SAVE-IT

A Final Report of SAfety Vehicle(s) using adaptive Interface Technology (SAVE-IT) Program: Task 14a Evaluation

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1 INTRODUCTION

1.1 Background

The SAfety VEhicle(s) using adaptive Interface Technology (SAVE-IT) project examines whether a system can be developed and deployed to enhance the effectiveness of collision warning systems and reduce distraction-related crashes by monitoring the driver and the driving environment. The proposed system involves three main components: driver state monitoring, situational threat assessment, and adaptive countermeasures. The integration of these three components should allow for a system that can direct driver attention to the roadway when the situation warrants it and appropriately warn drivers when needed of impending crash situations. The National Advanced Driving Simulator (NADS) evaluation, Task 14, is one of four planned evaluations of the SAVE-IT concept.

1.2 Objectives

The goal of this work was to assess the potential safety benefits and driver acceptance of a system comprised of adaptive safety warnings and distraction mitigation strategies. The portion conducted at the NADS concentrated on assessing the combined safety benefits of the distraction mitigation and adaptive safety warning subsystems. A simulator-based experiment was conducted in the NADS facility to evaluate the benefits associated with the SAVE-IT concept, as well as to examine the adaptive and non-adaptive implementations of the lane departure warning (LDW) and forward collision warning (FCW) systems.

1.3 General Requirements

The NADS experiment addressed four main experimental questions associated with the **safety benefit** of the SAVE-IT concept. Safety benefit was evaluated through dependent measures associated with driver response to the imminent collisions. The NADS high-fidelity driving simulator allows for safety benefits to be assessed in imminent collision situations without risk to the driver or experimenters.

- Is there a safety benefit associated with adapting forward collision warnings (FCW) in imminent collision situations?
- Is there a safety benefit associated with adapting lane departure warnings (LDW) in imminent lane departure situations?
- Is there a safety benefit associated with the use of distraction mitigation strategies?
- Is there a safety benefit associated with the use of a performance trip report?

The NADS experiment also addressed five experimental questions associated with the effect of these systems on **driver response**. Driver response can, but may not always, affect driving safety, and was therefore evaluated in addition to assessing the safety benefit.

- How does adaptation of a FCW system affect driver response to imminent collision situations?
- How does adaptation of a LDW system affect driver response to imminent lane departure situations?
- How does the adaptive SAVE-IT system affect driver response to imminent intersection incursion events?
- How do the various distraction mitigation strategies affect driver response to non-imminent conflict driving situations?
- How does a performance trip report affect driver response to conflict driving situations?

Additionally, the NADS experiment addressed four experimental questions associated with **driver acceptance** of these system concepts.

- What is the level of acceptance for adaptive FCW systems in contrast to a non-adaptive FCW system?
- What is the level of acceptance for adaptive LDW systems in contrast to a non-adaptive LDW system?
- What is the level of acceptance for the distraction mitigation system?
- What is the level of acceptance for the performance trip report?

2 METHOD

This study included five experimental designs: one mitigation strategies design, three imminent events designs (lane departure event, forward collision event, and intersection incursion event), and one trip report design. The mitigation strategies and imminent events experimental designs were integrated so that a combination of the designs was present in each of the study drives for each participant (e.g., distraction mitigation events combined with a lane departure event to become Drive 1).

Table 1 illustrates the combination of experimental designs and the order of the study drives. The trip report was presented between the second and third experimental drives, and its effect was tested by comparing behavior during the second and third drives.

Table 1. Order of study drives and events

Familiarization Drive (4 min)	**Study Drive 1** (10 min)		**Study Drive 2** (10 min)		Trip report (2 min)	**Study Drive 3** (10 min)	
	Distraction Mitigation	Adaptive Systems	Distraction Mitigation	Adaptive Systems		Distractio n Mitigation	Severe Distraction Mitigation Event
Practice	Distraction Mitigation Events	Imminent LD Event	Distraction Mitigation Events	Imminent FC Event	Feedback to Participant	Distraction Mitigation Events	Intersection Event

The three experimental drives differed primarily in the final event of each drive. The majority of the events during the first two drives addressed questions regarding the use of distraction mitigation systems. A trip report detailing driver performance in Experimental Drive 2 was presented to the driver prior to Experimental Drive 3. The single-page trip report contained the following information displayed over a map of the drive: a small picture along the road indicating where a FCW occurred, a small picture along the road indicating where an unintentional lane change occurred, a color-coded path overlaid on the road indicating the percent of time the IVIS system identified the head pose as “forward” and the speed as at least 5 mph. The majority of the third drive addressed the effect of the trip report. The final event in each drive addressed questions surrounding the degree to which the adaptive warning and distraction mitigation systems aid the driver.

2.1 Participants

Sixty-four participants, ages 35-55, completed this study. Participants were balanced for gender. Additionally, they were required to have a valid, unrestricted U.S. driver's license (exception for participants with corrective lenses), to drive equal to or more than 3,000 miles per year, to have their license for at least one year, and to not have participated in a driving simulator study in the previous 12 months. They were to be in good general health, have normal hearing, and not use special devices (e.g., spinner knobs, booster seats, etc.) while driving. Because this study evaluates collision warning systems, individuals who had participated in driving simulator studies using warning systems or assistive technologies were not enrolled in this study.

2.2 Apparati

2.2.1 National Advanced Driving Simulator

The National Advanced Driving Simulator, owned by the National Highway Traffic Safety Administration and located at The University of Iowa, is comprised of a 13-degree-of-freedom motion base with a 24-foot-diameter dome in which a Chevrolet Malibu cab was mounted for this study. Inside the dome, the cab was mounted to the floor through four hydraulic actuators. The dome can rotate about its vertical axis by 330 degrees in each direction and is mounted on top of a traditional hydraulic hexapod, which in turn is mounted on two belt-driven beams that can move independently along the X and Y axes in a 64-foot-by-64-foot bay. The visual system consists of eight liquid crystal display (LCD) projectors that project a 360-degree photo-realistic virtual environment. The front three projectors have a resolution of 1600 x 1200. The right and left projectors have a resolution of 1280 x 1024. The three projectors in the back have a resolution of 1024 x 768. All scenery is updated and displayed 60 times per second.

2.2.2 SAVE-IT System

This system is a set of interconnected subsystems that monitor the driver, the driving environment, and the in-vehicle systems in order to gauge driver distraction, driving demand, task load, and safety during critical driving events (Prieto, PowerPoint presentation). The system uses a single-camera driver-state monitor to observe the driver and determine whether the driver is attending to the roadway. Driver alerts for warning systems were auditory tones, visual icons, and haptic cues (Smith, PowerPoint, presentation). Distraction mitigation alerts took the form of changes to the display color of buttons and function lock-out associated with the in-vehicle information system (IVIS) display.

2.2.2.1 In-Vehicle Distraction Tasks

Two distraction tasks were presented to participants, a navigation task and a text message task. The system's display was positioned at the top of the center stack, replacing the cab's stereo interface (see **Figure 1**). Both distraction tasks required the driver to interact with the heads-down IVIS display associated with SAVE-IT. The text message task served as the distraction task associated with the distraction mitigation events. The navigation messages provided route information to the participant during their drives and served as the distraction task associated with the LDW and FCW events.

Figure 1. Position of IVIS display in cab's center stack

The navigation task required the driver to identify landmarks and street intersections on a map presented by the IVIS navigation system. The task served as a basis to distract the driver during the final events in each drive by encouraging them to look away from the roadway for a period greater than two seconds. An auditory cue describing a street or landmark was presented to participants, and their task was to locate this information on the map. To do this, participants were required to activate the map function within the navigation system of the IVIS and verbally respond with the requested information. This entailed pushing the "NAV" button to the left of the display screen, then pushing the "Map" button on the visual display.

Prior to entering the simulator, participants were trained on the general functionality of the IVIS system using a self-guided PowerPoint slide show; this included screen shots of the navigation system, as well as changes to the navigation system's visual display when distraction mitigation was activated. Training for the navigation task was conveyed using a paper handout that described the task and provided example maps and the landmark icons participants may be asked to identify while performing the task. After entering the simulator, participants were asked to access the navigation system and perform a navigation task during the familiarization drive. An example of the navigation task that participants engaged in is presented in **Figure 2**.

Information to be identified: "Please activate the map and identify the street the restaurant is on."

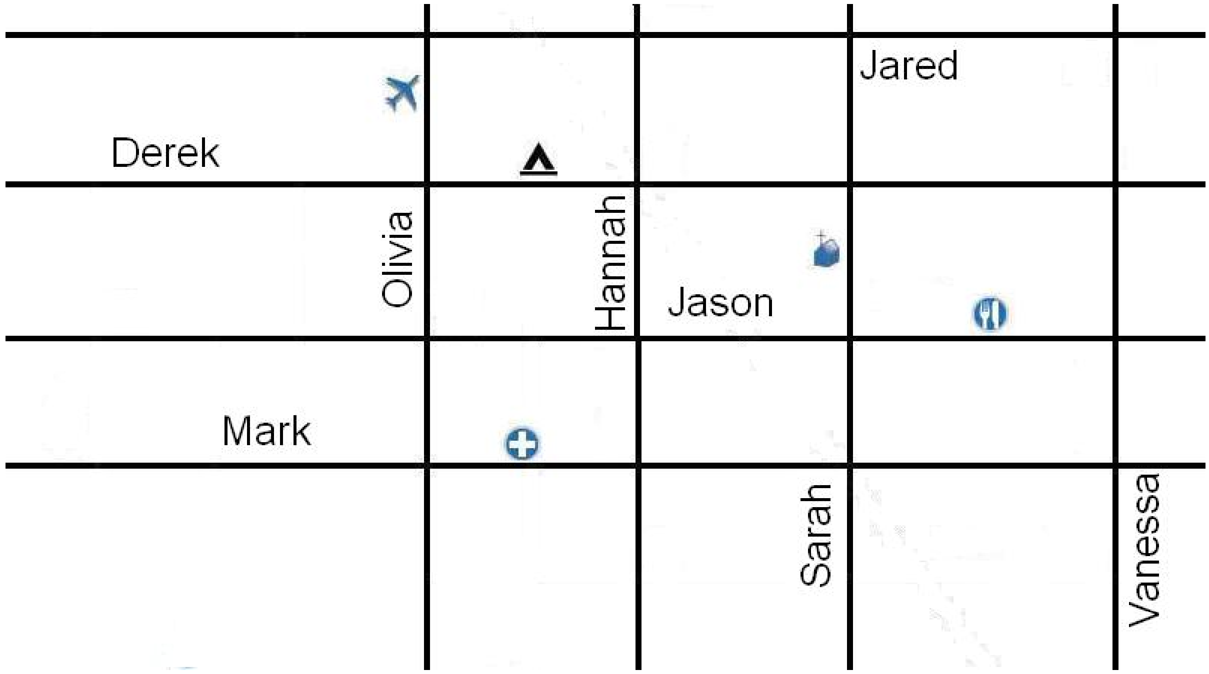

Figure 2. Example of navigation information requested

During each drive, participants also received a navigation message as they approached the transition between the urban and rural environments. Participants received an audio prompt to refer to the navigation system for route information using the same procedure described above for accessing the map. This navigation message was not used as a distraction task.

The text message task involved the driver obtaining brief text messages through the IVIS. This distraction task was modeled after the Baddeley working memory task (Baddeley, Logie, and Nimmo-Smith, 1985). The text message task was implemented to reflect distraction and no distraction. The series of sentences was presented on each road type. There were a series of four sentences presented during each instance of the text message task. The task involved recalling the subject of the series of sentences and determining if the sentence is sensible.

Participants were prompted to begin the text message task with an audio cue: "Incoming message. Determine subjects." Participants then pressed the text message button to the left of the IVIS display. Four sets of names and phone numbers appeared in the display window and corresponded to the four text messages the participant needed to open, read, sort, and recall; above this window was another window on which the message for each contact would be displayed. The first message appeared in the window without additional input from the participant; after the first message, the participant was required to press the down arrow next to the incoming messages' contact name and phone number to select the next message for display. After reading each message, the participants were to either press the "Save" button to indicate the message made sense or press the "Delete" button to indicate the message did not make sense. Then they were to press the down arrow button to display the next message and repeat the outlined procedure. Participants were allowed 30 seconds after the initial prompt to complete the task, and then they received a second prompt with the audio cue “Now” to verbally recall the subjects of the sentences.

2.2.3 Integration of SAVE-IT System into NADS

When integrating the lane departure warning into the NADS, there is no global position value indicating the vehicle position relative to other lanes on the road in the NADS raw collected data. The lane position data cell does not see the road as a whole, but rather a current position inside of a specific lane (from -x to x, where x is the lane width/2). Because of the way this positioning is done, we frequently encountered incorrect warnings (generally on the wrong side) when drifting over the center line or the shoulder. In order to properly interface with the IVIS logic, an external monitor in the CAN software was utilized to track the lane ID and position based on the simulator data. A set of road data was fed into the LDW CAN messages and the external monitor’s logic manipulated that data to ensure that the appropriate warning fired at the appropriate time. This approach was necessary due to the unique nature of the NADS system data available.

