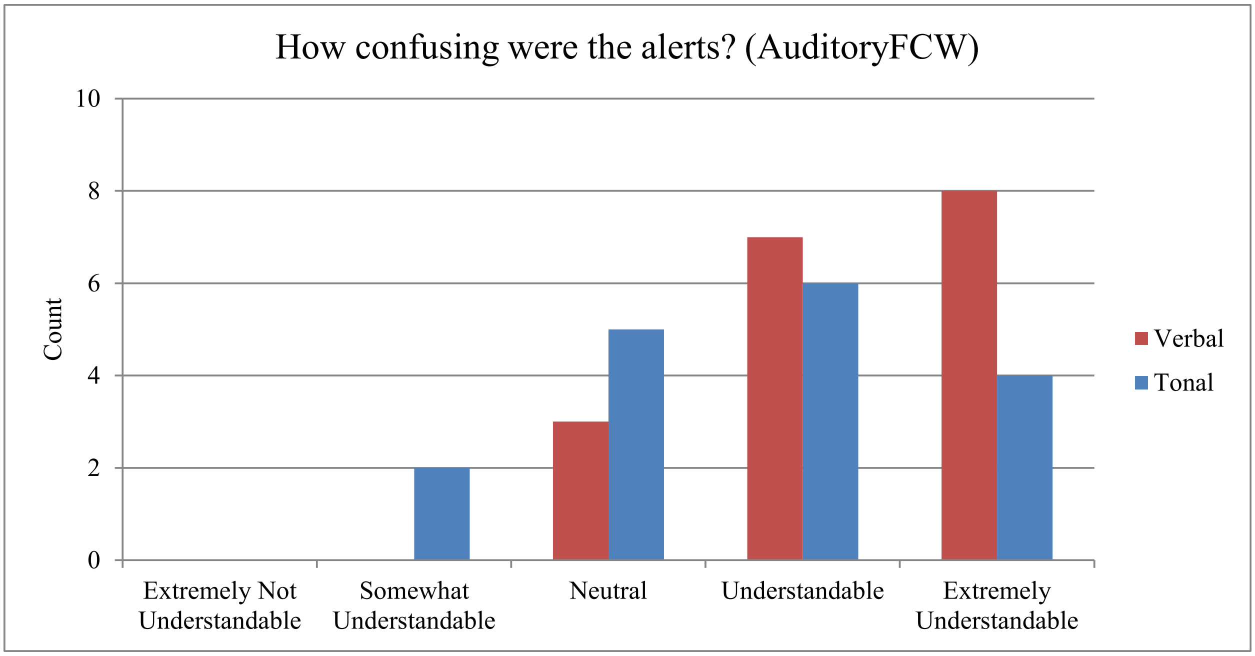


Figure 31. Level of Confusion (Auditory FCW)

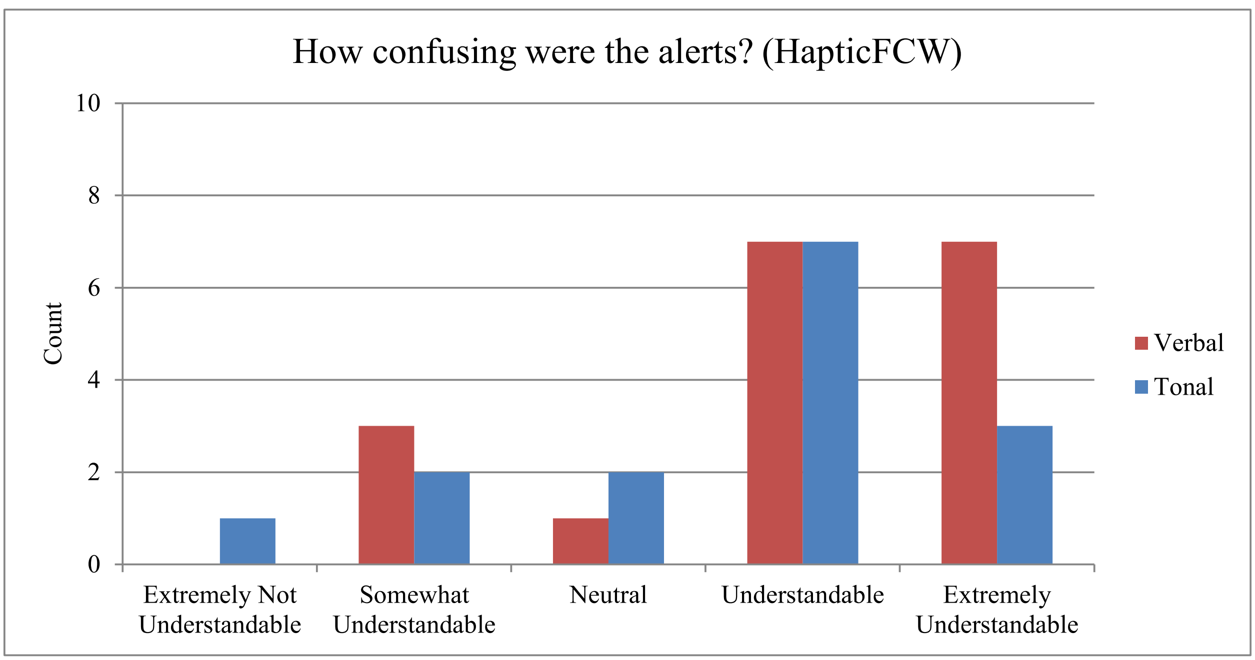


Figure 32. Level of Confusion (Haptic FCW)

Participants rated their drive with verbal EA as being slightly easier than those with tonal alerts. The combination of verbal EA with auditory FCW was rated as being the easiest (Figure 33).

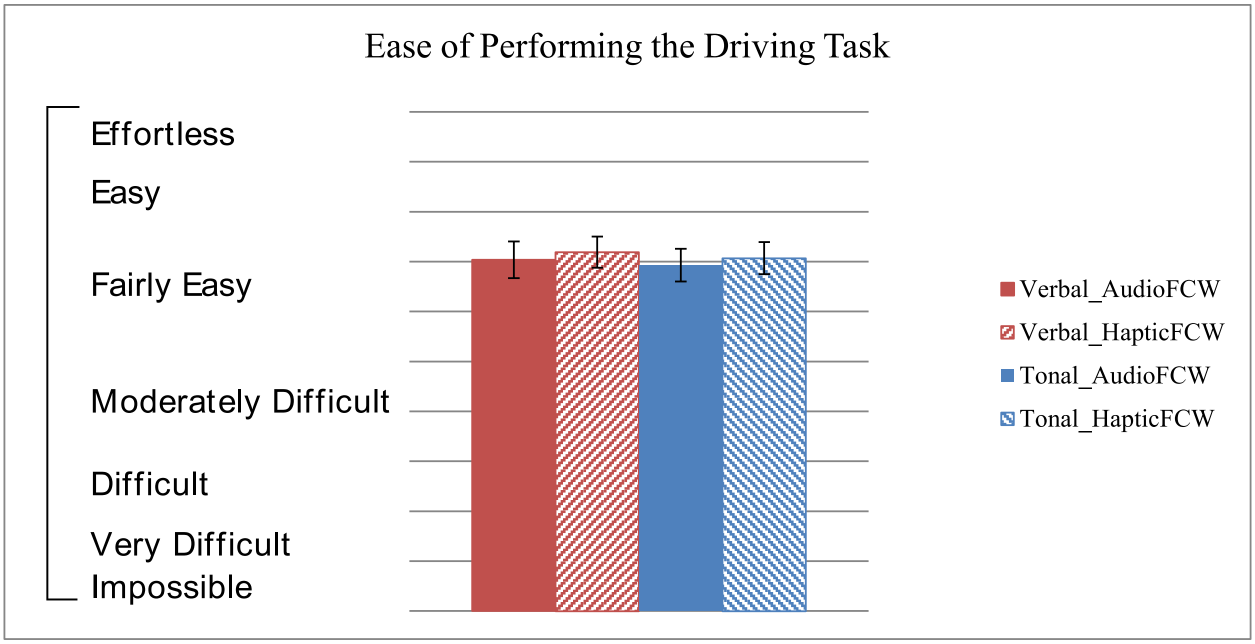


Figure 33. Ease of Performing the Driving Task

Participants rated that the verbal EA combined with auditory FCW alerts rated as being slightly easier on performing in-vehicle task (distractor task), although all combinations were rated as being closer to "Fairly Easy" (Figure 34).

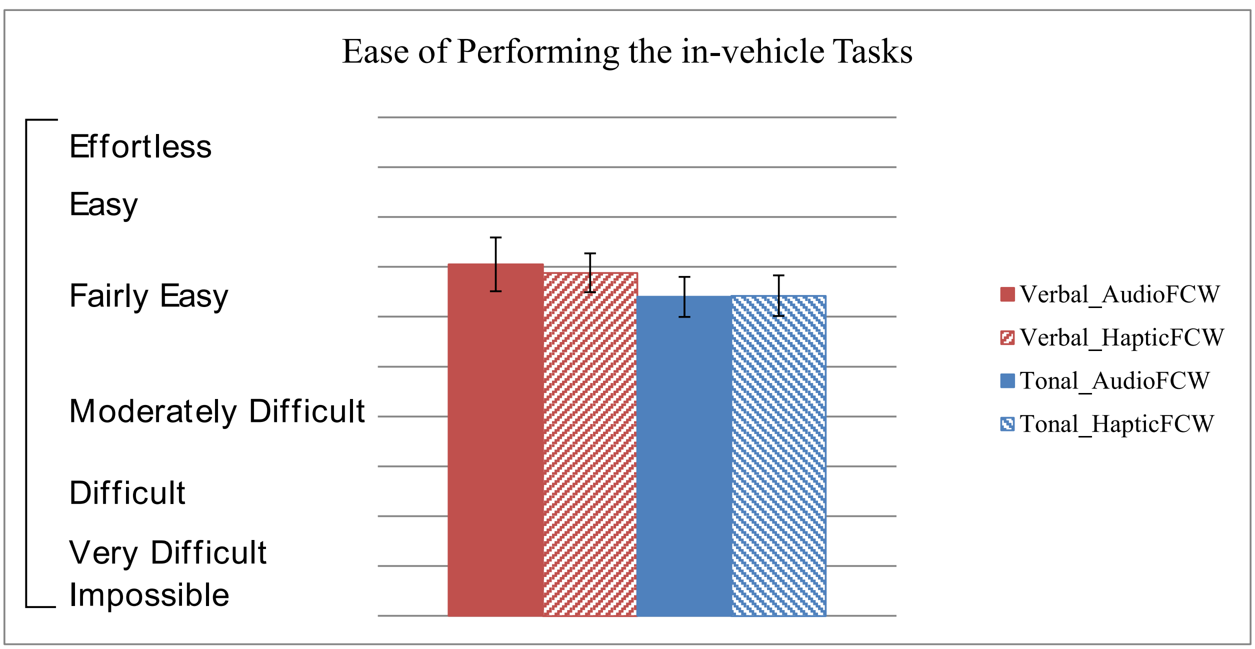


Figure 34. Ease of Performing the In-Vehicle Tasks

Having a verbal EA with auditory FCW was rated as having the least amount of discomfort or sense of risk than the other combinations (Figure 35).

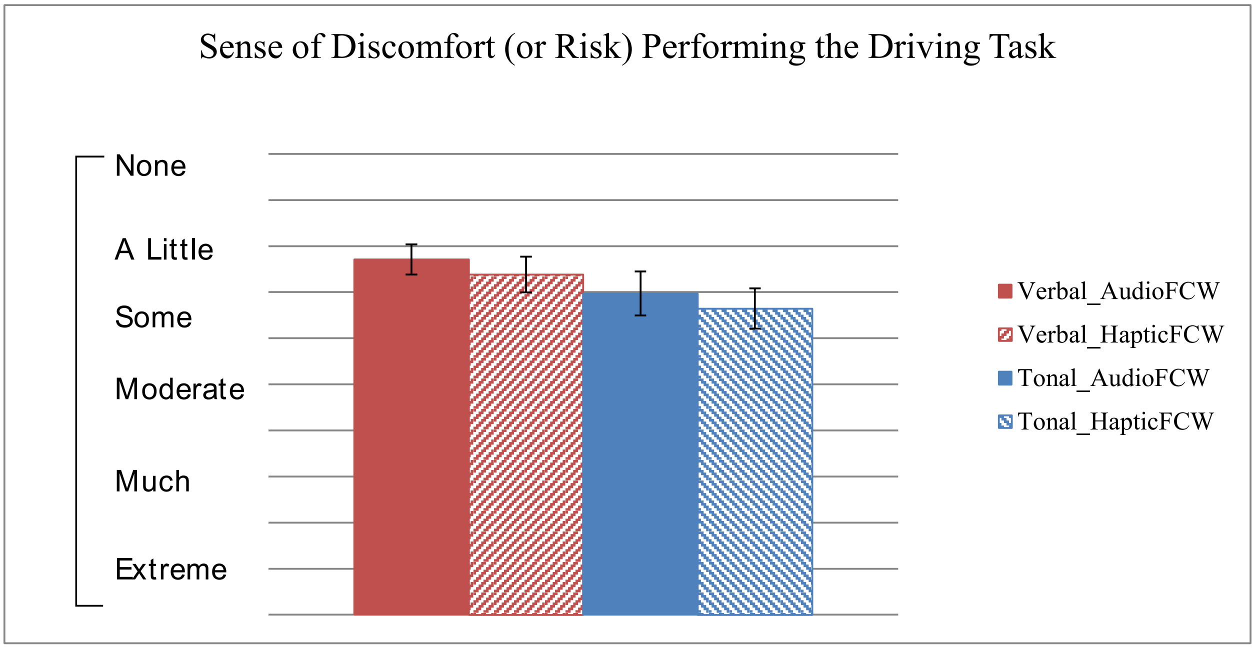


Figure 35. Sense of Discomfort or Risk Performing the Driving Task

Although verbal EA with auditory FCW was rated as having the least amount of discomfort, it also rated highest overall mental workload. All combinations were rated as being between "Moderate" and "Low" (Figure 36).