A limitation of the LDW system was that it did not function correctly inside intersections. Subsequently, this warning was temporarily disabled every time the vehicle traveled through an intersection to prevent incorrect warning triggers. This was solely the result of the method by which the lane position and lane identification is defined in the NADS system data. Save for this condition, the warnings fired consistently and correctly during experimentation.

The forward collision warning system was the most challenging aspect of the system to interface with. The collected NADS data tracks up to 20 dynamic objects in the scenario. The range, angle, and range rate were calculated for each dynamic object and then filtered down to those that would have fallen inside the forward-mounted camera’s operating angle and range and output onto the CAN bus. The implementation took some modification (especially in determination of the “most dangerous moving object,” which had to be done outside the IVIS system) and was slowed down somewhat by incorrect CAN message documentation and a lack of documentation and term-definitions for this system.

At the start of the experiment, based on operation of the system with respect to the scenario events, the FCWs fired consistently and correctly; however, there was no data to use as a frame of reference, so “correct behavior” is an assumption.

The IVIS computer software had to be modified in many ways to accommodate the experimental design. While the basic folder format of text messaging was already in place when the unit was received, additional programming was required to facilitate automated text message reception, deleting, saving, and tracking throughout the drives. The IVIS map display also required modification. Additional CAN messaging was used to signal “content updates” throughout the drive to the system and were then displayed. This added functionality was accomplished through collaboration between Delphi and NADS.

During experimentation these design elements functioned consistently and correctly. The experimental conditions (distraction mitigation, etc.) were easily activated and deactivated via the CAN bus and displayed correct system behavior.

For the simulator vehicle bypass, vehicle data was sent from the raw collected simulator data to the IVIS system and was correctly validated. No problems were experienced in this system.

For the driver state module, the exogenous display portion of this system was removed early on in the integration. The pose identification functioned correctly and, while "Adaptive Mode" was active, correctly adapted warnings when the driver was attending to the forward scene. Delphi requested that this camera be mounted immediately above the steering column. In this position, it was possible for the DSM camera to lose track of the face at times during the drive depending upon the behavior of the driver (e.g., steering wheel turns, hand position on the steering wheel, readjustment in the seat).

2.3 Procedures

2.3.1 Experimental Protocol

Informed consent (see Appendix **Error! Reference source not found.**) was obtained for all participants upon their arrival. The participants were then asked to complete a demographic questionnaire and an interpersonal trust questionnaire.

After they completed the questionnaires and prior to entering the simulator, participants received training that explained the FCW, LDW, and distraction mitigation systems installed in the vehicle through a self-paced PowerPoint presentation (see Appendix 6.3). The training on adaptation was at a high level, providing enough information to let the participants know that system warnings are adapted based upon their behavior, while still allowing participants to form their own mental models of how the systems work. High-level training is also indicative of the level of training most drivers receive when using various components of their own vehicles; roughly 5% of people actually read their owner's manuals. Staff also provided training on how to use the in-vehicle text messaging and navigation systems using paper-based instruction and practice for the navigation and text message tasks (see Appendix 6.3).

Following training, participants were escorted to the simulator. Participants completed four drives: one familiarization drive and three study drives. A questionnaire about the warnings the participants experienced was presented at the end of each of the study drives (see Appendix 6.4). If the participants were assigned to the trip report condition, it was presented between Study Drives 2 and 3 (the third and fourth drives, respectively), documenting and evaluating driving performance during Study Drive 2. After the final drive was complete, participants were escorted to the participant prep room where they completed the final portion of the study visit, debriefing (see Appendix 6.6).

After returning to the prep rooms, participants were debriefed concerning their experiences. The first task during the study debriefing was for participants to draw their mental models of the in-vehicle warning system they experienced during the study drives. Using the mental models as props, the researcher conducted semi-structured interviews, asking participants to discuss their mental models. Staff then reviewed, with the participants, video clips of the critical event for each of the three drives, asking questions about the drives and about the effect of the trip report on the final study drive. Video clips of the participants performing tasks with various levels of distraction and different levels of demand were also reviewed. Participants were presented with two anchor clips for distraction and two for demand and were then asked to rate video clips from their drives using the anchors as guides.

2.3.2 Scenarios

Experimental drive environment consisted of two environments, a four-lane urban roadway connecting to a two-lane rural roadway. The urban and rural portions of the drive were connected through an intersection at which the driver turned. Participants made either a left or right turn to transition between the urban and rural driving environments, depending upon the drive. Drives started at different points in the database to minimize the number of visual associations in landscape with study events, to ensure that the study drives had similar environmental conditions and to efficiently utilize the database. The dimensions of the database were sufficient to allow for just over ten minutes of driving at 45 mph. Each driver completed four drives while in the simulator. The initial drive was a familiarization drive. The three subsequent drives were study drives in which data were collected to answer the experimental questions.

2.3.2.1 Familiarization Drive

The familiarization drive lasted approximately four minutes and began in the rural segment of the scenario database and transitioned to the urban environment. During the practice drive, the participant became familiar with operating the vehicle in the simulator. This included the opportunity to accelerate, steer, and brake. Events included in the practice were mild and geared toward familiarizing the driver with vehicle handling. The text message, navigation task, and navigation message were presented during the familiarization drive to allow the participant to become familiar with the tasks and to instruct the participant to complete the left turn between the rural and urban environments. No braking or imminent events were presented during the practice drive.

2.3.2.2 Study Drives

Each of the three study drives included four non-imminent braking events, with lead vehicle headway of 1.7 seconds and a deceleration of 0.2g for 2 seconds, four distraction tasks, and a final event. Each study drive lasted approximately 10 minutes. The non-imminent events were designed to require a driver response but also so collisions could be easily avoided. Table 2 shows the conditions of the study drives. Only the braking events were analyzed.

Driving demand was replicated at low and high levels. The demand scenarios were designed such that high and low environments matched what IVIS recognized as high and low driving demand. High demand was generated by surrounding the driver’s vehicle with a cluster of study vehicles to create a higher level of local traffic density and a complex urban driving environment with a great deal of visual clutter; low demand was generated through the use of minimal traffic and a rural driving environment.

Table 2. Mitigation design variable levels

Variables	Levels of Demand and Distraction							
Driving Demand	Low	Low	Low	Low	High	High	High	High
Driver Distraction	None	High	None	High	High	None	None	High
Braking Event	Yes	Yes	No	No	Yes	No	Yes	No

The first experimental drive (Study Drive1) began in the urban segment of the scenario database and transitioned to the rural environment. The text message task and the navigation message and task were presented during the drive. The imminent event designed to evaluate the effectiveness of the adaptive warning system occurred during the last two minutes of the drive.

The first several minutes of Study Drive 1 included two distraction tasks with associated braking events, two distraction tasks not associated with braking events, and one navigation message instructing the participant to complete a left turn at the transition from the urban to the rural driving environments. The two distraction tasks associated with a high level of driving demand occurred in the urban segment of the scenario database, followed by the two distraction tasks associated with a low level of driving demand in the rural environment. The combination of the distraction tasks and braking events were presented in the order shown in Table 2, reading from right to left.

The final two minutes of Study Drive 1 included the imminent lane departure event, consisting of a wind gust from the left side of the roadway, forcing the participant's vehicle off the roadway onto the shoulder if no action was taken by the participant. Driver distraction was at two levels for this event, none and high. For participants assigned the high distraction condition, as the driver approached the end of the drive, he or she was instructed to begin the navigation task, which required participants to determine the street name. After the prompt to begin the task, a wind gust from the left side of the roadway was triggered. The wind gust was sufficiently strong to push the vehicle out of its lane and trigger an alert if the driver failed to intervene.

The second experimental drive (Study Drive 2) began in the rural segment of the scenario database and transitioned to the urban environment. The text message task and the navigation message and task were presented five times during the drive, not including the potential presence of an additional distraction task during the final imminent event. The forward collision imminent event occurred during the last two minutes of the drive.

The first several minutes of Study Drive 2 progressed in a manner similar to Study Drive 1. The drive began in the rural environment and transitioned to the urban environment with a left turn. There were again four distraction tasks, four braking events, and one navigation task. The combination of the distraction tasks and braking events were presented in the order shown in Table 2, reading from left to right. This resulted in the opposite presentation of events from Study Drive 1. The distraction events in this drive also serve as the baseline for the effects of the trip report. The trip report was presented to participants between Study Drives 2 and 3.

The final two minutes of Study Drive 2 included the imminent forward collision event, consisting of a severe lead vehicle braking event starting from an initial time headway of 1.7 s (deceleration of 0.65 g) requiring a braking response from the participant. Driver distraction was at two levels for this event, present and absent. For participants assigned the present/high distraction condition, as the driver approached the end of the drive, he or she was instructed to begin the navigation task. Lead vehicle deceleration was sufficiently strong to require an emergency response from the driver. Vehicles were present in the adjacent lane to discourage steering responses to the event.

The third experimental drive (Study Drive 3) began in the rural segment of the scenario database and transitioned to the urban environment. The text message task and the navigation message and task were presented during the drive. The intersection incursion imminent event occurred during the last two minutes of the drive.

The first several minutes of Study Drive 3 progressed in a similar manner to Study Drive 2. The drive began in the rural environment and transitioned to the urban environment with a right turn. There were four distraction tasks, four braking events, and one navigation task. The combination of the distraction tasks and braking events were presented in the same order as in Study Drive 1 (i.e., order shown in Table 1, reading from right to left), but the drive began in a different location in the database.

The final two minutes of Study Drive 3 included the intersection incursion imminent event, consisting of a lead vehicle turning right into an intersection in front of the participant's vehicle as the participant enters the intersection, requiring braking and/or steering responses from the participant. Driver distraction was at two levels for this event, none and high. Participants assigned the high distraction condition will receive a text message as they approach and enter the intersection. A vehicle was present in the traffic lane adjacent to the participant's lane one to two car lengths behind the participant's vehicle at the time of the event. The goal of this vehicle is to ensure that the driver is in the correct position for the event but is free to choose the most appropriate response.

2.4 Experimental designs

The five experimental designs (one mitigation strategies design, three imminent event designs, and one trip report design) address the thirteen experimental questions. The experimental designs were integrated to create the experimental conditions for each participant, see Table 3. The mitigation strategies design was implemented through distraction mitigation events during the first several minutes of each study drive. The three imminent event designs were implemented as a final event in each drive. The distraction mitigation baseline condition was always paired with FCW and LDW distraction because they are compatible and the required FCW and LDW distraction will not be mitigated. Distraction mitigation was always paired with FCW and LDW non-distracted because the absence of FCW and LDW distraction is compatible with distraction mitigation. The FCW and LDW systems were always active and, if FCW was adaptive, LDW was also.

Table 3: Integration of experimental designs into study drives

Number of Participants	Fam. Drive	Study Drive 1		Study Drive 2		Trip Report	Study Drive 3	
64	Practice acceleration, steering, braking	Distraction mitigation events	Imminent LD event	Distraction mitigation events	Imminent FC event		Distraction mitigation events	Intersection event

The three imminent event experimental designs examine the safety benefits of warning system adaptation on the effectiveness of warning systems and mitigation strategies in imminent collision situations: the lane departure scenario, the forward collision scenario, and the intersection incursion scenario. These experimental designs determine the experimental conditions for the final event in Study Drive 1, Study Drive 2, and Study Drive 3.

The order of presentation of the adaptive or non-adaptive system and the order of the level of visual distraction was balanced across the study participants. The lane departure scenario always precedes the forward collision scenario because previous work within the SAVE-IT project has shown that exposure to a lane departure event does not affect response to forward collision warning scenarios (Zhang, personal communication). As the intersection incursion scenario was designed to assess the safety benefit associated with mitigation systems and was not tied to the primary questions regarding the adaptive safety system, it was decided to present it last to avoid affecting response to lane departure or forward collision scenarios.

2.4.1 The Effect of Adaptation on Imminent Forward Collision Situations

Adaptation in the forward collision warning system was designed to affect the timing of the alert. Specifically, when adaptation of the warning was in place, earlier warnings would be presented to the drivers when they were not looking to the forward scene. The questions addressed by this portion of the experimental design are:

- Is there a **safety benefit** associated with adapting forward collision warnings (FCW) in imminent collision situations?
- How does adaptation of a FCW system affect **driver response** to imminent collision situations?

- What is the **level of acceptance** for adaptive FCW systems in contrast to a non-adaptive FCW system?

The FCW scenario was the final event in Study Drive 2, following the events from the Mitigation Strategies experimental design, and was a severe lead vehicle braking event, shown in **Figure 3**. The headway for the severe FCW event was 1.8 seconds. The event was tied to an in-vehicle secondary task for the distracted experimental conditions.