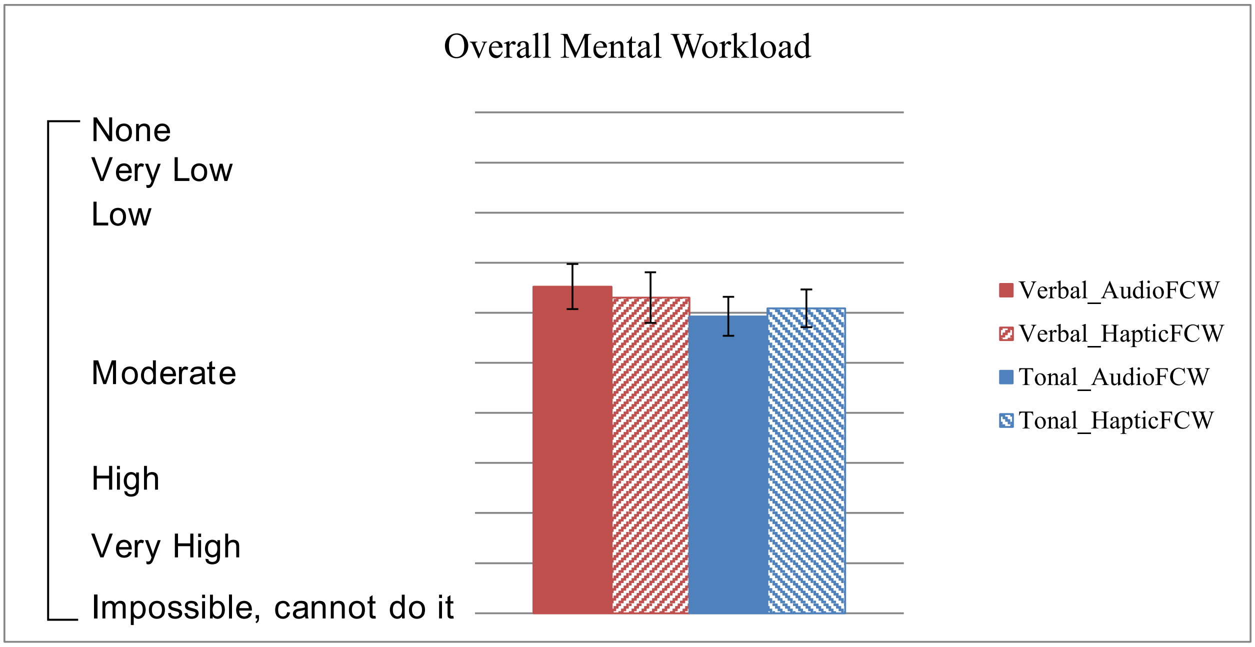
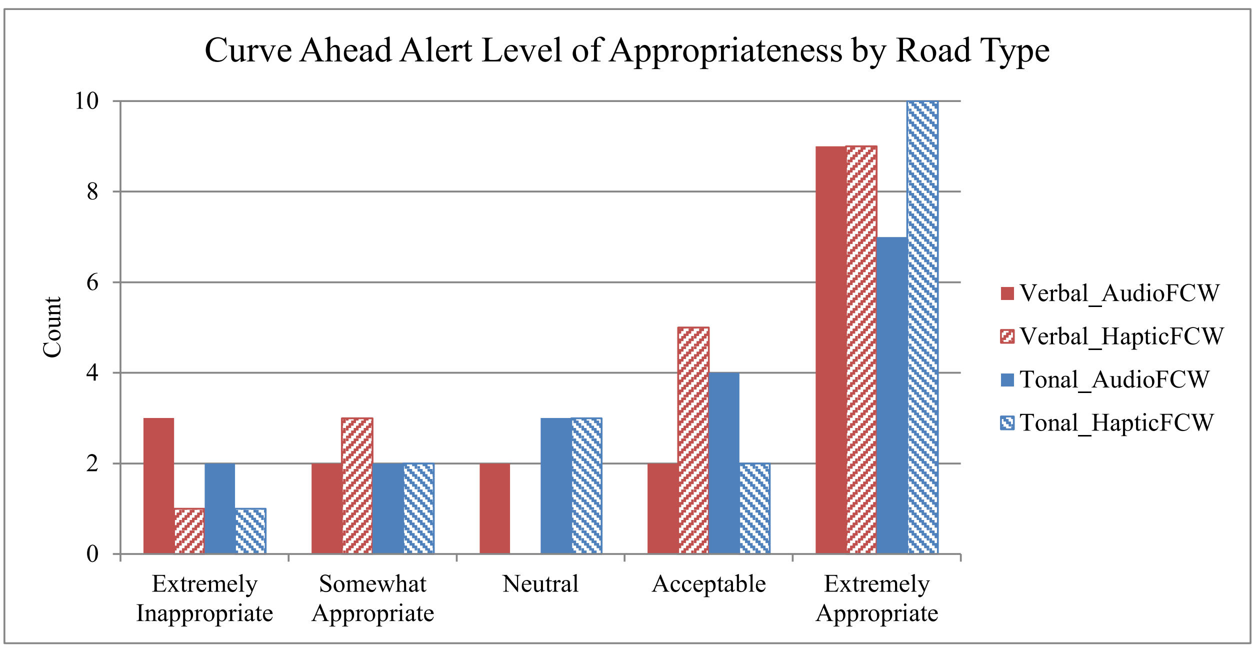


Figure 36. Overall Mental Workload

The following rating questions asked participants how appropriate they thought the EAs were during each road (Figure 37 to Figure 40). The tonal EA with haptic FCW combination was most often rated as being the most appropriate.



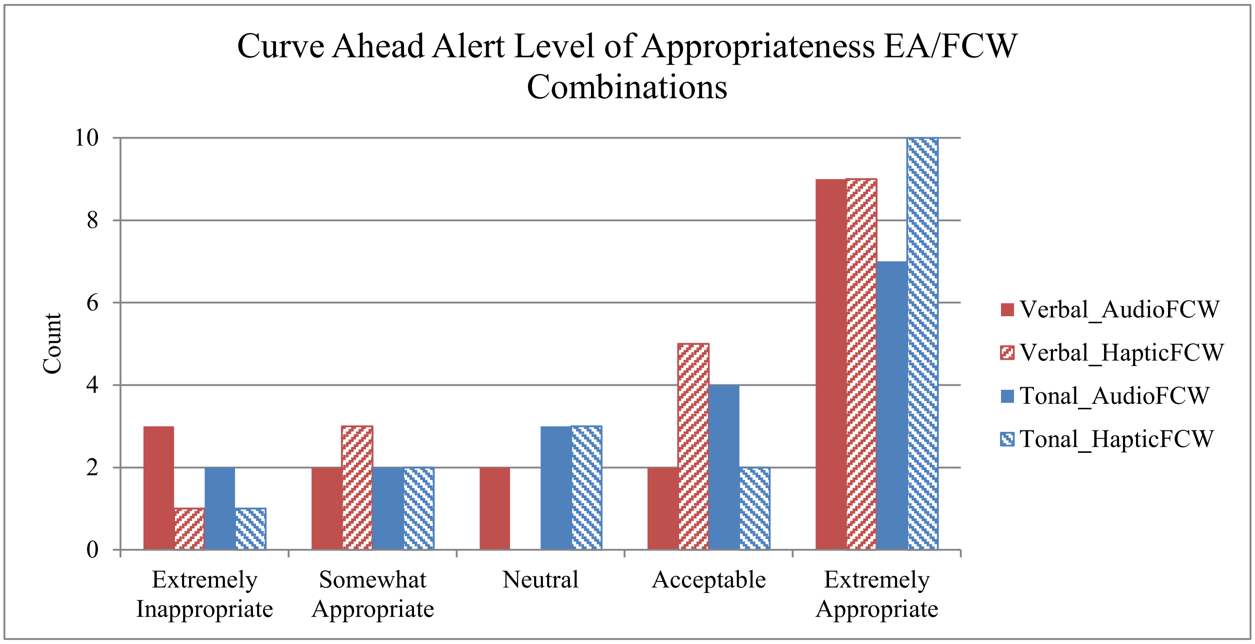
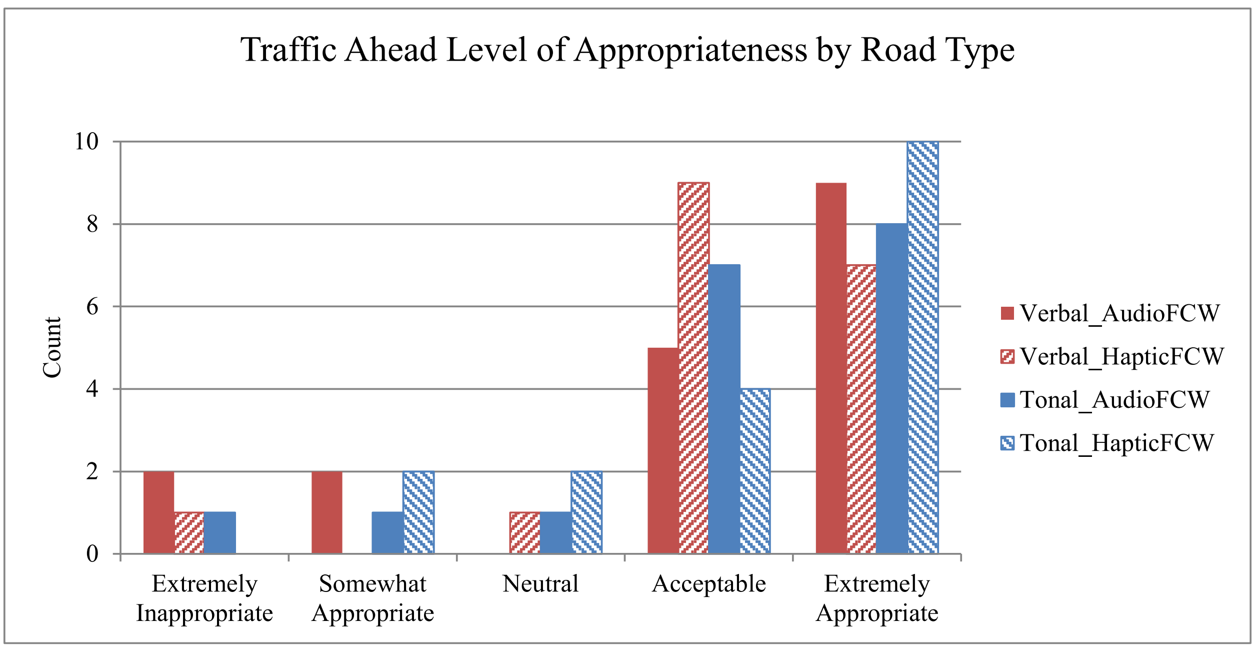


Figure 37. Curve Ahead Level of Appropriateness by EA/FCW Combinations



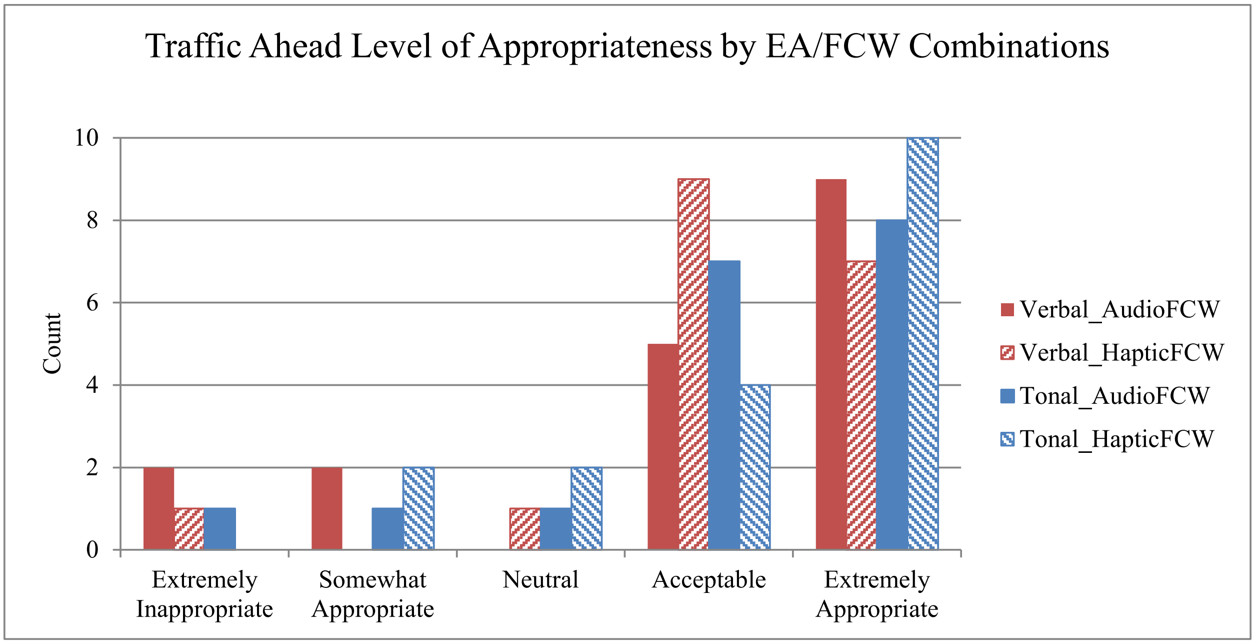
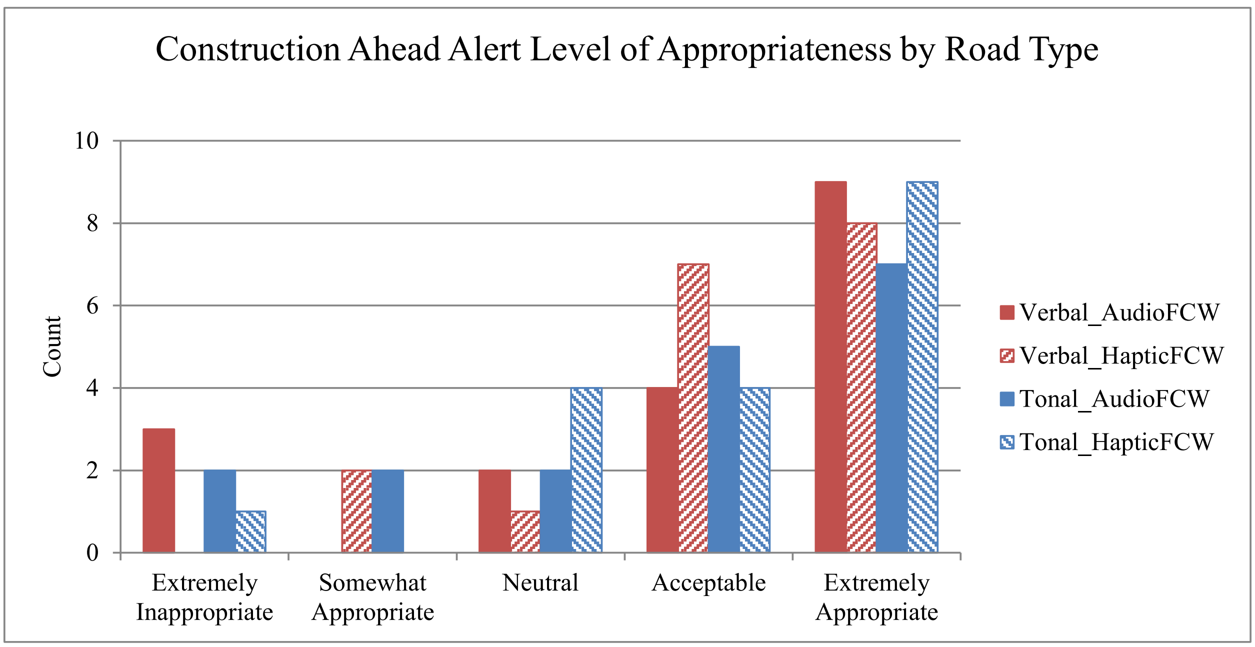


Figure 38. Traffic Ahead Level of Appropriateness by EA/FCW Combinations



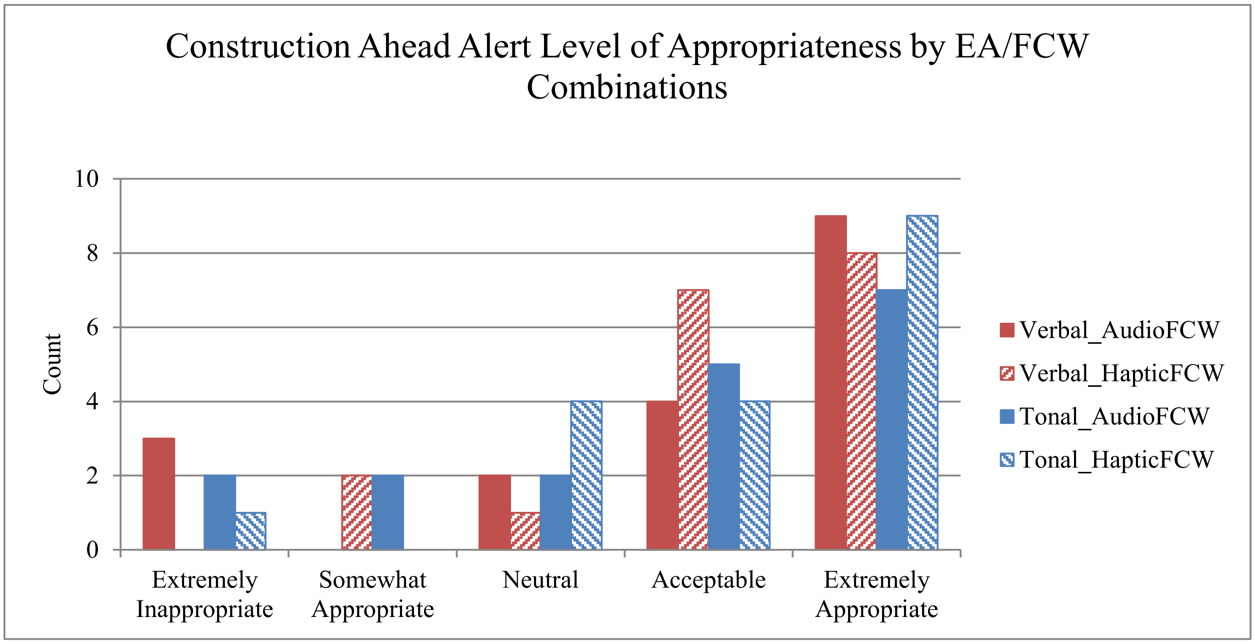
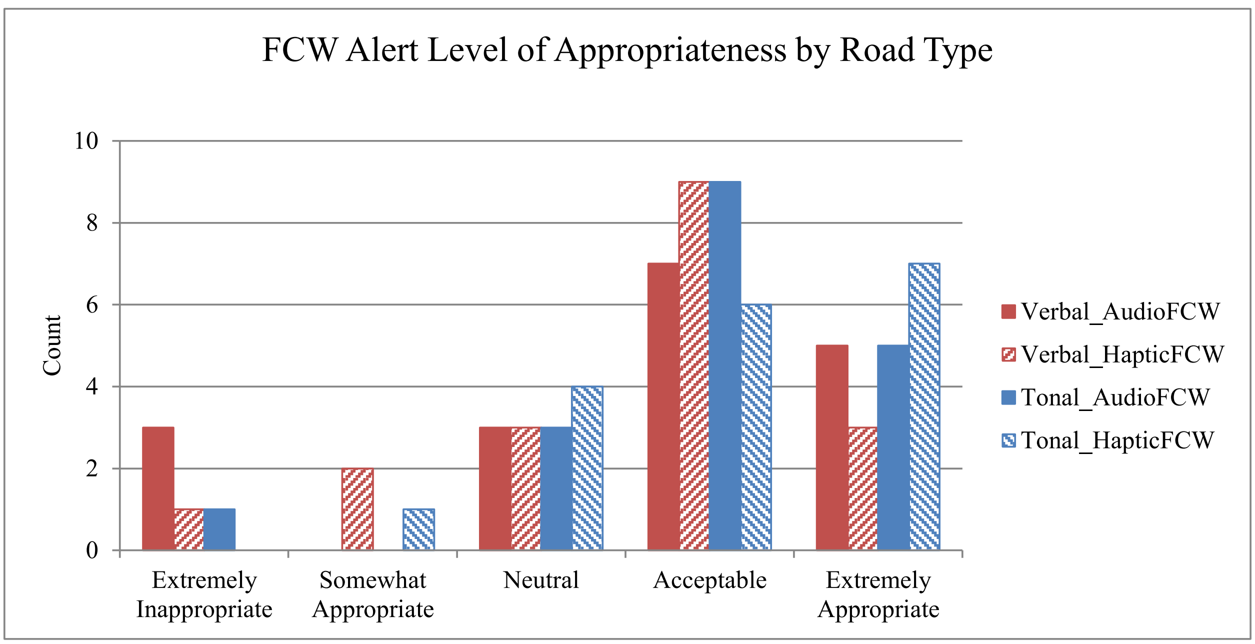


Figure 39. Construction Ahead Level of Appropriateness by EA/FCW Combinations



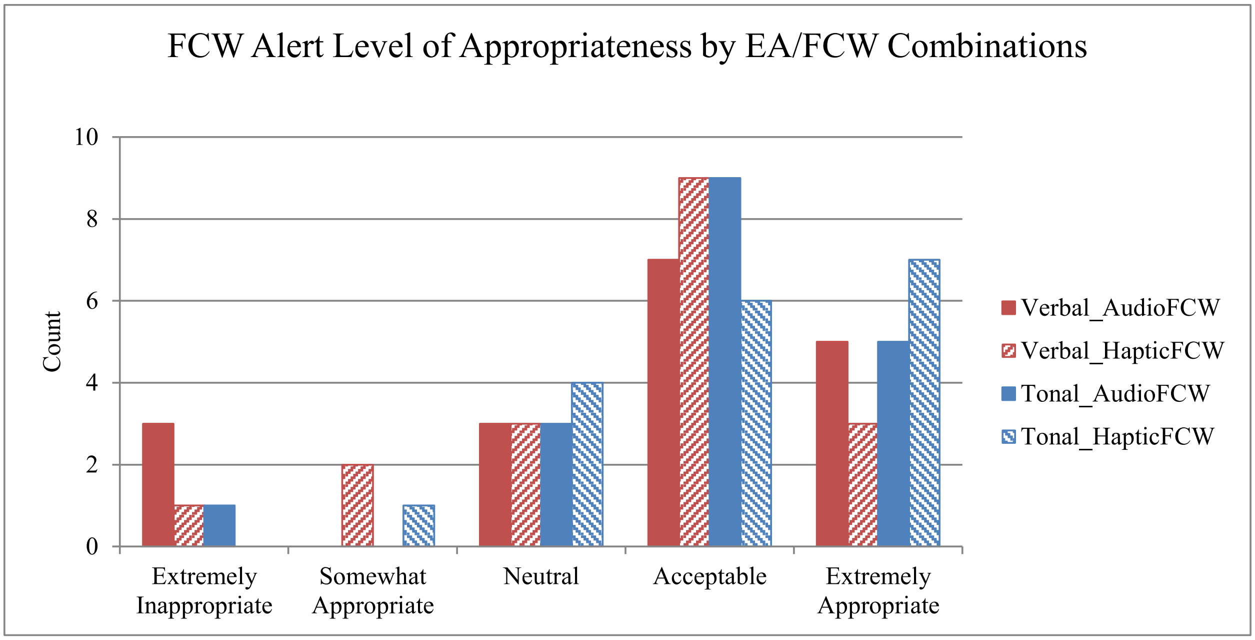


Figure 40. FCW Alert Level of Appropriateness by EA/FCW Combinations

4.0 DISCUSSION AND CONCLUSIONS

4.1 DISCUSSION

For this phase 2 PRP experiment, we examined how the temporal relationship of the EA to FCW onset can affect how DD respond to FCW. It is unclear how drivers' reaction time will differ when their attention is divided between two tasks (primary driving and the distractor task) at the onset of a critical event. This study hypothesizes that when presenting an in-vehicle task prior to a critical braking event, it will cause a delay in total reaction and braking reaction times, along with shortened distance between the SV and the LV.