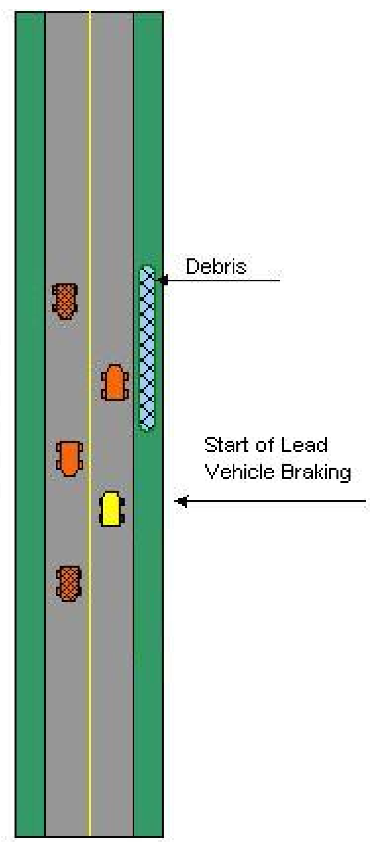

Figure 3. Forward collision scenario

The experimental design for the forward collision scenario was a 2^3 between-subjects design, with 8 participants per cell. The independent measures are the level of system adaptation, level of distraction, and type of system alert. Following the drives, questionnaires were administered and interviews were conducted in order to examine driver response to false alarms, driver acceptance, and driver mental models.

The independent measures—level of system adaptation, level of distraction, and type of system alert—are shown in **Table 4** under Study Drive 2. Level of system adaptation was either non-adaptive or adaptive. In the non-adaptive condition, the FCW alert timing was based only on environmental conditions, whereas in the adaptive condition, the FCW alert timing is based on both environmental conditions and the level of driver distraction as determined by the driver state module within the SAVE-IT system. Level of distraction refers to whether or not a participant was presented with a distraction task just prior to the event. For the imminent forward collision event, the distraction task level was none or high. The two levels of system alerts are two combinations of alerts: audio and visual alerts, and audio and visual alerts with a throttle release. The conditions for the FCW system were applied any time the FCW system was activated throughout each study drive. The throttle release condition is constant across all drives whether or not the FCW system was adaptive and at any time the FCW system was activated.

Table 4. Safety benefit analysis independent variables

Number of Participants	Fam. Drive (4 Min)	FCW Throt. Rel.	Study Drive 1 (10 min)			Study Drive 2 (10 min)			Trip Report	Study Drive 3 (10 min)		
			Distraction Mitigation	Adaptive Lane Departure Warning		Distraction Mitigation	Adaptive Forward Collision Warning			Distraction Mitigation	Mitigation Systems	
				System	Distraction		System	Distraction			System	Distraction
4		None	No Mitigation	Non-adaptive	Distracted	Mitigation	Adaptive	Not Distracted	Presented	Mitigation	Adaptive	Not Distracted
4		None	No Mitigation	Non-adaptive	Distracted	Mitigation	Adaptive	Not Distracted	Not Presented	Mitigation	Adaptive	Distracted
4		Included	No Mitigation	Non-adaptive	Distracted	Mitigation	Adaptive	Not Distracted	Presented	Mitigation	Adaptive	Distracted
4		Included	No Mitigation	Non-adaptive	Distracted	Mitigation	Adaptive	Not Distracted	Not Presented	Mitigation	Adaptive	Not Distracted
4		None	Mitigation	Non-adaptive	Not Distracted	No Mitigation	Adaptive	Distracted	Presented	No Mitigation	Adaptive	Distracted
4		None	Mitigation	Non-adaptive	Not Distracted	No Mitigation	Adaptive	Distracted	Not Presented	No Mitigation	Adaptive	Not Distracted
4		Included	Mitigation	Non-adaptive	Not Distracted	No Mitigation	Adaptive	Distracted	Presented	No Mitigation	Adaptive	Not Distracted
4		Included	Mitigation	Non-adaptive	Not Distracted	No Mitigation	Adaptive	Distracted	Not Presented	No Mitigation	Adaptive	Distracted
4		None	No Mitigation	Adaptive	Distracted	Mitigation	Non-adaptive	Not Distracted	Presented	Mitigation	Non-adaptive	Distracted
4		None	No Mitigation	Adaptive	Distracted	Mitigation	Non-adaptive	Not Distracted	Not Presented	Mitigation	Non-adaptive	Not Distracted
4		Included	No Mitigation	Adaptive	Distracted	Mitigation	Non-adaptive	Not Distracted	Presented	Mitigation	Non-adaptive	Not Distracted
4		Included	No Mitigation	Adaptive	Distracted	Mitigation	Non-adaptive	Not Distracted	Not Presented	Mitigation	Non-adaptive	Distracted
4		None	Mitigation	Adaptive	Not Distracted	No Mitigation	Non-adaptive	Distracted	Presented	No Mitigation	Non-adaptive	Not Distracted
4		None	Mitigation	Adaptive	Not Distracted	No Mitigation	Non-adaptive	Distracted	Not Presented	No Mitigation	Non-adaptive	Distracted
4		Included	Mitigation	Adaptive	Not Distracted	No Mitigation	Non-adaptive	Distracted	Presented	No Mitigation	Non-adaptive	Distracted
4		Included	Mitigation	Adaptive	Not Distracted	No Mitigation	Non-adaptive	Distracted	Not Presented	No Mitigation	Non-adaptive	Not Distracted

2.4.2 The Effect of Adaptation on Imminent Lane Departure Situations

Adaptation in the lane departure warning as designed to affect the presence of the alert. Specifically, when adaptation of the warning was in place, earlier warnings would be presented to the drivers when they were not looking to the forward scene. The questions addressed by this portion of the experimental design are:

- Is there a **safety benefit** associated with adapting lane departure warnings (LDW) in imminent lane departure situations?
- How does adaptation of a LDW system affect **driver response** to imminent lane departure situations?
- What is the level of **acceptance** for adaptive LDW systems in contrast to a non-adaptive LDW system?

The LDW scenario was the final event in Study Drive 1, following the events from the Mitigation Strategies experimental design. It consisted of a wind gust event on a straight roadway.

Each measure is again presented at two levels in a 2^2 between-subjects design, with 16 participants per cell, as shown in **Table 4**. Two of the independent measures are the same as those for the imminent forward collision event (level of system adaptation and level of distraction. There is only one level of system alert, which is a combination of audio, visual and haptic seat alerts.

The between-subject independent variables are level of visual distraction (none, high) and system adaptation (adaptive, non-adaptive). The levels of each variable are the same as previously described.

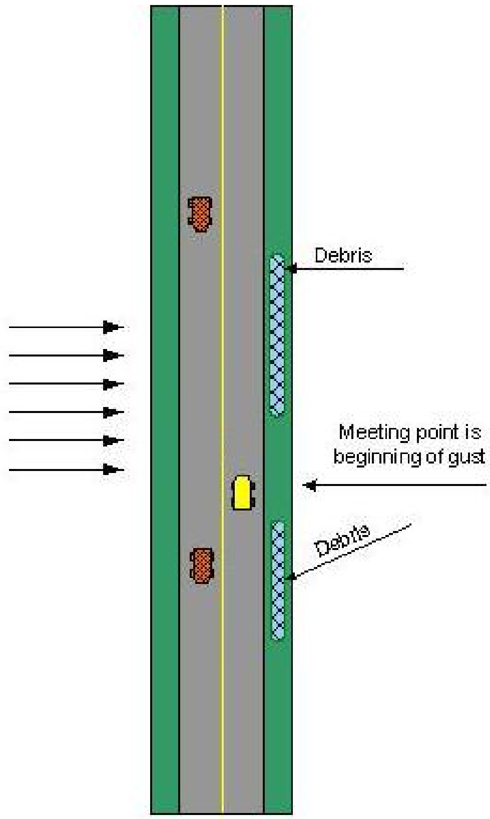

Figure 4. Lane-departure scenario

2.4.3 The Effect of Mitigation on Driver Distraction

The questions addressed by this portion of the experimental design are:

- How do the various distraction mitigation strategies affect **driver response** to non-imminent conflict driving situations?
- What is the level of **acceptance** for the distraction mitigation system?

This is a 2^3 within-subject design as shown in the Distraction Mitigation columns of **Table 4**. The experimental design to examine the effectiveness of mitigation strategies involves exposing participants to distractions while driving and alternately imposing several mitigation strategies toward these distractions. This experimental design examines driver response to and driver acceptance of these strategies.

The within-subject independent variables are level of visual distraction (none, high), level of demand (low, high), and level of mitigation (no mitigation, mitigation). All distraction mitigation portions of the drives would use the combined driver state and driving demand mitigation strategy. This experimental design consists of only the first several minutes of the first two study drives. The order of the level of mitigation conditions in Study Drive 1 and Study Drive 2 were balanced. Note that the experimental conditions of Study Drive 2 are duplicated in Study Drive 3 to examine the effects of presentation of the trip report.

2.4.4 The Effect of Trip reports on Driver Distraction

The trip report was presented to participants by the in-vehicle experimenter between Study Drive 2 and Study Drive 3. The experimental conditions from Study Drive 2 were replicated in Study Drive 3, except for the intersection incursion event, to allow for the analysis of the effects of presentation of the trip report. The intersection incursion event will be included in a separate analysis. Scenarios were designed to ensure that each of the scenarios contain the same events in different orders to avoid providing advance clue of the events.

The presentation of the trip report is a mixed within-between-subject experimental design and is shown in the Trip Report column of **Table 4**. Half of the participants were presented with the trip report between Study Drive 2 and Study Drive 3. Participants were balanced across gender. The experimental design was to examine the effectiveness of the trip report on changing driver behavior by presenting a summary of the driver's performance to half of the participants. This experimental design examines driver response to and driver acceptance of this type of feedback.

The within-subject independent variables are level of distraction (none, high) and level of demand (low, high). The between-subjects independent variables are the trip report providing participants with feedback (none, or trip report), and mitigation (no mitigation, mitigation). This experimental design consists of only the first several minutes of the last two study drives.

2.4.5 The Effect of Distraction Mitigation on Imminent Intersection Incursion Situations

This portion of the experimental design combines the conditions for possible forward collision and lane departure warnings in an imminent collision situation. Due to the nature of the event, however, it is anticipated that the only warning the driver will have time to receive is a distraction mitigation warning. Questions that may be addressed in this design include those previously discussed for FCW and LDW imminent collisions:

- Is there a **safety benefit** associated with distraction mitigation in imminent collision situations?
- How does the distraction mitigation SAVE-IT system affect **driver response** to imminent intersection incursion events?
- What is the level of **acceptance** for distraction mitigation systems?

The intersection incursion scenario is the final event in Study Drive 3, following events from the Mitigation Strategies experimental design. During this event, a vehicle makes a right turn in front of the participant vehicle as the participant vehicle approaches and enters an intersection. The event was tied to an in-vehicle distraction for the distracted experimental conditions.

This is a 2^2 between-subject design and is shown in the Mitigation Systems columns of **Table 4**, under Study Drive 3. The experimental design to examine the effectiveness of mitigation strategies involves exposing participants to a severe intersection incursion event. This experimental design examines driver response to and driver acceptance of the mitigation strategy in helping to avoid collisions that might not be captured by current collision avoidance system implementations.

The independent measures are the same as those for the imminent forward collision event and the imminent lane departure event (level of system adaptation, level of distraction, and type of system alert).

2.5 Measures

The measures can be divided into two general categories: those that came directly from the simulator data, and those that came from the debriefing. This section defines the dependent measures discussed in this report.

2.5.1 Simulator-based Dependent Measures

Simulator-based measures to assess the effect of adaptation on imminent forward collision situations can be divided into two groups: those that assess safety benefit, and those that assess driver response.

There were four measures that addressed safety benefit:

- Collisions – a binary variable indicating whether or not the driver collided with the lead vehicle.
- Minimum TTC – the minimum time-to-collision (TTC) with the braking lead vehicle ahead of the driver based solely on range and range rate measured in seconds.
- Adjusted Minimum TTC –the amount of spare time (or in the case of negative values, how much more time the driver would have needed) for avoiding a collision; this is calculated taking TTC that includes lead vehicle deceleration and calculating the amount of additional time needed when a collision occurred, measured in seconds (Brown, 2005).
- Relative Velocity at Collision – the difference in velocity between the driver's vehicle and the lead vehicle at the moment of collision measured in miles per hour.

There were seven measures that addressed driver response:

- Accelerator Release Reaction Time – the time from the onset of the event until the driver has a 10% release in the accelerator pedal position, measured in seconds.
- Brake Press Reaction Time – the time from the onset of the event until the driver initially presses the brake pedal, measured in seconds.
- Time to Maximum Brake Press – the time from the onset of the event until the driver reaches the maximum brake displacement, measured in seconds.
- TTC at Accelerator Release – time to collision at the point where the accelerator is released, measured in seconds.
- TTC at Brake Press – time to collision at the point where the brake pedal is initially pressed, measured in seconds.
- TTC at Maximum Brake – time to collision at the point where maximum brake pedal displacement occurs, measured in seconds.

- Minimum Acceleration –the maximum deceleration by the driver during the event, measured in g's.

Simulator-based measures to assess the effect of adaptation on imminent lane departure situations can be divided into two groups: those that assess safety benefit and those that assess driver response.

There were five measures that addressed safety benefit:

- Minimum Time-to-Lane-Crossing (TLC) – the minimum time, measured in seconds, until the vehicle crosses the lane boundary assuming current lateral velocity.

- Number of Excursions – the total number of events in which the driver exceeded the lane boundary represented as a binary measure.

- Length of Excursions – the total length of the excursion for the event measured from the first moment the vehicle departed the lane until it finally returned to the lane following the event, measured in feet.

- Extent of Excursion – the maximum distance from the lane marker to the leading edge of the participant's vehicle, measured in feet.

- Duration of Excursion – the total time the participant's vehicle spent out of the lane, measured in seconds; any time that the whole vehicle was inside the lane was not counted even if the driver overcorrected and exceeded the lane boundary again.

There were eleven measures that addressed driver response:

- Accelerator Release Reaction Time – the time from the onset of the event until the driver has a 10% release in the accelerator pedal position, measured in seconds.
- Brake Press Reaction Time – the time from the onset of the event until the driver initially presses the brake pedal, measured in seconds.
- Time to Maximum Brake Press – the time from the onset of the event until the driver reaches the maximum brake displacement, measured in seconds.
- Minimum Acceleration – this is the maximum deceleration by the driver during the event, measured in g's.
- Time to Steering Onset – the time from the start of the event until the driver has a corrective steering input exceeding five degrees, measured in seconds.
- TLC at Accelerator Release – time to collision at the point where the accelerator is released, measured in seconds.
- TLC at Brake Press – time to collision at the point where the brake pedal is initially pressed, measured in seconds.
- TLC at Steering Onset – time to collision at the point the steering maneuver begins, measured in seconds.

- Maximum Steering rate – the maximum rate of change of steering wheel position, measured in degrees/second.
- Maximum Lateral Acceleration – the peak lateral acceleration experienced by the participant, measured in g's.
- Maximum Lateral Jerk – the peak rate of change of lateral acceleration experienced by the participant, measured in g/second.

Simulator-based measures to assess the effect of mitigation on driver distraction addressed driver response:

- Accelerator Release Reaction Time – the time from the onset of the event until the driver has a 10% release in the accelerator pedal position, measured in seconds.
- Brake Press Reaction Time – the time from the onset of the event until the driver initially presses the brake pedal, measured in seconds.
- Time to Maximum Brake Press – the time from the onset of the event until the driver reaches the maximum brake displacement, measured in seconds.
- TTC at Accelerator Release – time to collision at the point where the accelerator is released, measured in seconds.
- TTC at Brake Press – time to collision at the point where the brake pedal is initially pressed, measured in seconds.
- TTC at Maximum Brake – time to collision at the point maximum brake pedal displacement occurs, measured in seconds.
- Minimum Acceleration – this is the maximum deceleration by the driver during the event, measured in g's.

Simulator-based measures to assess the effect of trip reports on driver distraction can be divided into two groups: those that assess safety benefit and those that assess driver response.

There was one measure that addressed safety benefit:

- Minimum TTC – the minimum time-to-collision (TTC) with the non-imminent braking lead vehicle ahead of the driver based solely on range and range rate, measured in seconds.

There were seven measures that addressed driver response:

- Accelerator Release Reaction Time – the time from the onset of the event until the driver has a 10% release in the accelerator pedal position, measured in seconds.
- Brake Press Reaction Time – the time from the onset of the event until the driver initially presses the brake pedal, measured in seconds.
- Time to Maximum Brake Press – the time from the onset of the event until the driver reaches the maximum brake displacement, measured in seconds.

- TTC at Accelerator Release – time to collision at the point where the accelerator is released, measured in seconds.
- TTC at Brake Press – time to collision at the point where the brake pedal is initially pressed, measured in seconds.
- TTC at Maximum Brake – time to collision at the point maximum brake pedal displacement occurs, measured in seconds.
- Minimum Acceleration – this is the maximum deceleration by the driver during the event, measured in g's.

Simulator-based measures to assess the effect of distraction mitigation on imminent intersection incursion situations can be divided into two groups: those that assess safety benefit and those that assess driver response.

There were nine measures that addressed safety benefit:

- Collisions – a binary variable indicating whether the driver collided with a vehicle during the event or not.
- Minimum TTC – the minimum time-to-collision with the braking lead vehicle ahead of the driver based solely on range and range rate, measured in seconds.

  Minimum Time-to-Lane-Crossing (TLC) – the minimum time until the vehicle crosses the lane boundary assuming current lateral velocity, measured in seconds

  Number of Excursions – the total number of events in which the driver exceeded the lane boundary, represented as a binary measure.

  Length of Excursions – the total length of the excursion for the event measured from the first moment the vehicle departed the lane until it finally returned to the lane following the event, measured in feet.

  Extent of Excursion – the maximum distance from the lane marker to the leading edge of the participant's vehicle, measured in feet.

  Duration of Excursion – the total time the participant's vehicle spent out of the lane, measured in seconds; any time that the whole vehicle was inside the lane was not counted even if the driver overcorrected and exceeded the lane boundary again.

There were fourteen measures that addressed driver response:

- Accelerator Release Reaction Time – the time from the onset of the event until the driver has a 10% release in the accelerator pedal position, measured in seconds.
- Brake Press Reaction Time – the time from the onset of the event until the driver initially presses the brake pedal, measured in seconds.
- Time to Maximum Brake Press – the time from the onset of the event until the driver reaches the maximum brake displacement, measured in seconds.

- TTC at Accelerator Release – time to collision at the point where the accelerator is released, measured in seconds.
- TTC at Brake Press – time to collision at the point where the brake pedal is initially pressed, measured in seconds.
- TTC at Maximum Brake – time to collision at the point maximum brake pedal displacement occurs, measured in seconds.
- Minimum Acceleration – this is the maximum deceleration by the driver during the event, measured in g's.
- Time to Steering Onset – the time from the start of the event until the driver has a corrective steering input exceeding five degrees, measured in seconds.
- TLC at Accelerator Release – time to collision at the point where the accelerator is released, measured in seconds.
- TLC at Brake Press – time to collision at the point where the brake pedal is initially pressed, measured in seconds.
- TLC at Steering Onset – time to collision at the point the steering maneuver begins, measured in seconds.
- Maximum Steering Rate – the maximum rate of change of steering wheel position, measured in degrees/second.
- Maximum Lateral Acceleration – the peak lateral acceleration experienced by the participant, measured in g's.
- Maximum Lateral Jerk – the peak rate of change of lateral acceleration experienced by the participant, measured in g/second.

2.5.2 Debriefing

During the study debriefing, qualitative and quantitative data were collected using a mixed-method approach in order to address user acceptance of the SAVE-IT concept as a whole, as well as teasing out user impressions of and responses to the various components of the system, including the adaptive warnings, the trip report, and the distraction mitigation system. This section discusses these dependent measures as well as the method of their derivation.

The qualitative approach to data collection is exploratory in nature, facilitating the capture of a broad range of responses from participants about their experiences using the warning system, as well as providing the researcher an opportunity to investigate concepts in greater depth as they arise through the research process. Due to the scope of the project, multiple research staff members were required to debrief participants. The experimental design accounted for this, therefore, by employing semi-structured interviews in order to reduce variability between research staff, while allowing for some flexibility in data collection (e.g., follow-up questions). Questionnaires were used in the study briefing and debriefing periods in order to collect complementary quantitative data.

For the purpose of this study, user acceptance has been divided into three distinct yet interrelated parts:

1. How does a perceived **understanding** of the system affect its acceptance?
    a. Explain the relationship between the driver and the system, the vehicle and the system, and the driver and vehicle.
    b. What expectations for the system does the user have as a result of his or her perceived understanding of how the system works?
2. How does user **reliance** on the system affect its acceptance?
    a. What is the driver's level of confidence relative to the driving task(s)? (scalar question between vulnerable and confident)
    b. What level of trust in technology does the user have? How does that affect the level of trust he or she has in the system?
    c. Describe instances of over- and under-reliance on the system (misuse in both directions)
3. How does the user's perceived **utility** of the system affect its acceptance?
    a. What is the safety benefit associated with the system?
    b. What is the driver's willingness to use the system? In what context(s)?
    c. What are the limits of the system's utility (when does it become a nuisance)?

The general assumption informing this sub-categorization is that system users will have certain expectations for the system based on how the user understands the system's design, function, and operation. User expectation will in part inform the degree to which the user relies on the system, as well as the degree to which he or she considers it useful (e.g., if the user has high expectations for the system, then mishaps, such as a false alarm, will have a negative effect on user reliance). It is also assumed that reliance and utility are context-dependent, and therefore the user may identify situations that would be better served by the system than others.

In order to capture users' perceived understanding of the system, research staff requested that participants draw their mental models of the system. Using the mental models as props, the researcher conducted a semi-structured interview, asking participants to document the relationship between (a) the driver and the vehicle, (b) the driver and the system, and (c) the vehicle and the system. Following from this, research staff asked a series of comparison questions, including (a) how was your experience driving with the system different than/similar to your experience driving your personal vehicle, and (b) how was your experience driving with the adaptive system different than/similar to your experience driving without the adaptive system. The comparative questions were designed to establish the distinctions participants make between a baseline driving experience (driving his or her personal vehicle) and a driving experience influenced by the use of a warning system, as well as the distinctions drawn between the adaptive and non-adaptive warning systems. Two questions were included in the post-drive questionnaire to evaluate the degree to which the participant understood the operation of the system and believed that his or her interpretation of the system's operation was accurate.

As with capturing how the user understands the system's operation, user reliance was evaluated using multiple methods. A pre-drive questionnaire (see Appendix 6.1) contained several questions addressing general levels of confidence relative to different driving situations, and the user's degree of trust in technology, particularly as it relates to the participant's daily activities, such as driving. To complement these questions, research staff conducted a semi-structured interview based on their review, with the participant, of video clips of the critical event for each of their three drives. After reviewing each drive, the researcher asked the participant to describe and/or comment on (a) his or her level of confidence as he/she negotiated the critical event (e.g., "When the vehicle departed from the lane, what was your feeling about the situation you found yourself in?"), (b) his or her reaction to the system itself (e.g., "When you were alerted to the fact that you were about to collide with the vehicle in front of you, what went through your mind as you reacted?"), especially when it was an imperfect system response (e.g., false alarm due to the system misinterpreting the driver's eye movement), and (c) his/her "misuse" of the system by over-relying or under-relying on its warnings. Particular attention is paid to the effect the trip report had on the participant's response to the intersection incursion event in the third drive.

In order to address the study's secondary questions assessing the accuracy of the distraction and demand modules, research staff and participants reviewed video clips of participants performing tasks with various levels of distraction, as well as clips of participants driving with different levels of demand. Staff selected video clips from the participant's drives that demonstrate the range of levels in each category, then they reviewed the clips with the participant. The participant was presented with two anchor clips for distraction and demand, then her or she was asked to rate video clips from his or her drive using the anchors as guides. The subjective data may be used to validate the predictions of level of distraction and level of demand generated by the system.

Data collection eliciting the user's perceived utility of the system is designed to evaluate the value the driver places on the system, as well as the limits of the system's usefulness in different contexts. "Context" includes both environmental conditions (e.g., heavy traffic, icy roads) and driver experience (novice drivers, etc). Data were obtained using a questionnaire (see Appendix 6.6.5). At the end of the questionnaire, there was an open-ended question asking for suggested improvements to the system.

Interviews were videotaped in order to capture the physical cues participants may use as they describe their mental models. The camera was positioned so that it captured the participant's drawing of his or her mental model and any gestures the participant may make with his or her hands. Interview data were analyzed using textual analysis, code mapping, and tabular summaries. The study team used a set of related themes to create a formative theoretical model for understanding user acceptance of in-vehicle adaptive warning systems. An initial coding system was devised using this formative theoretical model and applied to the interview transcripts and the observation notes from video analysis. The transcripts and notes were reviewed for material that does not fit into the original coding scheme, and the coding scheme will be revised accordingly. After coding research materials, research staff evaluated materials for patterns that address the research themes. Questionnaire data were analyzed using the appropriate parametric and non-parametric statistics.

3 EXPERIMENTAL RESULTS

3.1 Participant Demographic Information

There were 61 participants (30 male, 31 female) between the ages of 35 and 55 (mean 44.26 years, std. dev. 6.36). Seventy percent of the sample reported their total household income at $50,000 or more in the previous year; 59% reported having earned a bachelor's degree or higher. Eighty-seven percent of the participants reported driving at least once each day; roughly half drove 13,000 miles per year or more, well above the national average of 12,000 miles per year (US Environmental Protection Agency, Office of Transportation and Air Quality, "Emission Facts: Greenhouse Gas Emissions for Typical Passenger Vehicle," February 2005, p.4, http://www.epa.gov/otaq/climate/420f05004.pdf). The majority of participants reported driving in suburban environments (70%), as opposed to highway conditions (11.5%), a rural environment (9.8%), or small towns or cities (3.3% each).

Thirty percent reported receiving 1-2 moving violations in the past five years; 2% reported receiving 3-4 violations; the majority of the tickets were for driving at an excessive speed, although two tickets were issued for disobeying traffic signs, and three were issued for other violations (e.g., heavily tinted or dirty windows).