The two measures of most interest were total response time and distance. Total response time was defined as the start of the LV critical braking event to the end of accelerator to brake movement. distance was defined as the minimum distance between the SV and LV after a critical LV braking event. These measures are used to answer whether or not drivers are affected by an EA prior to an FCW onset while distracted.

When evaluating the total response time, the baseline2 condition resulted in the longest total response times. Baseline2 events were those events where an LV event is present and FCW is triggered without an EA. Baseline2 events resulted in slightly longer total response times in this phase 2 CWIM PRP, when participants were distracted, than in phase 1 CWIM PRP when participants were not distracted. Furthermore, an SOA of 150 or 1000 ms resulted in the second longest total response times followed by an SOA of 300 ms (on average for audio and haptic FCW, and tonal and verbal EA).

Interactions between EA type and SOA were found such that for the tonal EA group, total response time decreased at 150 and 300 ms, and increases at 1000 ms SOA, but decreases from 150 through 1000 ms for the verbal EA group. The tonal EA group findings are not consistent with those from the phase 1 CWIM PRP where the total response times slightly increased for 150 and 300 ms, followed decrease at 1000 ms.

There was a significant difference between FCW modes where haptic FCW events elicited shorter total response times than audio FCW events. These findings were identical to those found in phase 1 CWIM PRP. The phase 2 data also revealed an interaction between FCW type and SOA times where for the audio FCW events, total response time decreased as SOA increased, but for haptic FCW event with an SOA of 1000 ms, total response time had an increase. This may be evidence of possible PRP effect, but with mixed results it is not definite.

When distances for FCW modes were compared, there was a significant difference between audio and haptic FCW where haptic FCW resulted in longer minimum distances. These results were identical to those found in the phase 1 CWIM PRP. There was also a significant difference between SOA times where the larger the SOA, the longer minimum distance, except for SOA of 1000 ms. An interaction between SOA and FCW mode was also observed whereas SOA increased so did minimum distance except for events with haptic FCW and 1000 ms SOA. Although the increase of minimum distance as SOA increased may be evidence of possible PRP effect, mixed results, such as the haptic FCW at 1000 ms SOA makes it difficult to make such an assumption.

The interaction between SOA times and EA group illustrates opposite results for each group. For the tonal group, an increase of SOA resulted in an increase of minimum distance, in contrast, for the verbal group, an increase of SOA resulted in a decrease of minimum distance. These findings are the same than those found in phase 1 where an increase of SOA for the verbal group resulted in a decrease of minimum distance, and increase of minimum distance for the tonal group.

Overall this study found that the total response times for baseline2 (distractor and FCW only) were longer than phase 1 baseline (FCW without distractor). This study also found that having participants distracted during LV braking events at times resulted in an increase of collisions. For example, the number of collisions changed drastically from phase 1 where only 2 collisions were recorded than in phase 2 which resulted in 11 collisions, not counting collisions from baseline1.

For the tonal EA group, the total response times for the 150 and 300 ms SOA resulted in shorter times compared to the phase 1 results.

Minimum distance was also affected by distraction in phase 2 where it was shorter in comparison to phase 1.

The eye glance behavior showed that the distractor task did as intended and kept participants engaged in a task while before the critical event. Although glances to the road were recorded during this period, eye glance data showed that participants kept most of their glances to the LCD monitor. When taking a closer look at eye glances at FCW alert onset, it revealed that most participants were in fact looking at the LCD monitor when the critical event occurred.

4.2 CONCLUSIONS

As was the case for CWIM PRP phase 1, the findings from this study tend to suggest that having a non-urgent safety related EA prior to an FCW during a LV braking event was a potential benefit most of the time than not having an EA present.

Participants in CWIM PRP phase 2 had quicker total response times than those in CWIM PRP phase 1. When reviewing video data, it was found that several participants reacted to the distractor task audio cue in anticipation to a critical LV braking event although over half of distractor task events were not paired with critical LV braking. These results may suggest that the combination of a distractor task and short SOA may create a startling affect which may have resulted in shorter total response times.

If considering an FCW system in a vehicle, the results still support a haptic FCW over an audio FCW in producing shorter response times and longer minimum distances during LV braking events regardless of whether participants are detracted or not. Between the audio and haptic FCW modes, participants felt the haptic FCW was slightly more startling and reported not noticing it more often than the audio FCW.

It was no surprise that more participants rated having a greater sense of discomfort with the combination of tonal EA and haptic FCW. They also rated the tonal/haptic combination made it more difficult to perform the main driving task and the distractor task.

Similarly to findings in research by Wiese and Lee, an SOA of 300 ms caused less temporal conflict and less of an effect on the driver's performance than other SOAs. Overall, an SOA of 300 ms resulted in shorter total response times and longer minimum distances. The total response times for an SOA of 1000 ms were also similar to those that Wiese and Lee found where participants had slower brake reaction times than those with 350 ms (300 ms for this study) but not slower than those with 0 or 150 SOA.

When comparing results between phases 1 and 2 the following were observed. In CWIM PRP phase 1, having an SOA of 1000 ms resulted in quicker total response times than other SOAs, but this was not the case in phase 2 where participants were distracted during critical events. Lastly, participants tended to drive poorer in CWIM PRP phase 2, when distracted, resulting in more collisions, longer total reaction times, and shorter minimum distances for baseline events than they did in CWIM PRP phase 1.

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APPENDIX A

Driving Simulator Participant Documents and Forms

TABLE OF CONTENTS

INTRODUCTION TO THE DRIVING SIMULATOR STUDY

The purpose of this study is to evaluate driver behavior interaction with a series of vehicle system technology enhancements, which include various alert types and technologies. This study will be conducted in the DRI Full Motion Driving Simulator. The DRI Driving Simulator is a high-tech device designed to simulate the actual driving conditions of a vehicle, allowing you to experience feelings similar to real-life driving conditions. You will sit in a modified vehicle "cab" with instrumented controls and displays. Computer generated roadway scenes are used, and simulator motion is provided by a hexapod motion system. The driving simulator is similar to a flight simulator with a moving cab, or an easy ride at a theme park, such as Disneyland. The risks you will experience are similar to those of an engineering office environment, combined with some aspects of a mild amusement-park-like ride. A DRI Research Assistant will be in the cab with you at all times.

During this study, you will be driving on a four-lane highway with two lanes in each direction. You will be following a lead vehicle at all times. The simulator computer records driving data for each drive, such as your path and steering control actions and in addition, video will be recorded.

The study will consist of a single session and the total completion time will be about 3 hours. This includes arrival, preparation, driving, evaluations, and rest periods outside of the simulator.

Please read and fill out all of the accompanying documents. This should include:

- General Information and Health Questionnaire
- Driver Consent Form
- Applied Research Participant Confidentiality Agreement
- Daily Health Questionnaire

TYPICAL EVALUATION SESSION

During this study, you will be asked to drive on a variety of roads. The simulator will automatically record data for each drive, such as your path and steering control actions.

At the beginning of the driving session, you will have a practice driving session. The main purpose of this is to acquaint you, or re-acquaint you, with the simulator itself and the characteristics of the simulated car.

After the practice run, the evaluation will begin. Your primary task is to drive in the manner instructed by the DRI staff member. It is important that you be alert and comfortable throughout the session.

SAFETY PRECAUTIONS WITH THE DRIVING SIMULATOR

DRI knows that it is important to ensure the safety and well-being of all study participants. Toward that end, we want to make you aware of a number of safety precautions and procedures that have been implemented. Important among these are hardware and software safety interlocks built into the simulator. In addition are precautions you can take as follows:

In general, if you think there is a problem with the simulator procedures, say "STOP" in a loud voice. The operator will immediately shut down the simulator.

GENERAL INFORMATION AND HEALTH QUESTIONNAIRE

This questionnaire is intended to help us determine your suitability to participate in this study. The information you provide will be kept strictly confidential by the research team within DRI.

Name (Legal name) ____ Date ___________

Address ____Phone - Home_______________

City/State/Zip ____ - Work ______________

Email Address (optional) ____

Note: Your email address will only be used to contact you about future DRI Projects.

Emergency Contact ___________________________________ Their Phone ________________

PERSONAL INFORMATION:

Height ________________ Gender _________ Birthdate (MM/DD/YY) __________________

Occupation _____________________________ Employer ______________________________

General Availability for Future Studies ____

____

HEALTH INFORMATION:

1. How would you rate your general health?

   ❑ Excellent ❑ Good ❑ Fair ❑ Poor

Note: If your answer is fair or poor, you should not participate.

2. Do you wear glasses or corrective lenses for driving? ❑Yes ❑ No
3. Do you have any uncorrected visual impairment? ❑Yes ❑ No
4. What is your level of night vision?

   ❑Excellent ❑Good ❑Fair ❑Poor

5. Are you color blind? ❑Yes ❑No
6. Do you have any hearing impairment? ❑Yes ❑No
7. Do you have a heart condition? ❑Yes ❑No
8. Do you currently have back/neck pain or have you received treatment for back/neck problems within the last 3 years? ❑Yes ❑No

GENERAL INFORMATION AND HEALTH QUESTIONNAIRE (cont.)

9. Have you had or do you have any disorders that would impair your current driving ability? If yes, describe ❑Yes ❑No

____

10. Do you have any physical disability that might affect your ability to drive a car or to participate in the evaluation? If yes, describe ❑Yes ❑No

____

11. Have you had any seizures or loss of consciousness within the last 6 months? If yes, describe ❑Yes ❑No

____

12. If you are female, are you pregnant? ❑Yes ❑No

13. Are you addicted to or have you taken any illegal drugs within the last 6 months? ❑Yes ❑No

14. Do you smoke?

❑o ❑ccasionally ❑egularly

15. Do you consider yourself to be susceptible to motion sickness, such as car sickness or sea sickness?

❑ No ❑ Seldom ❑ Occasionally ❑ Often ❑ Always

16. Please list any medications or drugs you are currently taking

____

OTHER INFORMATION:

1. Are you or anyone in your family currently involved in a lawsuit regarding a vehicle, use of a vehicle, or a vehicle accident; or have you or they been involved in such a lawsuit within the past 5 years?

❑ No ❑ Yes ❑ Decline to answer

If yes, please briefly describe your or their involvement:

____

____

DRI PARTICIPANT RECRUITMENT DIALOGUE

Hello, may I please speak to *participant's name*?

This is *your name* from Dynamic Research, Inc. You participated in a driving study with us about *# of months/years* ago and we wanted to know if you would be able to help us out again. **pause to allow participant to respond**

This study involves a single session and you will receive an honorarium of *$200* for approximately 3 hours of your time. The study will take place at our Torrance location.

Do you think you would be available to participate?

(if Yes) That's great!
(*List any prerequisites required to make sure the subject qualifies*)
Are you available on *date* at *time*? *(state the first date and time available. Continue to schedule for other appointments, if necessary)*
Do you need our address and phone number? *(355 Van Ness Ave #200 Torrance CA 90501, 310-212-5211)*

Thank you for your time, *participant's name*. We will see you on *scheduled date* at *time*. If for any reason you are running late or are unable to make your appointment please give us a call.

(if No)I'm sorry to hear that. Thank you for your time, *participant's name*. Please call back if you become available.

ID#

DAILY HEALTH QUESTIONNAIRE

1. How would you describe your general health today?
   ❑ Excellent ❑ Good ❑ Fair ❑ Poor
   If your answer is fair or poor you should discuss how you feel with a project team member.

2. Has there been any change in your general health in the past few days? If yes, please describe ❑ Yes ❑ No

   ____

   ____

3. In the last 24 hours have you experienced any of the following conditions?

Unusually tired feeling	❑ Yes	❑ No
Unusual hunger	❑ Yes	❑ No
Hangover	❑ Yes	❑ No
Headache	❑ Yes	❑ No
Cold symptoms	❑ Yes	❑ No
Depression	❑ Yes	❑ No
Emotional upset	❑ Yes	❑ No
Other illness or injury	❑ Yes	❑ No

4. Have you taken any prescription or non-prescription drugs in the last 48 hours? If yes, please describe ❑ Yes ❑ No

   ____

   ____

ID#

DAILY HEALTH QUESTIONNAIRE (cont.)