Sixteen participants reported being involved in a motor vehicle accident in the past five years; 11 experienced one accident, four experienced two accidents, and one experienced four or more accidents. Three-quarters of the accidents involved another vehicle. Of the 20 accidents for which details were reported, 30% were from rear-end collisions, 20% occurred when oncoming vehicles collided with participants' vehicles in intersections, 15% each were attributed to forward collisions or to deer, and 10% each were from weather-related crashes or from collisions in parking lots while driving in reverse.

Roughly 12% of participants reported that their primary vehicle had a trip computer, that at a minimum provided information about the trip and/or the vehicle's status. Ninety-two percent of participants had vehicles with CD or cassette players.

3.2 Safety Benefits

The NADS experiment addressed four main experimental questions associated with **safety benefits** of the SAVE-IT concept.

- Is there a safety benefit associated with adapting forward collision warnings (FCW) in imminent collision situations?
- Is there a safety benefit associated with adapting lane departure warnings (LDW) in imminent lane departure situations?
- Is there a safety benefit associated with the use of distraction mitigation strategies?
- Is there a safety benefit associated with the use of a performance trip report?

3.2.1 Forward Collision Warning

The independent measures included in this analysis were level of system adaptation, level of distraction, and type of system alert. The results of the significance tests for the dependent measures related to safety are shown in **Table 5**.

Table 5. The effect of system adaptation on safety for forward collision warning event

Level of System Adaptation	Mean		Standard Deviation		Sample Size		Significance
	Adaptive	Non-Adaptive	Adaptive	Non-Adaptive	Adaptive	Non-Adaptive	
Minimum Time to Collision (s)	0.37	0.29	0.25	0.27	31	32	F(1,55) = 1.35 P = 0.2506
Adjusted Minimum Time to Collision (s)	-0.04	-1.12	1.46	3.73	31	32	F(1,55) = 2.29 P = 0.1361

Table 6. The effect of distraction on safety for forward collision warning event

Level of Distraction	Mean		Standard Deviation		Sample Size		Significance
	Distracted	Not Distracted	Distracted	Not Distracted	Distracted	Not Distracted	
Minimum Time to Collision (s)	0.30	0.36	0.28	0.25	31	32	F(1,55) = 0.83 P = 0.3666
Adjusted Minimum Time to Collision (s)	-1.22	0.03	3.77	1.43	31	32	F(1,55) = 2.86 p = 0.0964

Table 7. The effect of throttle release on safety for forward collision warning event

Throttle Release in FCW Alert	Mean		Standard Deviation		Sample Size		Significance
	Present	Not Present	Present	Not Present	Present	Not Present	
Minimum Time to Collision (s)	0.32	0.34	0.27	0.26	31	32	F(1,55) = 0.19 p = 0.6654
Adjusted Minimum Time to Collision (s)	-0.73	-0.44	2.79	3.00	31	32	F(1,55) = 0.14 p = 0.7124

Figure 5 shows the means for each of the independent variables. Differences can be seen between the adaptive and non-adaptive conditions as well as the distracted and not-distracted conditions. The adaptive condition did have a longer minimum time to collision than the non-adaptive condition, which could indicate a benefit to the adaptive warnings. The minimum time to collision was shorter for the distracted condition, which would be expected. However, the standard deviations, shown by the error bars, are so large that no statistical significances were found. **Figure 6** shows a similar pattern of the adjusted minimum time to collision. A negative adjusted minimum time to collision indicates how much sooner participants would have had to react in order to avoid collisions. The shorter adjusted time to collision for the adaptive condition could indicate some level of safety benefit.

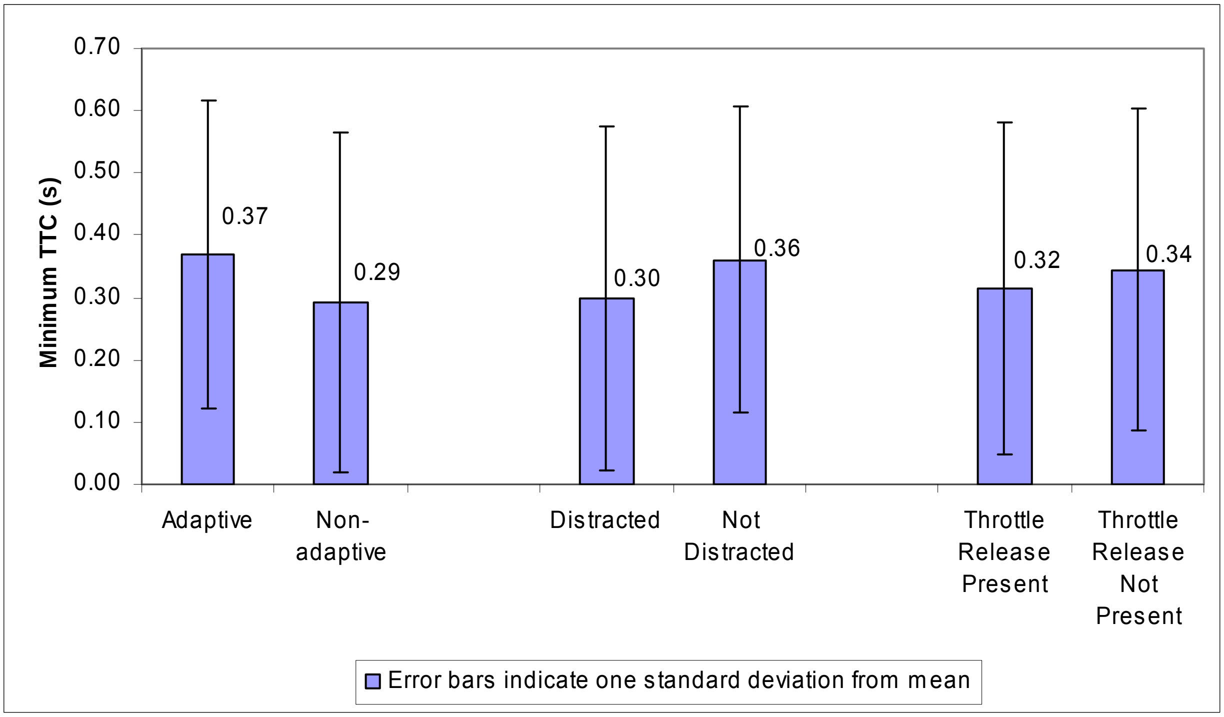

Figure 5. Minimum time to collision in the forward collision warning event

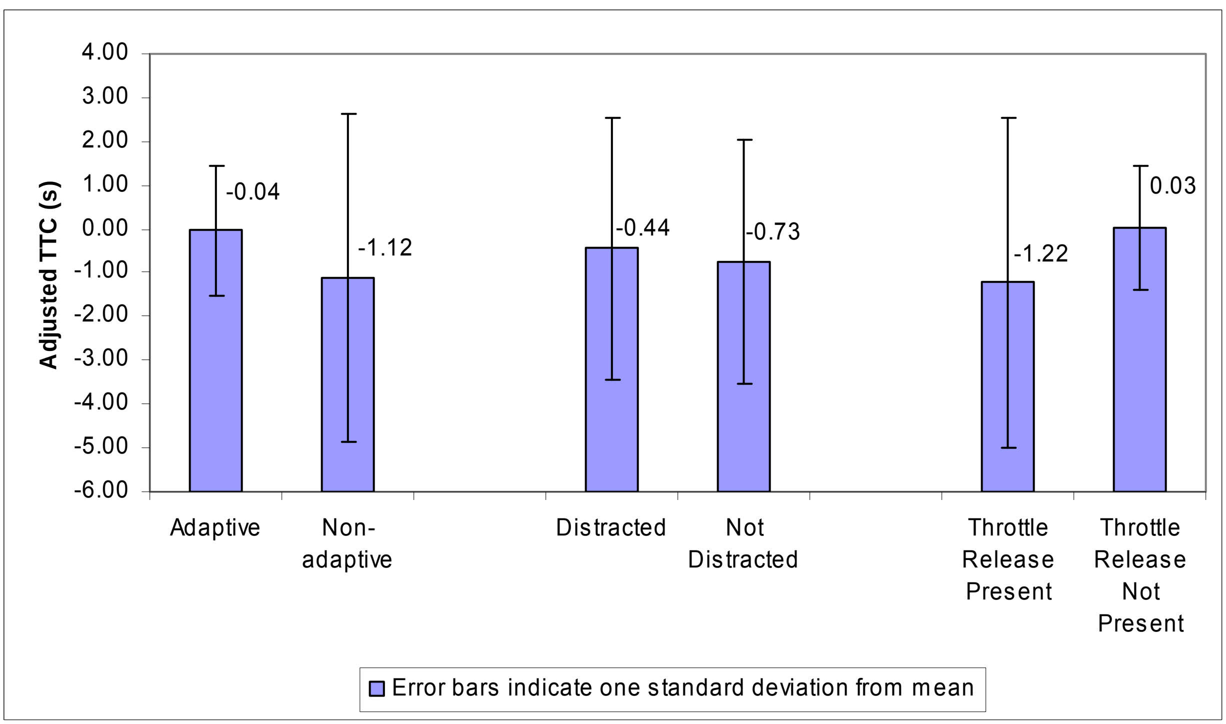

Figure 6. Adjusted minimum time to collision in the forward collision warning event

A Chi-square analysis was run for collisions. Table 8 shows the frequency of collisions by system condition. Fisher's Exact test (p= 0.4171) revealed no differences between adaptive and non-adaptive systems in terms of collisions. Due to the relatively low number of collisions, relative velocity at collision was not analyzed. The mean relative velocity in the adaptive condition was 17.31 mph (standard deviation 20.77), and was 20.78 (standard deviation 9.34) in the non-adaptive condition.

Table 8. Frequency of collision by level of system adaptation for forward collision warning event

Level of Distraction	No collision	Collision	Total
Adaptive	28	3	31
Non-adaptive	26	6	32
Total	54	9	63

3.2.2 Lane Departure Warning

The independent measures included in this analysis were level of system adaptation and level of distraction. The results of the significance tests for the dependent measures related to safety are shown in **Table 9** and

Table 10.

Table 9. The effect of system adaptation on safety for lane departure warning event

Level of System Adaptation	**Mean**		**Standard Deviation**		**Sample Size**		**Significance**
	Adaptive	**Non-Adaptive**	**Adaptive**	**Non-Adaptive**	**Adaptive**	**Non-Adaptive**	
Minimum Time to Lane Crossing(s)	0.24	0.23	0.35	0.32	32	31	$F(1,59) = 0.03$ $p = 0.8664$
Length of Excursion (overall) (ft)	122.73	101.62	149.16	145.74	32	29	$F(1,57) = 0.33$ $p = 0.5708$
Extent of Excursion (overall) (ft)	3.53	2.44	4.09	2.69	32	29	$F(1,57) = 1.55$ $p = 0.2184$
Duration of Excursion (overall) (s)	1.79	1.31	2.47	2.05	32	29	$F(1,57) = 0.68$ $p = 0.4145$

Table 10. The effect of distraction on safety for lane departure warning event

Level of Distraction	Mean		Standard Deviation		Sample Size		Significance
	Distracted	Not Distracted	Distracted	Not Distracted	Distracted	Not Distracted	
Time to Lane Crossing (s)	0.20	0.27	0.33	0.34	32	31	F (1,59) = 0.60 p = 0.4423
Length of Excursion (overall) (ft)	140.72	83.74	167.85	116.93	31	30	F(1,57) = 2.18 p = 0.1456
Extent of Excursion (overall) (ft)	3.64	2.37	4.03	2.79	31	30	F(1,57) = 2.02 p = 0.1606
Duration of Excursion (overall) (s)	1.70	1.42	2.23	2.34	31	30	F(1,57) = 0.22 p = 0.6406

The mean minimum time to lane crossing for each of the independent variables is shown in **Figure 7**. There is little difference between the adaptive and non-adaptive conditions. The difference between when distraction was present and not present is again as would be expected. **Figure 8** through **Figure 10** show the means for each of the independent variables for the length, extent, and duration of excursions. Differences can be seen between the adaptive and non-adaptive conditions, with higher means for the length, extent, and duration of excursion in the adaptive condition. The LDW was suppressed in the adaptive mode if the driver was determined to be attentive or likely attentive by the driver state monitor within the SAVE-IT system. It was common for participants to make quick glances back and forth from the in-vehicle display and the roadway when the distraction task was present. It is possible these two things combined to result in the higher means in the adaptive condition.

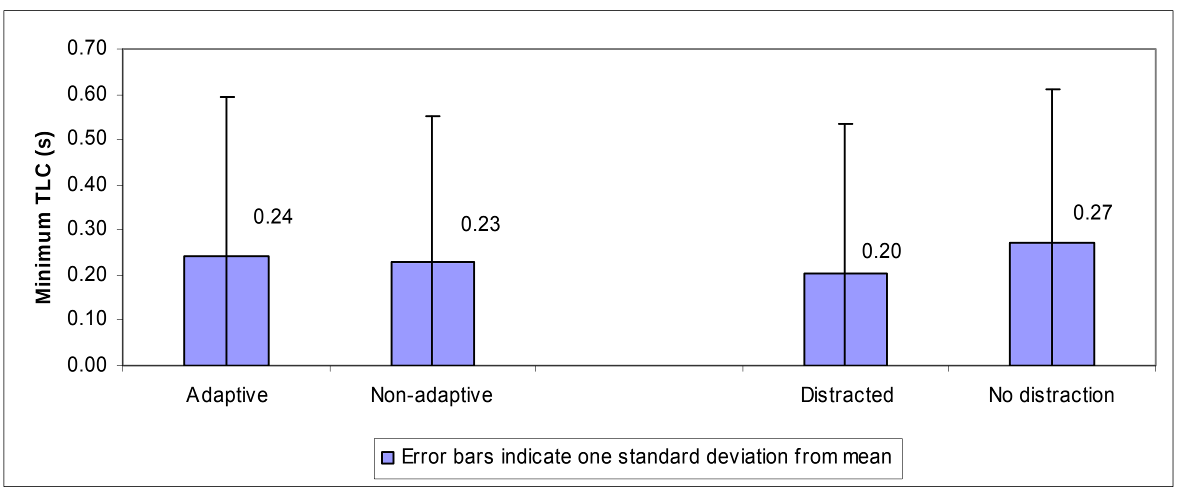

Figure 7. Minimum time to lane crossing in lane departure warning event

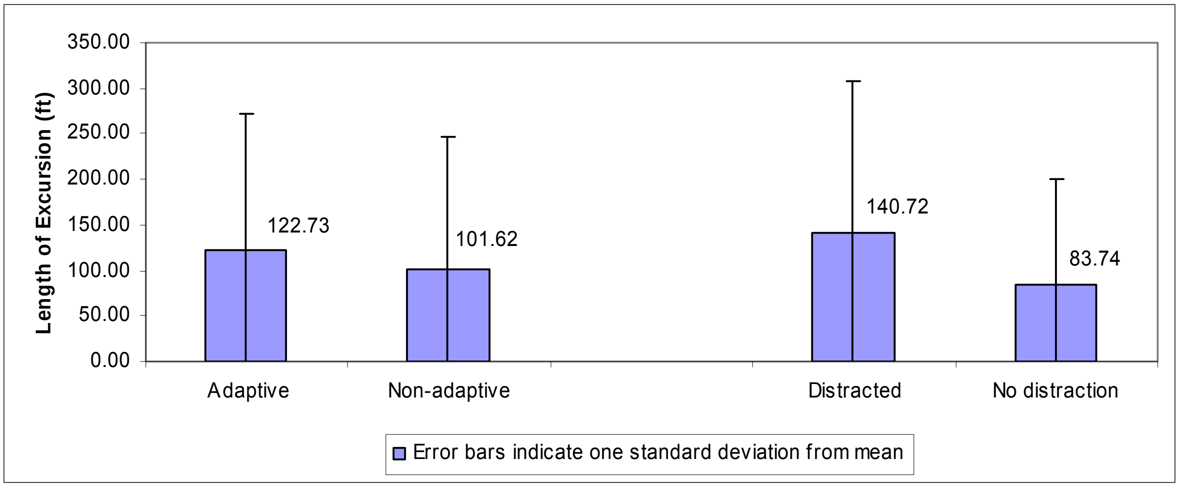

Figure 8. Length of excursion in lane departure warning event

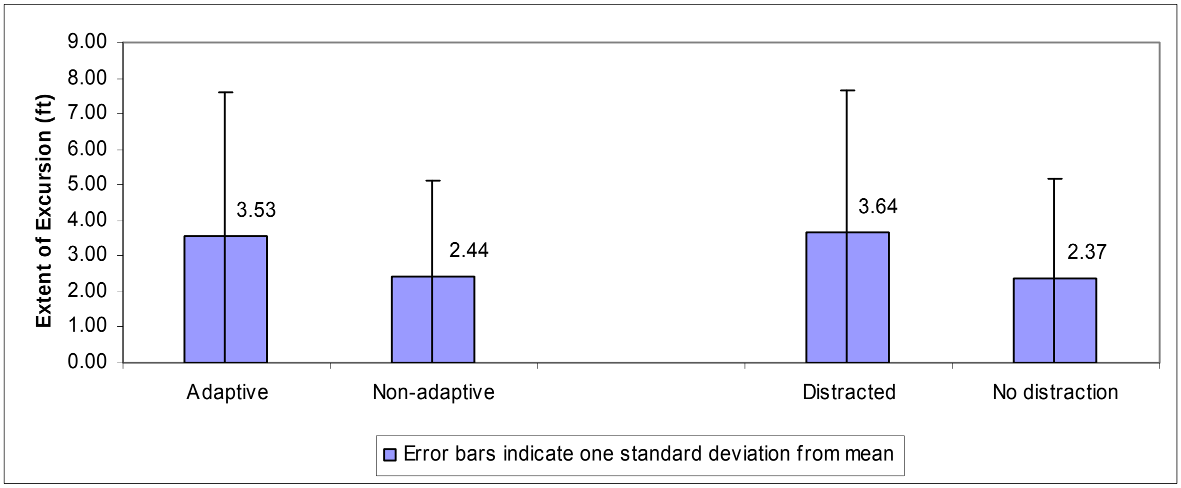

Figure 9. Extent of excursion in lane departure event

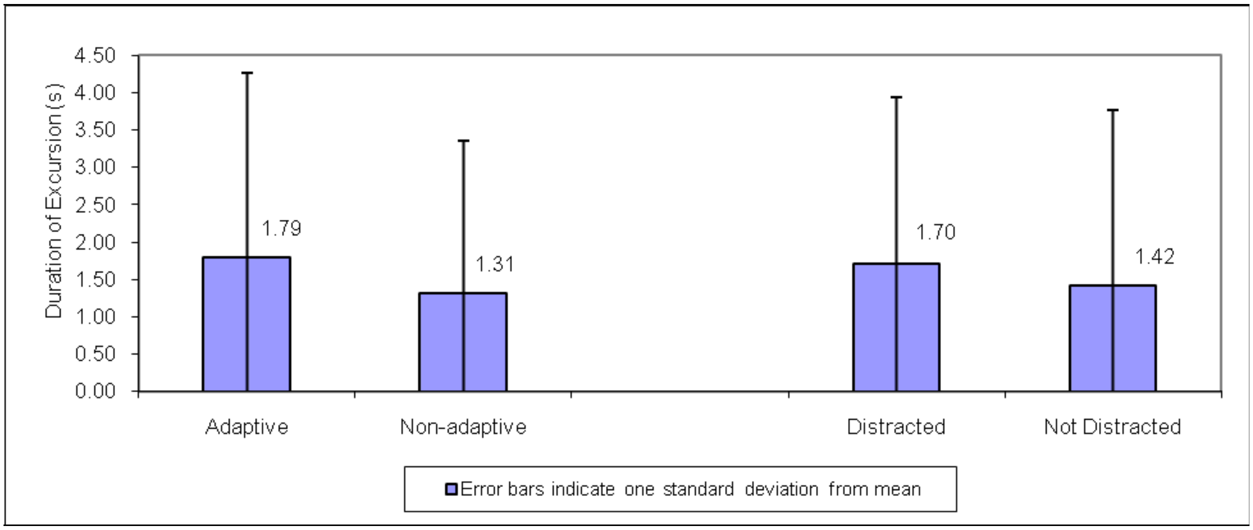

Figure 10. Duration of excursion in lane departure warning event

A Chi-square analysis was run for excursions. Table 11 shows the frequency of excursions by system condition. Fisher's Exact test (p= 0.6131) revealed no differences between adaptive and non-adaptive systems in terms of excursions. Additionally, there were no differences revealed for the Fisher's Exact test (p=0.3114) for distraction (see Table 12).

Table 11. Frequency of excursion by level of system adaptation for lane departure warning event

Level of System Adaptation	No Excursion	Excursion	Total
Adaptive	11	21	32
Non-adaptive	15	16	31
Total	26	37	63

Table 12. Frequency of excursion by level of distraction for lane departure warning event

Level of Distraction	No Excursion	Excursion	Total
Distracted	11	21	32
Not Distracted	15	16	31
Total	26	37	63

3.2.3 Distraction Mitigation

The safety benefit for mitigation of alerts was evaluated in the context of the intersection incursion event at the end of the third study drive. The within-subject independent variables are level of distraction (none, high) and mitigation (no mitigation, mitigation). The results of the significance tests for the dependent measures related to safety are shown in **Table 13** and **Table 14**.

Table 13. Effect of distraction on safety for intersection incursion event

Level of Distraction	Mean		Standard Deviation		Sample Size		Significance
	Distracted	Not Distracted	Distracted	Not Distracted	Distracted	Not Distracted	
Minimum Time to Collision (s)	0.02	0.06	0.06	0.16	31	29	F(1,56) = 1.61 p = 0.0298
Minimum Time to Lane Crossing(s)	0.56	0.89	2.32	2.31	31	30	F(1,57) = 0.35 p = 0.5590
Length of Excursion (overall) (ft)	32.08	11.18	28.27	16.76	31	30	F(1,57) = 12.22 p = 0.0009
Extent of Excursion (overall) (ft)	1.61	0.75	1.37	1.17	31	30	F(1,57) = 6.96 p = 0.0107
Duration of Excursion (overall) (s)	1.34	0.61	1.07	0.96	31	30	F(1,57) = 7.76 p = 0.0072

Table 14. Effect of mitigation on safety for intersection incursion event

Level of Mitigation	Mean		Standard Deviation		Sample Size		Significance
	Mitigation	No Mitigation	Mitigation	No Mitigation	Mitigation	No Mitigation	
Minimum Time to Collision (s)	0.25	0.06	0.07	0.15	29	31	F(1,56)= 1.19 p = 0.2802

The mean of minimum time to collision for the independent variables are shown in **Figure 11**. A lower minimum time to collision in the distracted condition than in the condition without distraction is to be expected. The lower minimum time to collision in the condition with mitigation than in the condition without mitigation may indicate a negative effect of mitigation on safety. A Chi-square analysis was run for collisions. **Table 15** shows the frequency of collisions by system condition. Fisher's Exact test (p= 0.7997) revealed no differences between the mitigation and no mitigation conditions in terms of collisions.

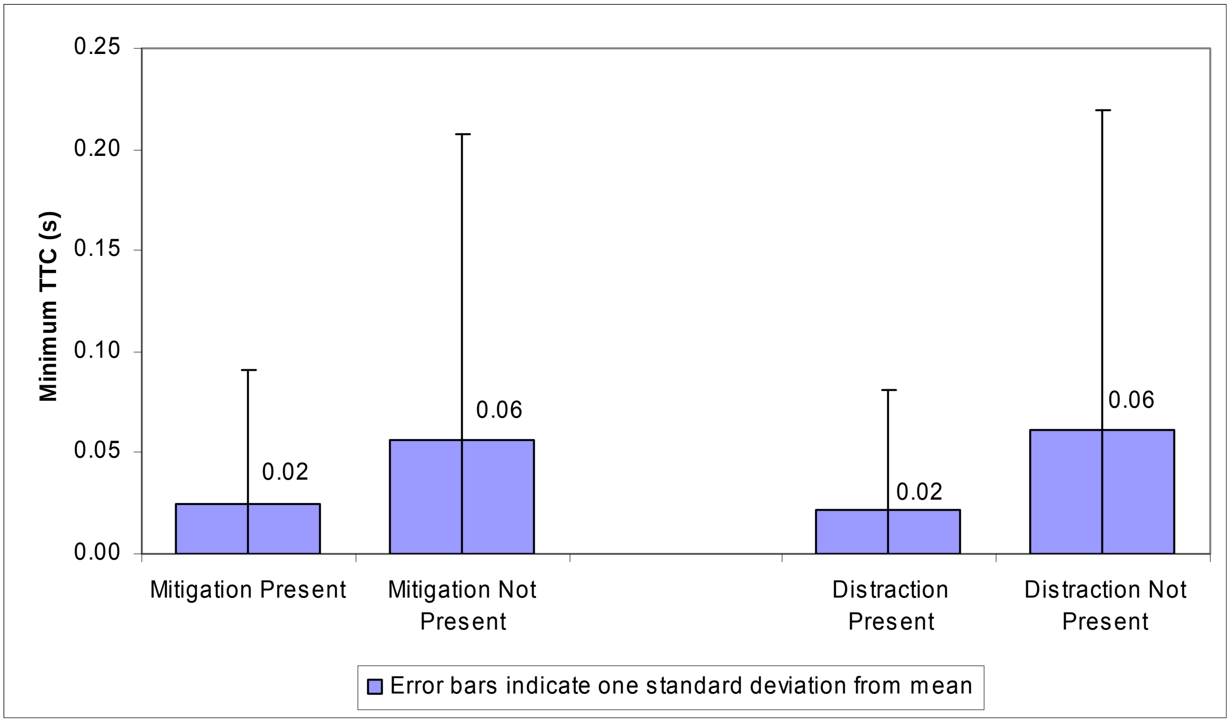

Figure 11. Minimum time to collision for intersection incursion event

Table 15. Frequency of collision by mitigation condition for intersection incursion event

Level of Distraction	No collision	Collision	Total
Mitigation Present	14	16	30
Mitigation Not Present	16	15	31
Total	30	31	61

3.2.4 Trip Report

Independent Variables

The within-subject independent variables are level of distraction (not distracted, distracted), level of demand (low, high), and mitigation (no mitigation, mitigation). The between-subjects independent variables were the trip report providing participants with mitigation feedback (none in previous trial, or mitigation feedback) and presentation of the trip report (not presented, presented). This experimental design consists of only the first several minutes of the last two study drives.