5. Have you consumed any alcohol (beer, wine, liquor, etc.) in the last 24 hours?

   If yes, please describe type and amount. ☐ Yes ☐ No

   ____

   ____

6. Is the main car you are currently driving different than the one you were using when you completed the General Information Questionnaire? ☐ Yes ☐ No

There are some small risks you may be exposed to as a volunteer in this study. The driving simulator is similar to a video game. Since the driving simulator projects the road ahead on a screen, you may experience some of the symptoms of motion sickness; such as a headache, uneasiness, or other discomfort. You will not be driving an actual automobile or truck. So, the risks you will experience are similar to those of an office environment, combined with some aspects of a mild amusement-park-like ride. If you feel uneasy, disoriented, or motion sick, please tell a member of the evaluation team, so you can take a break. You can stop participating in this study at any time, by just telling a member of the team.

I understand the purpose of this study and the possible risks involved, and I am in good health today and ready to participate.

Signature ____ Date ________________

Team Member (Witness) ____________________________

INFORMED CONSENT FORM

Please read and understand the following.

1. Your participation. You are being asked to volunteer as a driver subject in a research project whose purpose and description are contained in the document entitled "Introduction to the Driving Simulator Study." Please read that description now, if you have not done so. Your participation will involve a single session, for about 3 hours.

2. Risks in the Study. There are some risks that you may expose yourself to in volunteering for this research study. The evaluations will be accomplished in the DRI Driving Simulator Laboratory at its facility in Torrance. The driving simulator is similar to a video game. Since the driving simulator projects the road ahead on a screen, you may experience some of the symptoms of motion sickness; such as a headache, uneasiness, or other discomfort. You will not be driving an actual automobile or truck. The risks you will experience are similar to those of an office environment, combined with some aspects of a mild amusement-park-like ride. If you feel uneasy, disoriented, or motion sick during the driving portion, please tell a member of the research team, so you can take a break. If you become too uncomfortable you can end your participation at any time (see Item 9, below).

3. Precautions. The following precautions are taken prior to and during your participation:

   – A member of the research team will be in the cab with you.

   – You will be asked to wear the shoulder/lap restraint system while in the cab.

   – Before and during the evaluations, you will be briefed on the procedures and what we want you to do.

   – DRI staff will be directing all activities and serving as safety observers.

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INFORMED CONSENT FORM (cont.)

4. Use of Data and Confidentiality. The data from this study will be treated anonymously, and your name will not be identified in any publically available records or reported results. You will be video recorded during the study for data reduction and analysis purposes **only**. If you do not agree to be video recorded please let a research team member know. The data and the results of the evaluations will be the exclusive property of DRI and its customer.

5. Benefit of the Study. While there are no direct benefits to you from this research (other than an honorarium for participation), your help with the study will contribute to our knowledge of how drivers interact with various automotive technologies and driving situations.

6. Qualifications to Participate. You should not participate in this research if you are under 18 years of age, or you do not have a valid driver's license, or you are pregnant, or you have taken any drugs, alcoholic beverage, or medication within the last 24 hours that might interfere with your ability to drive or to operate a vehicle safely. It is your responsibility to inform a research team member of any conditions that might interfere with your ability to participate or drive safely. Such conditions would include inadequate sleep, fatigue, hunger, hangover, headache, cold symptoms, depression, allergies, premenstrual syndrome, emotional upset, uncorrected visual or hearing impairment, seizures (fits), nerve or muscle disease, or other similar conditions.

7. No Smoking. There will be no smoking in the simulator or inside the DRI facility.

INFORMED CONSENT FORM (cont.)

8. Questions. You should know that the research team will answer any questions that you may have about this project. You should not sign this consent form until you are satisfied that you understand all of the previous descriptions and conditions. If you have any questions please contact:

Ana Bakker
Project Engineer
Dynamic Research, Inc.
355 Van Ness Avenue, Torrance, CA 90501
Ph: 310-212-5211

or another DRI staff member

9. Okay to Stop Participating. You may withdraw from participation in this study at any time you wish now or during the session and without any penalty. Should you, for any reason, feel the need or desire to stop participating, please do not hesitate to let the safety observer or another research team member know. The DRI research team also reserves the right, for any reason, to terminate your participation in the study. You will still be paid the honorarium.

INFORMED CONSENT FORM (cont.)

10. Signature of the volunteer and date:

I have read and understand the description and scope of this research project, and I have no questions. I understand the risks outlined in Item 2, I acknowledge reading about the safety features of the driving simulator, and I satisfy all the requirements and restrictions of Item 6 (Qualifications to Participate). I hereby agree and consent to participate, and I understand that I may stop participation if I choose to do so at any time, either prior to or during the evaluation day.

Signature ________________________________

Date __________________________________

11. Witnessing signature of a member of the research team or other responsible DRI employee and date:

Signature ________________________________

Date __________________________________

APPLIED RESEARCH PARTICIPANT CONFIDENTIALITY AGREEMENT

As a participant in an applied research study at Dynamic Research, Inc., (DRI), I recognize that such research studies involve confidential and proprietary information and matters. This includes data, information, software, hardware, and inventions that are considered proprietary by DRI or its customers.

I agree not to divulge or discuss the details of these confidential activities, and related data, information, software, hardware, and inventions to anyone outside of DRI, either during the study period or at any time in the future. I further agree not to remove from DRI any such data, information, software, hardware, or inventions.

I hereby waive the rights to any results, findings, or consequences thereof which may result from my activities for DRI.

I agree that this research activity participation is on a voluntary at-will basis, which means that either I or DRI can terminate the relationship at any time, without prior notice, and for any reason or for no reason or cause.

I understand and agree to the above.

Signed_________________________________

Printed_________________________________

Date___________________________________

Witnessed______________________________

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RESEARCH ASSISTANT PROCEEDURES AND SUBJECT INSTRUCTIONS

The following items are to be discussed with the participants before they participate in the driving simulator evaluation. Instructions in *italic* are to be given to the participants.

1. Give the participant a copy of the pre-test documentation package, and ask him to fill it out. Answer any questions the participant has while filling it out. Review the completed form. If any of the conditions listed on the daily questionnaire indicate that the participant would not be suitable to test in the simulator, thank the participant for his willingness to participate but tell him that he is being excused, and that the reason will be kept confidential. If the form is acceptable, sign and file it.

2. Review the purpose of the study, and descriptions of the evaluation.

3. How the evaluation will be conducted:

   "Today's evaluation will consist of 3 drives with a break. The entire study should take approximately 3 hours including paperwork, breaks and ratings.

   When you are asked to drive the simulator, you will be driving a two-lane highway with a single lane going in each direction at approximately 55 mph. We ask that you drive on the main road at all times unless otherwise instructed. The conditions are daytime, and the weather will be clear. To start driving the vehicle you simply need to depress the accelerator, and to stop the vehicle you would use the brake. You will not need to worry about shifting gears.

   During your drive, you will be exposed to various alert systems and technologies in the vehicle. Please respond promptly by stating aloud what you thought each alert is/meant. Keep in mind that today's study may ask you to do things while driving that you may not ordinarily do in the real world. The simulator allows you to perform such tasks in a safe and controlled environment therefore please perform all tasks to the best of your *ability but keeping in mind that driving safely, keeping the correct distance from the vehicle traveling in front of you, and responding to any alerts are your primary tasks.*

Anytime you are driving, I will be in the passenger seat to answer questions, give you the proper instructions, and to be a safety observer. If you feel uncomfortable in any way or you want to take a break at any time, please let me know right away.

After we are in the cab, I will need you to adjust your seat so that you can easily reach your pedals, and adjust your steering wheel so that you can easily see all the displays on your dashboard. When adjusting your seat, ensure that you can clearly see the LCD monitor located in the center console on your right. Feel free to adjust the air vents in the cab. Once we are in the vehicle we will double check that everything is adjusted properly. For safety reasons, I will need you to fasten your seatbelt and keep it fasted until I indicate it is safe to unfasten it.

Before starting, we're going to do a quick color blindness test. After passing that, we'll go down to the simulator and get started.

4. Ratings:

   Before each driving task, review all ratings and rating scales. Describe what is being asked exactly, so that each participant will answer with the same considerations. This makes the data more consistent and more meaningful. Explain how to complete the rating scales.

The following items are to be performed as the participant enters the simulator room and proceeds to the cab.

1. Assist the participant into the cab.

2. Have the participant adjust the seat position.

3. Assist participant with the seat belt.

The following items are to be described and performed with the participants after getting in the car.

1. Review safety features:

    - Stay seated until told they can get out of the cab.
    - Use of seat belt.
    - If the participant feels any discomfort, RA should inform the Simulator Operator (SimOp) immediately.
    - Use small, smooth steering inputs and corrections. Also use smooth brake and throttle applications.

Miscellaneous pre-test tasks to be performed by the SimOp:

1. Inform the business office that testing is in progress. If testing is being performed at night, please let the business office know you will be there after hours.
2. Check cameras are adjust (face and foot)
3. Hands on steering wheel do not block the LCD monitor
4. Steering wheel is adjusted so they can see entire IP area
5. Seat belts on
6. Air vents adjusted to their preference

INSTRUCTIONS: WARMUP

The following instructions are to be given to the participants while in the driving simulator. Instructions in *italic* are for the participant.

[In the Cab]

You will first drive a warm up highway. This time is intended to familiarize you with operating the driving simulator, to introduce you to all alerts, and to practice performing the in-vehicle task (or number task) you will be asked to do during the actual study. At the beginning of your drive, you only need to depress the accelerator to start the vehicle moving. You will be following a lead vehicle during your drive, so as soon as you see the lead vehicle appear, you may begin driving. Generally, you will use small, smooth steering inputs and corrections to control your vehicle. [Demonstrate to Participant]

You will be driving approximately 55 mph on a two-lane highway with one lane going in each direction. We ask that you drive on the main road at all times and do not pass the lead vehicle unless otherwise instructed. In the event that you encounter an obstacle, please feel free to brake to avoid any collisions. Your primary tasks are to drive safely, maintain the proper distance from the lead vehicle, and respond to any alerts. But try to do the other in-vehicle tasks to the best of your ability. The gauge located in your dashboard will indicate if you are at the correct distance from the lead vehicle in front of you [point out gauge to driver]. *When the needle on the gauge is in the green zone, you are at the correct distance. If the needle is in the right red portion of the gauge, it means you are following too closely to the vehicle in front of you. If the needle is in the left red potion of the gauge, it means you are falling too far behind. You will get a chance to test the gauge during your warm-up drive. Please try to maintain your distance within the green zone as much as possible. If for some reason you stay in red zone for too long, you will be given an audio reminder to "Stay in the green zone."*

During your warm-up drive, you will be exposed to various alert systems and technologies in the vehicle.

You will also have the opportunity to practice the in-vehicle secondary task (or Number task) so that you are comfortable with it. Before starting, let's go through the instructions for the in-vehicle task.

INSTRUCTIONS: NUMBER TASK

You will know it is time to perform a number task because you will hear an audio instruction say "Number Task." A sequence of five digits will be displayed on this small LCD screen [Point to LCD screen]. *The number task happens quickly so please look over at the screen immediately after hearing the number task command.* ***Once the sequence begins, I need you to recite back numbers aloud, as they appear.*** *Accuracy is important so please do the best you can. Do you have any questions about the Number Task? If not, let's start the warm-up drive.*

The warm-up drive will be approximately 15 minutes long and will give you the opportunity to become familiar with all the items we have discussed. If after your warm-up you still feel like you require more practice, please let me know. Are you ready to begin?

[to SimOp] Okay, we're ready to begin the warm-up 1.

INSTRUCTIONS: DURING WARMUP DRIVE

The following instructions are to be given to the participants while driving the warm-up road in the simulator. Make sure to read each instruction prior to the event occurring. Please following along with a runlog to ensure that instructions are given in the proper order. Instructions in *italic* are for the participant.

[In the Cab]

During this warm-up drive I will be narrating what events are coming up so that you know what to expect.

7. Curve: *You will be receiving an audio cue alerting you that a curve is coming up on the road. That's an alert you will have to identify during the actual study.*

8. LV_Brake (Aud): *You will experience a situation in which the auditory FCW will play so that you are familiar with the system.* **[After alert]** *That was the auditory version of the FCW. That's an alert you will have to identify during the actual study.*

9. Number Task: *When you hear the "Number Task" audio cue you will be trying out the number task while driving. Remember that after you get the cue you should immediately look down at the LCD monitor on your right and repeat the numbers aloud, as they appear.*

10. Traffic: *You will be receiving an audio cue indicating that there is traffic ahead. That's an alert you will have to identify during the actual study.*

11. Construction: *You will be receiving an audio cue letting you know that a construction zone is coming up on the road. That's an alert you will have to identify during the actual study.*

12. Number Task: *When you hear the "Number Task" audio cue remember to repeat the numbers aloud, as they appear.*

13. Number Task: *When you hear the "Number Task" audio cue remember to repeat the numbers aloud, as they appear.*
14. Number Task: *When you hear the "Number Task" audio cue remember to repeat the numbers aloud, as they appear.*

15. Traffic: *You will be receiving an audio cue indicating that there is traffic ahead.*

16. Number Task: *When you hear the "Number Task" audio cue remember to repeat the numbers aloud, as they appear.*

17. LV_Brake (Hap): *You will experience a situation in which the haptic FCW (forward collision warning) will activate so that you are familiar with the system.* **[After it occurs]** *That was the Haptic FCW you just felt. Haptic refers to that feeling of braking you felt. That's an alert you will have to identify during the actual study.*

18. Number Task: *When you hear the "Number Task" audio cue remember to repeat the numbers aloud, as they appear.*

19. Curve: *You will be receiving an audio cue alerting you that a curve is coming up.*

20. Construction: *You will be receiving an audio cue letting you know that a construction zone will be coming up on the road.*

21. Number Task: *When you hear the "Number Task" audio cue remember to repeat the numbers aloud, as they appear.* **[After Baseline]** Pretend it was unintended.

That was the end of the Warm-Up. Are you feeling comfortable with using the following distance gauge? Are you comfortable performing each secondary task while driving? Do you have any questions about the secondary task (number task)? Alerts? Or other items you experienced during your Warm-Up drive? Do you feel you are ready to continue on to the actual study?

[if Ready to move on]
Ok, let's get started.

[if not ready to move on]
Either start at the middle of the Warm-Up road for more practice or consult with the SimOp on how to proceed. If consulting with SimOp, take a break and consult in private.

INSTRUCTIONS: STUDY DRIVE (ROAD 1 AND 2)

[If second drive] *This drive will be very similar to the first.*

This is not a practice drive, which means we will be collecting data from this point forward. I will no longer be narrating the events before they occur. You will [continue to] *experience the various alerts you experienced during your warm-up/first drive. While driving I need you to promptly respond to each alert verbally by telling me what you think the alert means, aloud.* [If auditory drive] *During this drive, all of the alerts you experience will be auditory.* [If haptic drive] *During this drive you will have both auditory and haptic alerts.*

You will also have the same in-vehicle (number task) task we practiced during the warm-up. Do you have any questions about the number task? [If yes, review the secondary task instructions once again]. *Keep in mind your primary tasks are to drive safely, maintain the correct distance from the lead vehicle, and responding to any alerts, but please try to do the secondary task (number task) to the best of your ability.*

You will continue to use the color gauge display in your dashboard (IP or Instrument Panel) to determine if you are at the correct distance from the lead vehicle. Try to maintain your distance within the green zone as much as possible. If for some reason you stay in red zone for too long you will be given an audio reminder to "Stay in the green zone" to ensure that you are at the correct following distance.

You will be driving approximately 55 mph on a two-lane highway with one lane going in each direction. We ask that you drive on the main road at all times and do not pass the *lead vehicle unless otherwise instructed. In the event that you encounter an obstacle, please feel free to brake to avoid any collisions.*

This drive will be approximately 25 minutes long. During your driving talking will be kept to a minimum but please speak up if you feel uncomfortable or if you need to take a break.
Do you have any questions? Ok, we are ready to start].

Break – be sure that the participant does not remove seatbelt until the SimOp indicates it is safe to do so. Make sure ratings are completed during the break. Take at least 10 minutes between drives and allow participant to stretch their legs, use the restroom, or grab a drink/snack.

FOLLOWING THE STUDY

You have now completed all of your test drives. Please complete this wellness survey and rating form [hand the SSQ and rating form to the subject]. *To complete each rating, please draw a short horizontal line on each vertical scale, at the position that most accurately describes your feelings. You may place the line anywhere along the vertical scale.*

You will be rating the appropriateness of alerts in different driving situations. How appropriate do you think that alert was?

Appropriate refers to how suitable the alert was under the driving conditions. Did you understand the alert without being too startled?

You will be rating on a scale of 1 to 5.

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

DESCRIPTIONS OF THE RATING SCALES

After each set of tasks, you will be asked to make several subjective ratings, defined as follows.

The "Ease of Performing the Primary Driving Task" refers to the mental and control effort, and attention, it took to do the main driving task of steering and speed control while also doing the secondary task. How difficult was it to accomplish the goal of the main driving task, which was to keep the car in the center of the lane at a constant speed?

The "Sense of Discomfort (or Risk) Performing the Primary Driving Task" refers to your own feeling of mental and situational discomfort while driving. During the driving task, how much did you feel insecure, unsafe, stressed, and apprehensive; versus secure, safe, relaxed, and unconcerned. Did you feel like you were in control of the situation at all times? Note that any physical discomfort you felt should not be included in this rating.

The "Ease of Performing the Secondary Entry Task" refers to the mental and control effort, and attention, it took to perform the secondary task while driving. How well did you accomplish the goals of the secondary task while also operating the car? This includes the period from the first to the last interaction with the task.

The "Overall Mental Workload" refers to how much mental attention and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.). "Overall" refers to the combination of the primary driving task and the secondary task. Was the overall mental effort easy or demanding, simple or complex? Was it easy to divide your attention between the 2 tasks, and to do both tasks at the same time?

Participant: ______

Rating Scales for CWIM 167-5

Group: ______

Road: 1 (Auditory / Haptic)

(Tonal / Verbal)

The following ratings should be given after each drive.

Ease of Performing the Driving Task

- Effortless
- Easy
- Fairly Easy
- Moderately Difficult
- Difficult
- Very Difficult
- Impossible

Sense of Discomfort (or Risk) Performing the Driving Task

- None
- A Little
- Some
- Moderate
- Much
- Extreme

Ease of Performing the in-vehicle Tasks

- Effortless
- Easy
- Fairly Easy
- Moderately Difficult
- Difficult
- Very Difficult
- Impossible

Overall Mental Workload

- None
- Very Low
- Low
- Moderate
- High
- Very High
- Impossible, cannot do it

Rating Scales for CWIM 167-5

Participant: ______

2 / 5

Group: ______

Road: 1 (Auditory / Haptic)

(Tonal / Verbal)

The following ratings should be given after each drive.

Appropriate refers to how suitable the alert was under the driving conditions. Did you understand the alert without being too startled?

Curve Ahead Alert

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

Construction Ahead Alert

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

Traffic Alert

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

FCW Alert

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

Rating Scales for CWIM 167-5

Participant: ______

Group: ______

Road: 2 (Auditory / Haptic)

(Tonal / Verbal)

The following ratings should be given after each drive.

Ease of Performing the Driving Task

- Effortless
- Easy
- Fairly Easy
- Moderately Difficult
- Difficult
- Very Difficult
- Impossible

Sense of Discomfort (or Risk) Performing the Driving Task

- None
- A Little
- Some
- Moderate
- Much
- Extreme

Ease of Performing the in-vehicle Tasks

- Effortless
- Easy
- Fairly Easy
- Moderately Difficult
- Difficult
- Very Difficult
- Impossible

Overall Mental Workload

- None
- Very Low
- Low
- Moderate
- High
- Very High
- Impossible, cannot do it

Rating Scales for CWIM 167-5

4 / 5

Participant: ______

Group: ______

Road: 2 (Auditory / Haptic)

The following ratings should be given after each drive. (Tonal / Verbal)

Appropriate refers to how suitable the alert was under the driving conditions. Did you understand the alert without being too startled?

Curve Ahead Alert

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

Construction Ahead Alert

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

Traffic Alert

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

FCW Alert

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

5 / 5

Rating Scales for CWIM 167-5

Participant: ______

Group: ______

Road: ______

The following ratings should be given at the end of the study.

---

1. During your drives, did you experience situations where more than one alert occured nearly at the same time? Where you received an auditory alert promptly followed by a second auditory alert? If yes, continue. If no, skip to question 2.

☐ Yes ☐ No

1a. Appropriate refers to how suitable the alert was under the driving conditions. Did you understand the alert without being too startled?

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

1b. How confusing were the alerts? Were they presented in a way that was easy to understand and clearly interpreted?

Extremely NOT Understandable	Somewhat Understandable	Neutral	Understandable	Extremely Understandable
1	2	3	4	5

2. During your drives, did you experience situations where more than one alert occured nearly at the same time? Where you received an auditory alert promptly followed by a second haptic alert? If yes, answer the next rating question. If no, skip the next rating question.

☐ Yes ☐ No

2a. Appropriate refers to how suitable the alert was under the driving conditions. Did you understand the alert without being too startled?

Extremely Inappropriate	Somewhat Appropriate	Neutral	Acceptable	Extremely Appropriate
1	2	3	4	5

2b. How confusing were the alerts? Were they presented in a way that was easy to understand and clearly interpreted?

Extremely NOT Understandable	Somewhat Understandable	Neutral	Understandable	Extremely Understandable
1	2	3	4	5

SSQ - POST EXPOSURE SYMPTOM CHECKLIST

Date: Participant #: Study: 167-5

Please 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.	Headache	None	Slight	Moderate	Severe
4.	Eyestrain	None	Slight	Moderate	Severe
5.	Difficulty focusing	None	Slight	Moderate	Severe
6.	Increased salivation	None	Slight	Moderate	Severe
7.	Sweating	None	Slight	Moderate	Severe
8.	Nausea	None	Slight	Moderate	Severe
9.	Difficulty concentrating	None	Slight	Moderate	Severe
10.	Fullness of the head	None	Slight	Moderate	Severe
11.	Blurred vision	None	Slight	Moderate	Severe
12.	Dizziness (eyes open)	None	Slight	Moderate	Severe
13.	Dizziness (eyes closed)	None	Slight	Moderate	Severe
14.	Vertigo*	None	Slight	Moderate	Severe
15.	Stomach awareness**	None	Slight	Moderate	Severe
16.	Burping	None	Slight	Moderate	Severe

* Vertigo is experienced as loss of orientation with respect to vertical upright.
** Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

IMPORTANT: Please inform the Research Assistant if you feel any “Moderate” or “Severe” symptoms.

POSSIBLE QUESTIONS PARTICIPANTS COULD ASK, AND ANSWERS TO BE GIVEN

1. How did I do? This study is to examine drivers' behavior. There were no measures to determine how you did.

2. The simulator did not seem realistic or correct? Thank you for your feedback. We will consider your comments. Remember, this is a simulator and some difference with the real-world is to be expected.

3. Who is this study sponsor? US Department of Transportation.

4. Will there be a way to see the results from this study? There will be a report to our customer but ID of SSN is confidential and protected. To be determined by the customer.

5. Will there be future similar studies? If interested, we can put your name down if future studies come up.

POST STUDY INSTRUCTIONS

1. Indicate to the participant that he/she should wait/rest for at least 20 min. before leaving DRI. Offer additional time to rest if the participant indicates any discomfort or fatigue. If necessary, offer to arrange alternative transportation.

2. IMPORTANT: Remind the participant that the driving in the simulator should not necessarily reflect in any way how he/she should drive back on the road. The handling of the driving simulator may not be the same as their own car. The participant needs to continue to drive in a safe manner.

3. Ask if it would be okay for someone to contact him/her at a later time to make sure everything is okay.

Dynamic Research, Inc.

HONORARIUM RECORD

I, ______________________________ received $____150.00________ check from
Print Name (Full Legal Name) Amount

Dynamic Research, Inc. for my participation as a research subject on

_________________.
Date

Social Security _________-__________-_______

NOTE: All personal information will be kept confidential. Your SSN will only be used in the event that you receive more than $600 from DRI in one calendar year. If this happens, DRI will send you a 1099 form for tax purposes.

____ _________________
Sign Here Date

Internal use only:
Job #: 167-5
Task #: 23100
Check # _________ (AIB)

355 Van Ness Avenue • Torrance, California 90501 • 310-212-5211 • FAX: 310-212-5046

SIMULATOR INCIDENT REPORT

Date ________________ Time ________________ Location Full Motion Simulator (Torrance)_______

Participant number ______________ Participant name ______________________________

Research assistant __________________________ Simulator operator ____________________________

DRI staff or others present____

Project name 167-5 Configuration number _________ Run number ________ Runs comp.____________

Road name or description ____

Brief description of occurrence ____

____

Subject comments or complaints ____

____

Injuries? (yes/no) _________ Describe ____

Medical assistance provided? __________ By whom?____

Describe ____

Other comments ____

Prepared by _____________________________ Date _________________ Time ________________

APPENDIX B

Scenario Specification

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LIST OF FIGURES

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B.1 ROADWAY

The roadway consisted of straights and curves on rural streets with the occasional intersection (Figure B1). The main road was 2 lanes with a single lane going in each direction. The length of the main road was approximately 26 mi. The posted speed limit will mostly be 55 mph with one lane going in each direction. The experimental drive was approximately 25 min in duration. Events occurred in every drive in the same order but appeared to be in a different order to the participants when starting at different locations. In addition to the main starting point, the road contained several alternative starting points. When there was a need to reset the simulator or other unexpected event the driver was placed on the road closer to where they were before the reset or unexpected event rather than starting from the beginning.