Table 16. Effect of trip report and mitigation on safety

Level of Mitigation	Trip Report Present Y = Yes N = No	Mean		Standard Deviation		Sample Size		Significance
		Mitigation	No Mitigation	Mitigation	No Mitigation	Mitigation	No Mitigation	
Minimum Time to Collision (s)	Y	0.96	0.88	0.63	0.41	128	128	F(1,476) = 3.69 p = 0.0555
Minimum Time to Collision (s)	N	0.73	0.79	0.30	0.28	126	126	

Table 17. Effect of trip report and demand on safety

Level of Demand	Trip Report Present Y = Yes N = No	Mean		Standard Deviation		Sample Size		Significance
		High	Low	High	Low	High	Low	
Minimum Time to Collision (s)	Y	0.72	1.22	0.22	0.66	128	128	F(1,476) = 3.12 p = 0.0778
Minimum Time to Collision (s)	N	0.62	0.91	0.23	0.29	128	124	

Table 18. Effect of trip report and distraction on safety

Level of Distraction	Trip Report Present Y = Yes N = No	Mean		Standard Deviation		Sample Size		Significance
		Distracted	Not Distracted	Distracte d	Not Distracted	Distracted	Not Distracted	
Minimum Time to Collision (s)	Y	0.93	0.91	0.65	0.38	128	128	F(1,476) = 2.03 p = 0.1550
Minimum Time to Collision (s)	N	0.72	0.81	0.35	0.21	127	125	

The trip report was presented to participants between Study Drive 2 and Study Drive 3 for half of the participants. Figure 12 shows the means for minimum time to collision for the four combinations of trip report presentation and the presence of distraction. The bars on the left side of Figure 12 indicate the mean minimum time to collision for the participants prior to the presentation of the trip report. There is a systematic difference between the participants who were about to receive a trip report and those who were not. Presentation of the trip report was balanced across the other experimental conditions, see Table 4. Presentation of the trip report shortened minimum time to collision in the events where distraction was present, but lengthened minimum time to collision when distraction was not present. There was little difference between the participants who did not receive the trip report when distraction was not present. Participants who did not receive the trip report had slightly longer minimum time to collision in the third drive than in the second.

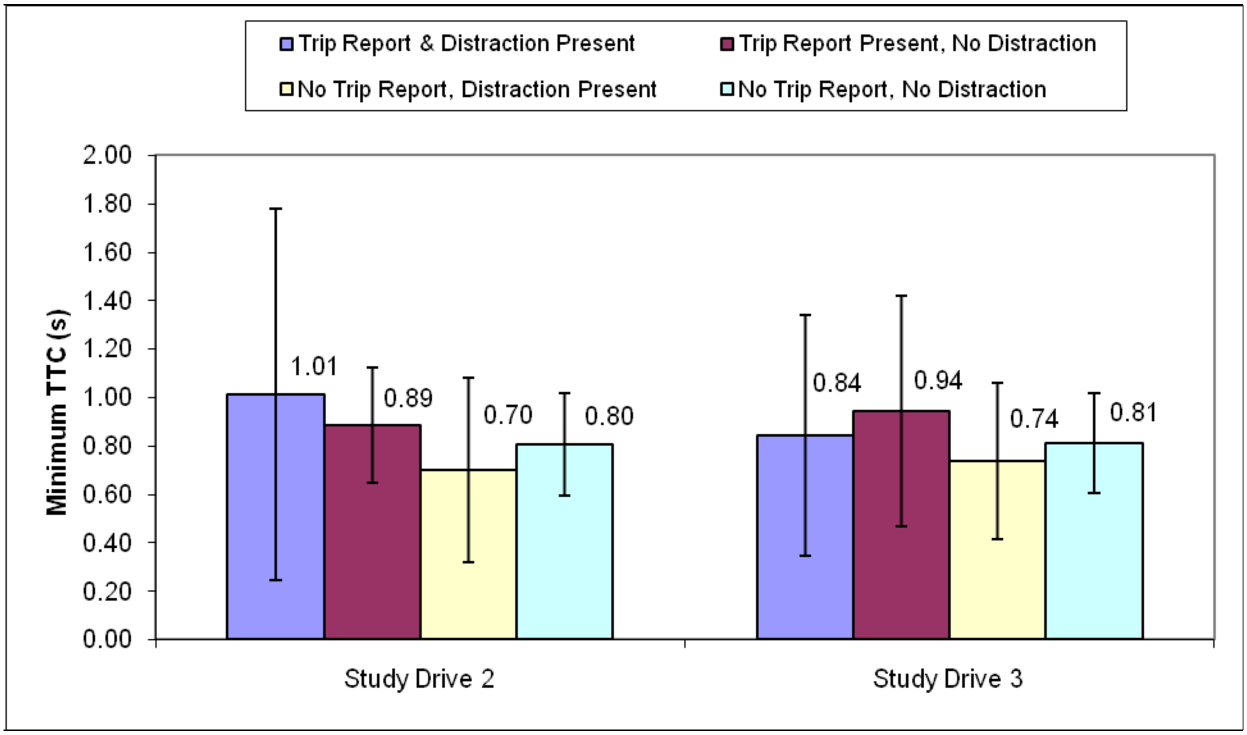

Figure 12. Interaction between distraction and trip report

The same systematic difference for presentation of the trip report was not seen between participants with and without mitigation during Study Drive 2; however, there was some difference between participants who were not to receive the trip report. When both trip report and mitigation were present or when both were absent, there was no change in minimum time to collision between Study Drives 2 and 3. The difference between both present and both absent is fairly large, indicating there is an effect of one or both on minimum time to collision. Presentation of the trip report when no mitigation was present shortened minimum time to collision, while there was a small increase between Study Drive 2 and Study Drive 3 when mitigation was present and the trip report was not presented. It seems there was a negative effect of presenting the trip report, while over time the presence of mitigation may have an increasing positive effect.

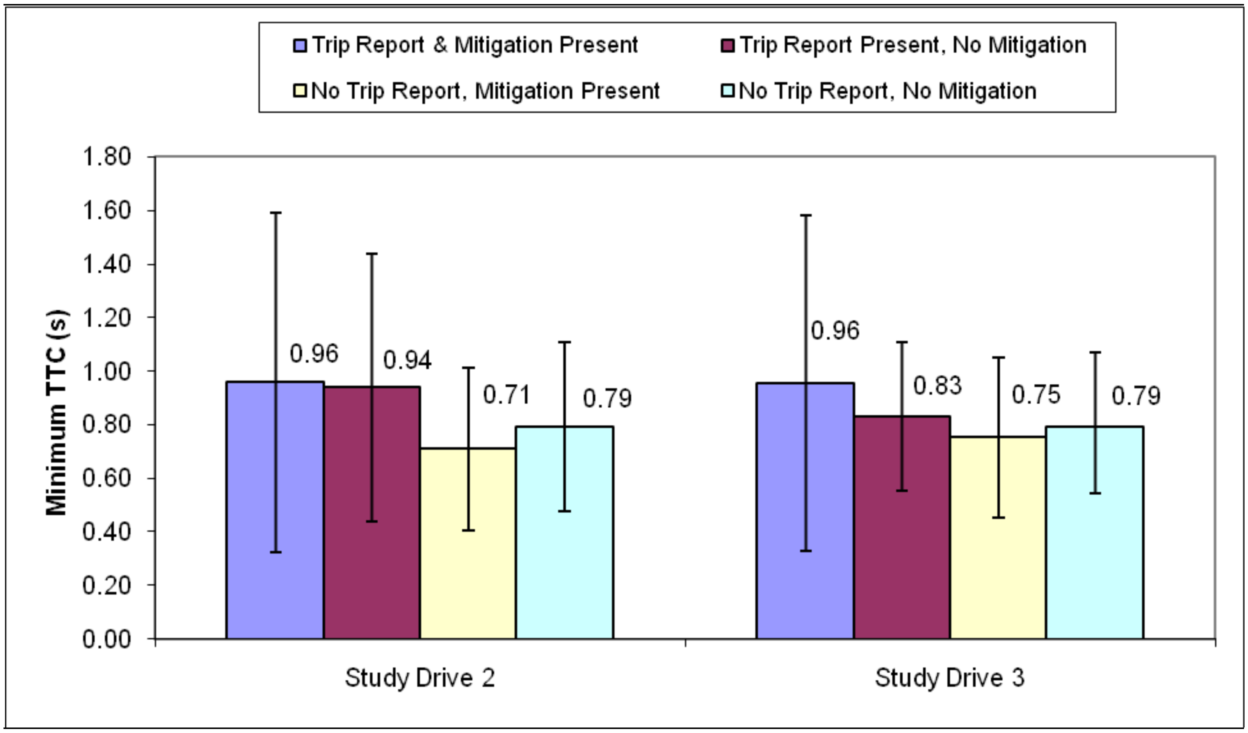

Figure 13. Interaction between mitigation and trip report

3.3 Driver Response

The NADS experiment also addressed five experimental questions associated with the impact of these systems on **driver response**.

- How does adaptation of an FCW system affect driver response to imminent collision situations?
- How does adaptation of an LDW system affect driver response to imminent lane departure situations?
- How does the adaptive SAVE-IT system affect driver response to imminent intersection incursion events?
- How do the various distraction mitigation strategies affect driver response to non-imminent conflict driving situations?
- How does a performance trip report affect driver response to non-imminent conflict driving situations?

3.3.1 Forward Collision Warning

The independent measures included in this analysis were level of system adaptation, level of distraction, and type of system alert. The results of the significance tests for the dependent measures related to safety are shown in **Table 19** through **Table 21**. Only participants with their foot on the accelerator at event onset were included in the analysis of accelerator release reaction time and time to collision at accelerator release. Similarly, only participants who had a braking response were included in the analysis of brake reaction time, maximum brake reaction time, time to collision at brake response, time to collision at maximum brake response, and minimum acceleration.

The frequency of accelerator release prior to event onset is shown in **Table 22**. Over half, 62%, of participants released the accelerator pedal prior to event onset. A Fisher's Exact Test (p= 0.3055) did not reveal a difference between the adaptive and non-adaptive conditions. However, a Fisher's Exact Test (p= 0.0006) did reveal a difference when distraction was present and was not present. Participants released the accelerator pedal prior to the onset of the event more often when the distraction task was present, as shown in **Table 23**. One possible explanation is that because the distraction task began prior to event onset, it could be a self-mitigating action to decrease the risk associated with engaging in a non-driving task while driving.

Table 19. Effect of system adaptation on driver response for forward collision warning event

Level of System Adaptation	Mean		Standard Deviation		Sample Size		Significance
	Adaptive	Non-Adaptive	Adaptive	Non-Adaptive	Adaptive	Non-Adaptive	
Accelerator Release Reaction Time (s)	0.69	0.38	0.34	0.17	14	10	F(1,17) = 2.27 p = 0.1501
Time to Collision at Accelerator Release (s)	0.99	1.06	0.14	0.07	14	10	F(1,17) = 0.27 p = 0.6119
Brake Reaction Time (s)	0.99	1.08	0.32	0.46	30	31	F(1,53) = 0.92 p = 0.3416
Maximum Brake Reaction Time (s)	2.57	2.65	0.44	0.36	30	31	F(1,53) = 0.66 p = 0.4193
Time to Collision at Brake Response (s)	0.93	0.89	0.14	0.23	30	31	F(1,53) = 1.19 p = 0.2796
Time to Collision at Maximum Brake Response (s)	0.42	0.37	0.25	0.27	30	31	F(1,53) = 0.85 p = 0.3606
Minimum Acceleration (g)	-1.19	-1.22	0.04	0.25	30	31	F(1,53) = 0.34 p = 0.5601

Table 20. Effect of distraction on driver response for forward collision warning event

Level of Distraction	Mean		Standard Deviation		Sample Size		Significance
	Distracted	Not Distracted	Distracted	Not Distracted	Distracted	Not Distracted	
Accelerator Release Reaction Time (s)	0.65	0.54	0.46	0.28	5	19	F(1,17) = 0.55 p = 0.4703

Time to Collision at Accelerator Release (s)	1.03	1.02	0.15	0.11	5	19	F(1,17) = 0.31 p = 0.5866
Brake Reaction Time (s)	1.20	0.89	0.45	0.27	29	32	F(1,53) = 11.00 p = 0.0016
Maximum Brake Reaction Time (s)	2.63	2.60	0.48	0.33	29	32	F(1,53) = 0.11 p = 0.7425
Time to Collision at Brake Response (s)	0.87	0.94	0.24	0.13	29	32	F(1,53) = 2.01 p = 0.1618
Time to Collision at Maximum Brake Response (s)	0.37	0.42	0.28	0.24	29	32	F(1,53) = 0.49 p = 0.4870
Minimum Acceleration (g)	-1.20	-1.22	0.13	0.22	29	32	F (1,53) = 0.27 p = 0.6078