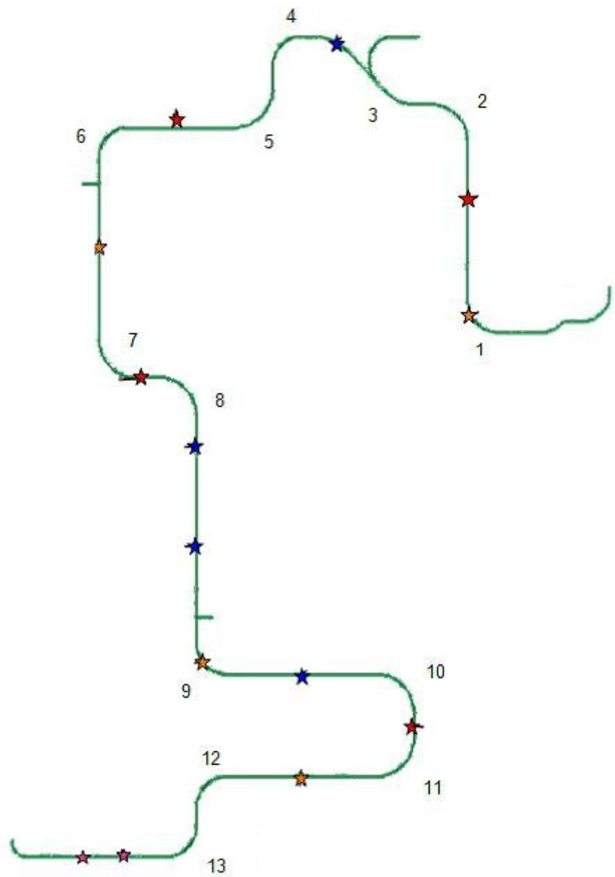

Figure B1. Graphics Roadway

B.2 FORWARD COLLISION WARNING SPECIFICATIONS

The forward collision warning (FCW) system had two modes or ways to inform the driver that it is being activated: audio alert and haptic braking pulse. The mode was set for each participant's drive using a configuration file and was not changed during the drive. The mode determined whether the participant heard an audio alert or received a haptic braking pulse.

B.2.1 Auditory FCW

Auditory alerts called the driver's attention to a conflict. The audio alert is a beeping tone with a period of 400 ms, a 50% duty cycle, 75 dB, and a total length of 4 sec.

B.2.2 Haptic FCW

The specification for the active system brake pulse was accomplished by pulling the simulator platform back approximately 4.8 in in 0.2 sec. After 0.2 sec, the platform was set back to zero. This offset went over whatever maneuver the participant was currently performing.

B.2.3 FCW alert threshold

Although the distance gauge was based on a TTC of 2.5 sec, the FCW system used was not based on TTC. The FCW system issued an alert concurrently with the lead vehicle performing the critical braking maneuver which was triggered when the participant driver passed over a specific tripwire set along the road. This was done so that the FCW system was 100% guaranteed to issue its alert before the subject could detect or react to the lead vehicle braking maneuver and to help eliminate early braking responses to critical lead vehicle braking events.

B.3 LEAD VEHICLE EVENTS

B.3.1. LV braking critical event

The SV was traveling at 55 mph on straight and level road following a LV that was also traveling at 55 mph when the LV suddenly decelerates to 25 mph. See Figure B2.

Figure B2. Lead Vehicle Braking Event

B.3.4 Following distance display

The headway distance or following distance was displayed using a simulated analog headway display, which gave the driver feedback on how they should adjust their speed to meet the needs of the study (Figure B3). The display was be located just under the speedometer on the right hand side (Figure B4). A color indicator was be used where the display showed

- Green: when the driver was at the target following distance
- Red: when the driver was too close to the LV the needle was in the right red zone (i.e., going too fast), and too close to the LV the needle was in the left red zone (i.e., going too slow). An acceptable range was currently set between a 2 and 2.5 sec time-headway.

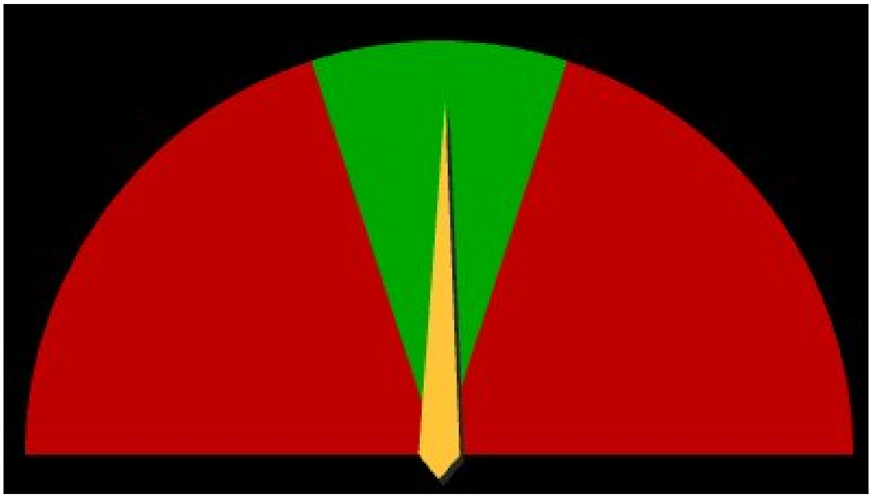

Figure B3. Following Distance Display

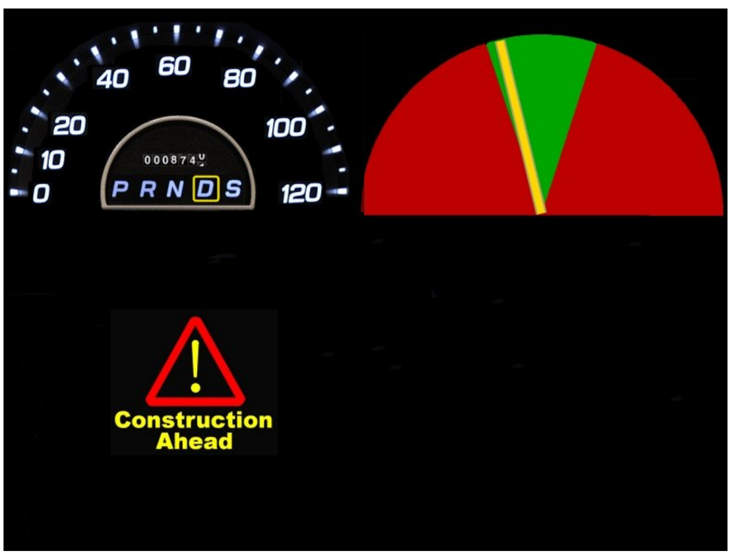

Figure B4. Dashboard Displays

B.4 EA

At times the EAs were activated before an FCW alert at varying SOA time periods of either 150 ms, 300 ms, or 1000 ms. The SOA time period was begin at the start of the EA and ended at the start of the FCW alerts as described in Figure B5. Alerts were displayed just under the speedometer in the dashboard on the left hand side, see Figure B4.

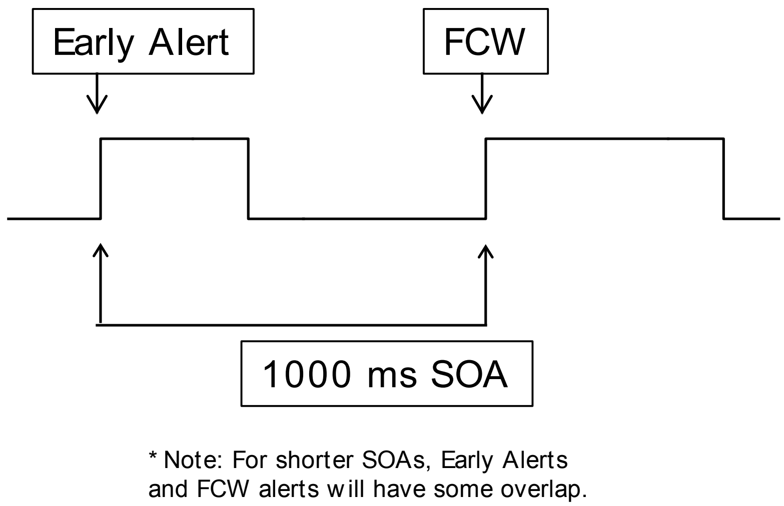

Figure B5. SOA Time Period

B.4.1 EA types

All tonal EAs used the same auditory tone. All verbal EAs were messages spoken aloud in a female voice The verbal alerts spoken were “traffic ahead,” “curve ahead,” and “construction ahead.” Both the tonal and verbal alerts were the same duration.

The following EA icons were used for this study:

– Slow traffic ahead alert 

– Curve speed alert 

– Construction ahead alert 

All early alerts occurred in realistic situations, for example, the traffic alert were always followed by a cluster of vehicles in front of the vehicle to mimic a traffic congested zone. The curve ahead alert occurred before entering into a curve on the road, and the construction alert occurred before approaching a construction zone on the opposing traffic side. The reason the construction zone was placed on the opposing side was to prevent the participant from slowing their traveling speed and changing their headway distance, especially before an FCW event.

Figure B6. Sample Construction Zone

B.5 DISTRACTOR TASKS

Within each session only the number task was occasionally be paired with early and FCW alerts in LV critical braking events.

B.5.1 Number task

A sequence of five digits was displayed in a small LCD screen that the participant was asked to recite. The display was be mounted in the center console area and was adjusted to each participant to ensure they could see the LCD monitor after making necessary seat and steering wheel adjustments. There are a total of sixteen different 5-digit sequences as described in Table B1. On occasion this task was be triggered 0.82 s prior to an EA and FCW. This task was updated later to promote that participants keep their eyes on the LCD for the duration of the task.

Table B1. Number task list

Task	Sequence	Task	Sequence
1	8-3-6-5-6	9	6-0-9-1-0
2	4-5-9-6-7	10	0-5-1-8-3
3	1-6-0-2-1	11	5-9-2-7-3
4	8-2-4-1-2	12	4-7-3-9-5
5	5-9-1-4-6	13	3-6-5-8-3
6	7-2-3-6-2	14	5-7-4-7-6
7	5-8-3-5-2	15	3-4-1-2-1
8	2-0-8-6-3	16	9-5-7-3-0

B.6 SCENARIO SEQUENCE

Scenarios were triggered through tripwires or markers along the road. When the SV traveled over a tripwire a series of events occurred. Tripwires were also responsible for setting up data collection. Below is an example timeline or runlog, which outlines the order in which scenarios occurred during a group 1 drive.

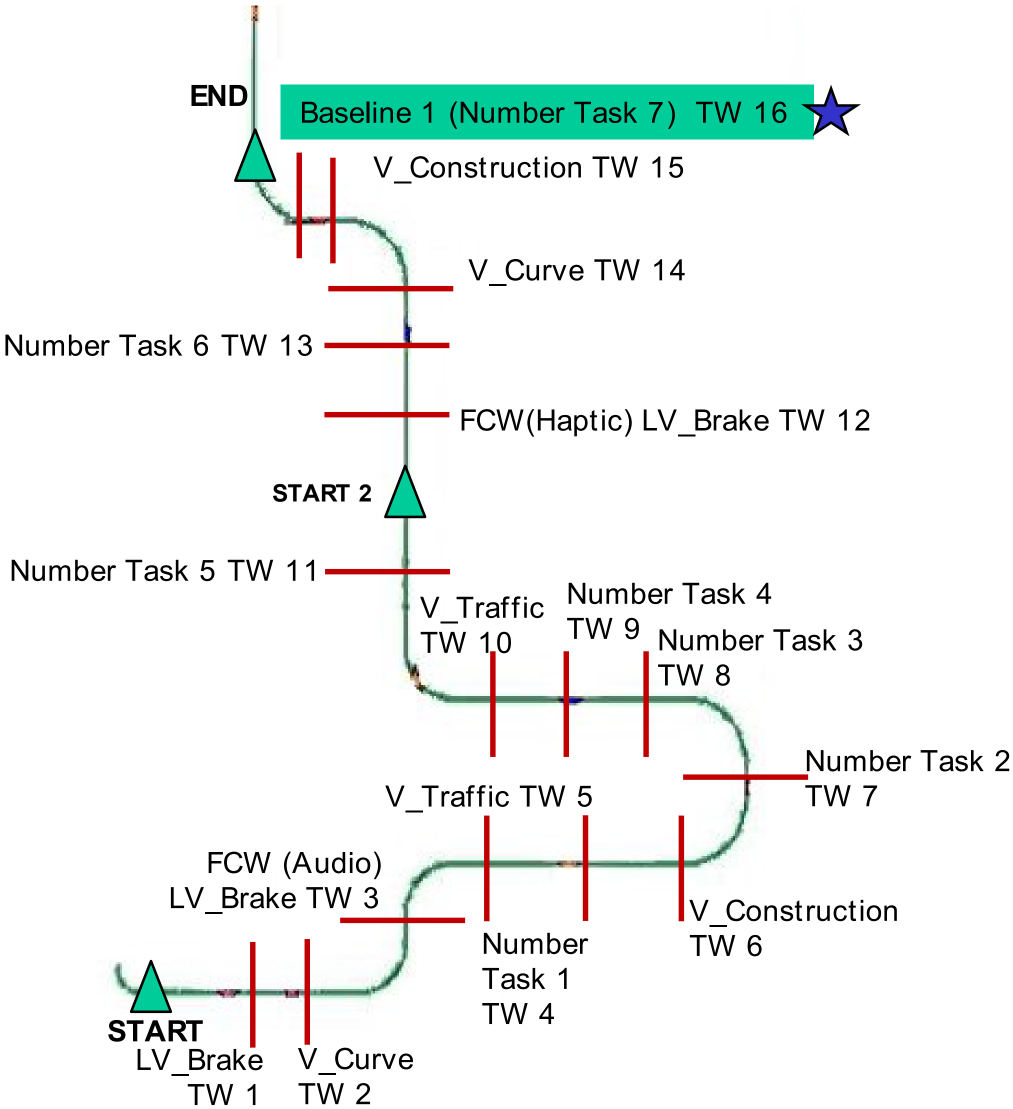

Figure B7. Warm-up Road for Group 1

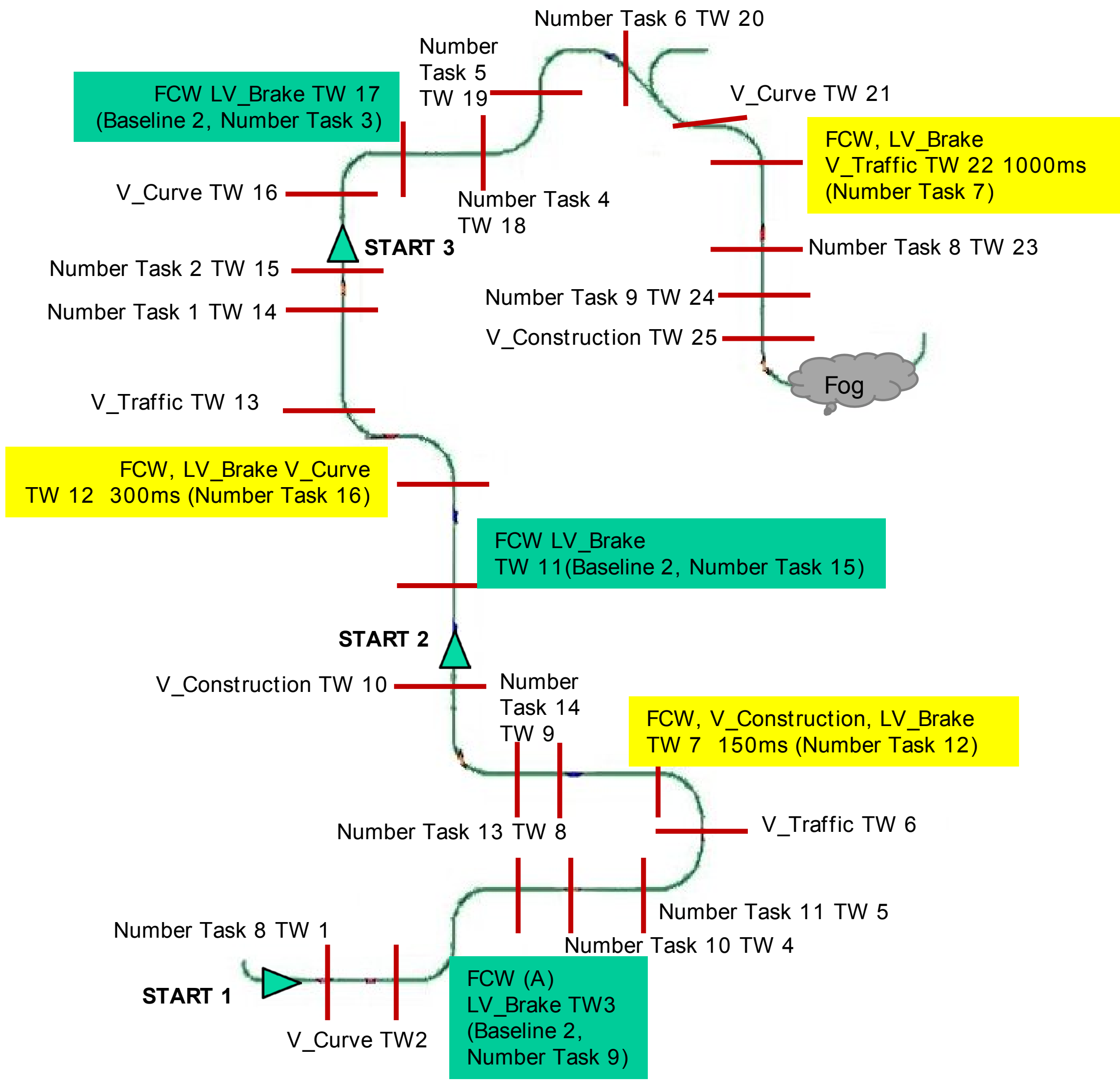

Figure B8. Road 1 for Group 1

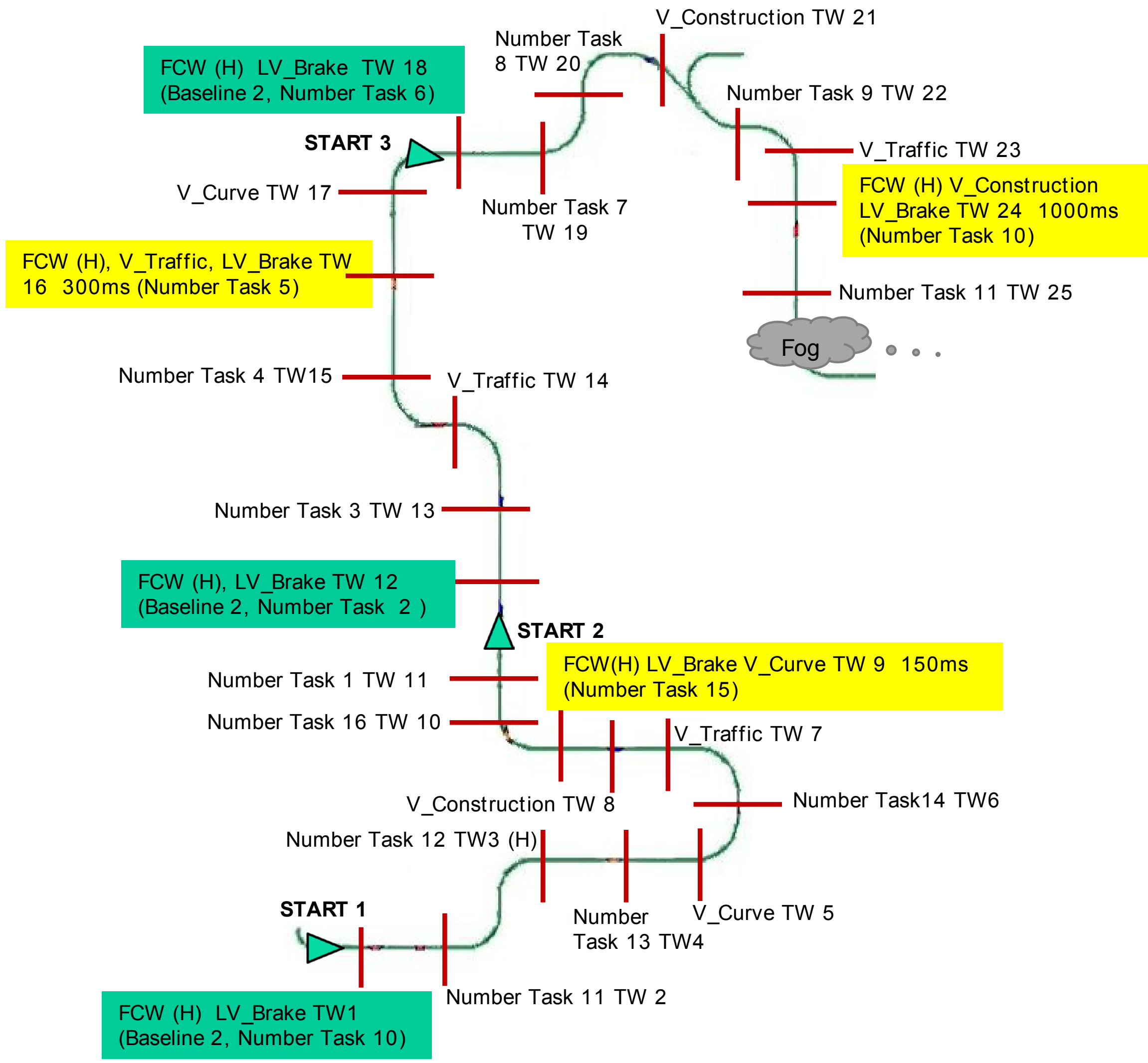

Figure B9. Road 2 for Group 1

B.7 EVENT SPECIFICATIONS

This section details events and secondary tasks.

B.7.1 Lead vehicle events

LEAD VEHICLE CRTICIAL BRAKING WITH SECONARY TASK	
RATIONALE	This portion of the scenario triggers the FCW alert.
ROAD NETWORK REQUIREMENTS	Straight, level road
PREPARATION	Tripwires labeled Number task and LV_Brake activate scenario.
START CONDITIONS	SV traveling approximately 55 mph on straight, level road following the LV.
ACTUAL EVENT	A number task audio instruction will be given 0.82 s prior to an EA. While participant is looking away the LV will suddenly decelerate (at a rate of 0.5 g) and slows to 25 mph. The EAt will be triggered, followed by an FCW alert.
END CONDITIONS	The LV gradually accelerates back to 55 mph. As the LV starts to move, the participant begins to follow the LV trying to maintain the appropriate headway.
PERFORMANCE MEASURES	Driver response time (braking/steering), minimum distance to lead vehicle, time of accelerator release, maximum deceleration or brake force

FOLLOWING DISTANCE	
RATIONALE	To ensure the SV is at the correct distance when scenarios are activated.
ROAD NETWORK REQUIREMENTS	Highway
PREPARATION	LV; Analog headway display
START CONDITIONS	LV in front of SV with a starting distance of 181.5 ft.
ACTUAL EVENT	Driver must try to stay close to the target distance (between 2 and 2.5 sec time headway) by using analog headway display. The color indicator shows when driver is too close or too far (in red), and at an acceptable range from LV (in green).
END CONDITIONS	The display is on continuously.
PERFORMANCE MEASURES	Continuous headway distance to lead vehicle.

B.7.3 Early alerts

EARLY ALERTS	
RATIONALE	Alerts are used for SOA purpose.
ROAD NETWORK REQUIREMENTS	None
PREPARATION	Tripwires labeled Traffic, Construction and Curve activate this scenario.
START CONDITIONS	Alert may be triggered on its own in null events or when SOA is 150, 300, or 1000 ms from FCW in critical events.
ACTUAL EVENT	Participant is driving along the road when an alert in the form of an icon appears and tone (T)/verbal (V) alert sounds. Alerts will be triggered in a realistic environment. The Traffic Ahead alert will be triggered before approaching a cluster of vehicles mimicking traffic in front of the lead vehicle. The Construction Ahead will be triggered before approaching a construction zone located in the opposing side of traffic. The Curve Ahead alert will appear before approaching a curve on the road.
DRIVER RESPONSE	Driver should respond to the alert by verbally stating which of the EAs thought was presented by stating, traffic ahead, curve ahead, or construction ahead.
CLEANUP	None
PERFORMANCE MEASURES	Continuous headway distance to lead vehicle.

B.7.4 Distractor tasks

NUMBER TASK	
RATIONALE	Tasks are ruse to mask the true purpose of the study.
ROAD NETWORK REQUIREMENTS	Straight, level road
PREPARATION	Tripwires labeled number task activate this scenario.
START CONDITIONS	The SV drives over the tripwire that initiates this task.
ACTUAL EVENT	Participant is given a verbal command and the number sequence of numbers is displayed on the LCD located in the center console. The driver is asked to verbally recite the number sequence verbally as each number appears.
END CONDITIONS	The participant tries to complete the secondary task while continuing to drive. After the task is over, driver tries to focus on maintaining headway distance.
PERFORMANCE MEASURES	Errors in number task. Eye glance data during task.

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