Table 21. Effect of throttle release on driver response for forward collision warning event

Throttle Release in FCW Alert	Mean		Standard Deviation		Sample Size		Significance
	Present	Not Present	Present	Not Present	Present	Not Present	
Accelerator Release Reaction Time (s)	0.52	0.61	.33	.32	13	11	F(1,17) = 1.10 p = 0.3088
Time to Collision at Accelerator Release (s)	1.04	1.00	0.92	0.14	13	11	F(1,17) = 1.14 p = 0.3014
Brake Reaction Time (s)	1.06	1.01	0.38	0.42	30	31	F(1,53) = 0.49 p = 0.4849
Maximum Brake Reaction Time (s)	2.55	2.67	0.42	0.38	30	31	F(1,53) = 1.37 p = 0.2470
Time to Collision at Brake Response (s)	0.91	0.91	0.19	0.19	30	31	F(1,53) = 0.02 p = 0.8812
Time to Collision at Maximum Brake Response (s)	0.40	0.39	0.27	0.25	30	31	F(1,53) = 0.00 p = 0.9642
Minimum Acceleration (g)	-1.19	-1.23	0.14	0.21	30	31	F(1,53) = 0.67 p = 0.4153

Table 22. Frequency of accelerator release prior to event onset by level of system adaptation for forward collision warning event

Level of System Adaptation	Accelerator Depressed at Event Onset	Accelerator Released at Event Onset	Total
Adaptive	14	17	31
Non-adaptive	10	22	32
Total	24	39	63

Table 23. Frequency of accelerator release prior to event onset by level of distraction for forward collision warning event

Level of Distraction	Accelerator Depressed at Event Onset	Accelerator Released at Event Onset	Total
Distracted	5	26	31
Not Distracted	19	13	32
Total	24	39	63

There was a significant effect of the presence of the distraction task on brake reaction time. As shown in **Figure 14**, when participants were distracted, the time to the beginning of their braking response was longer than when they were not distracted. There were no significant difference in terms of adaptation and throttle release.

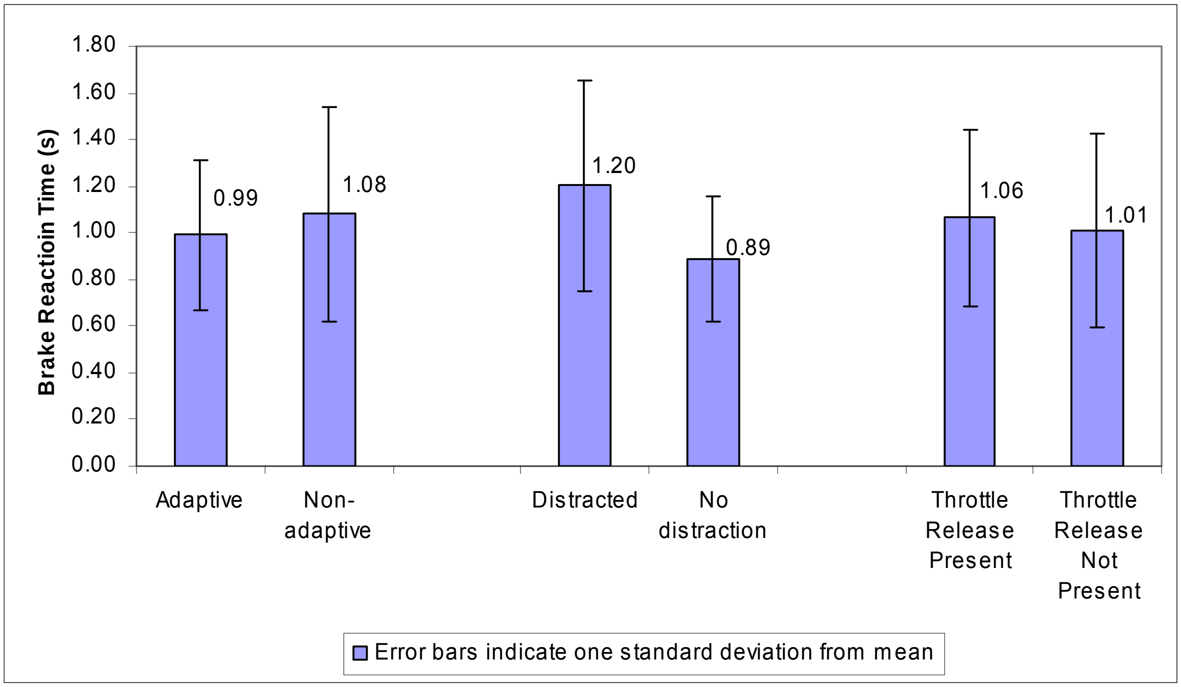

Figure 14. Brake reaction time for forward collision warning event

Figure 15 through **Figure 20** illustrate that for the remaining dependent measures—adaptation, distraction level and throttle release—there were no statistically significant results for any of the independent variables. It is important to note that the standard deviations continue to be large relative to the differences in the means.

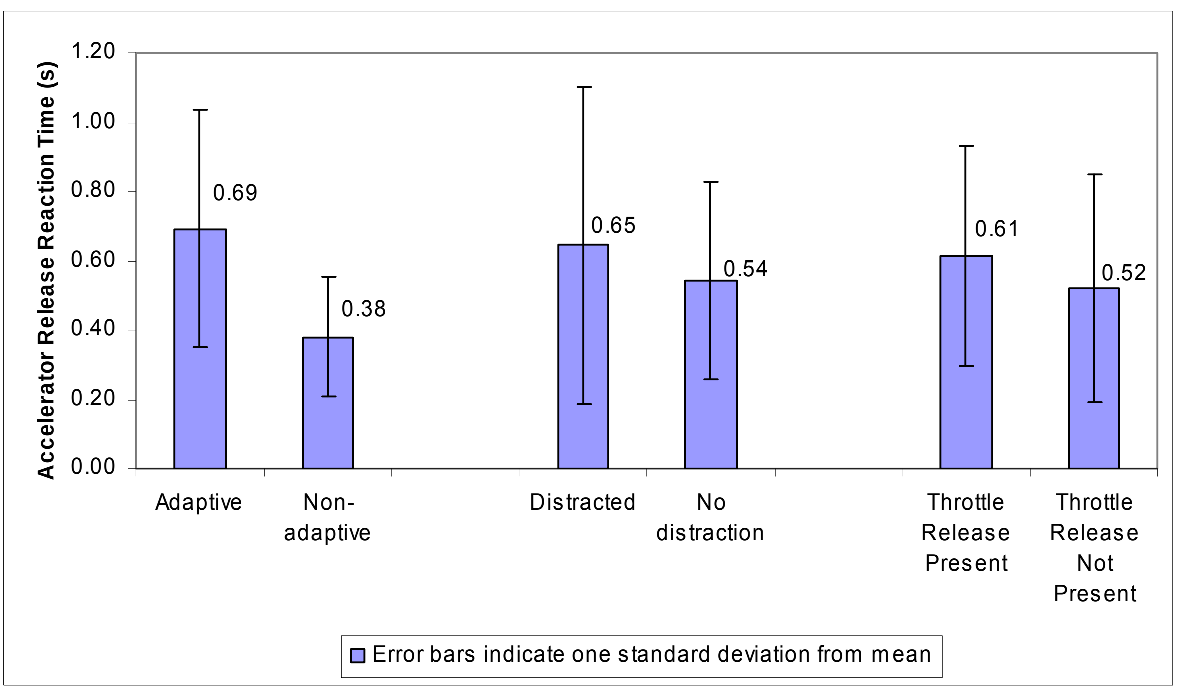

Figure 15. Accelerator reaction time for forward collision warning event

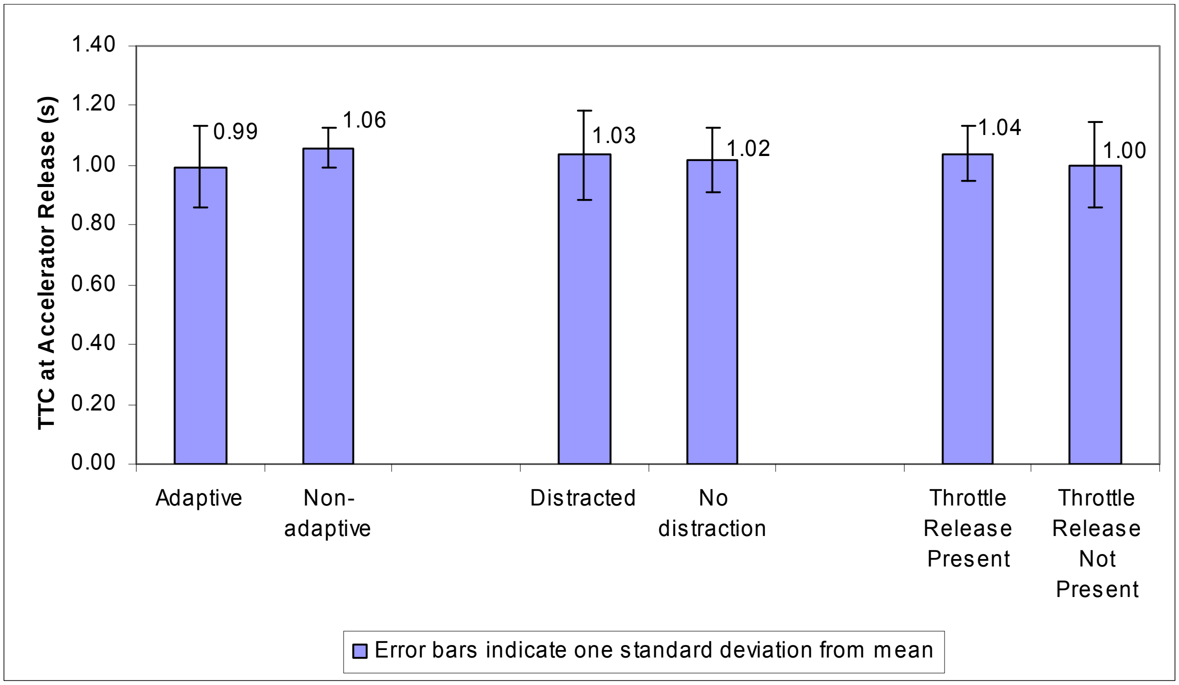

Figure 16. Time to collision at accelerator release for forward collision warning event

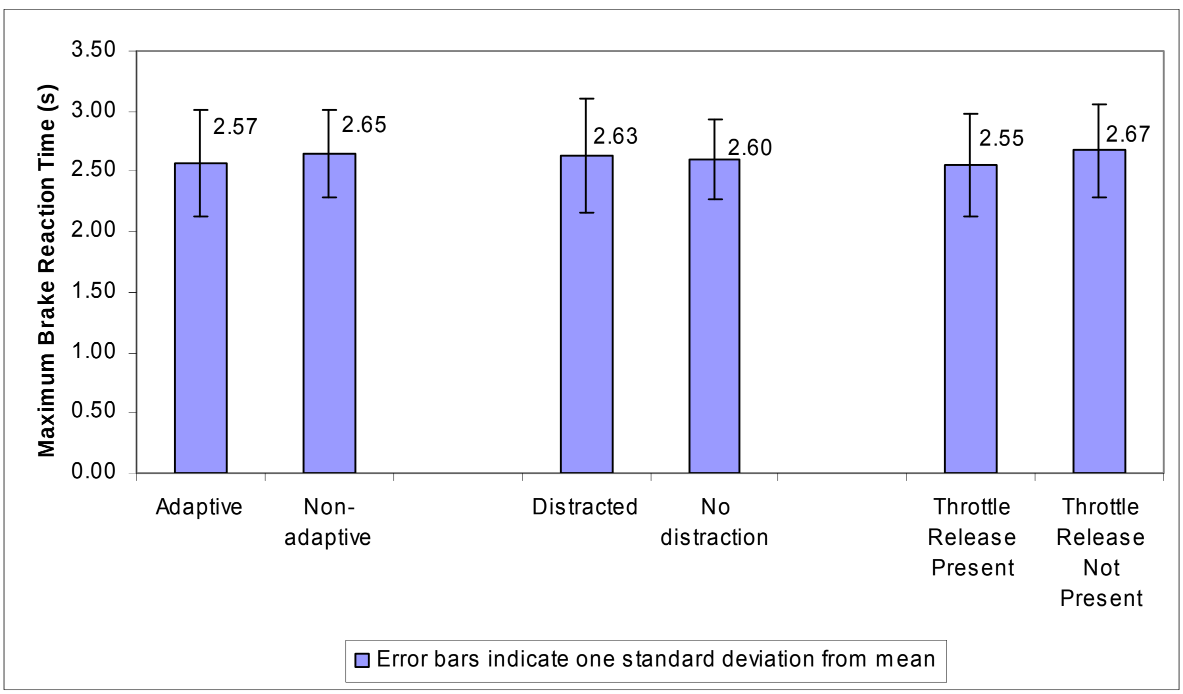

Figure 17. Maximum brake reaction time for forward collision warning event

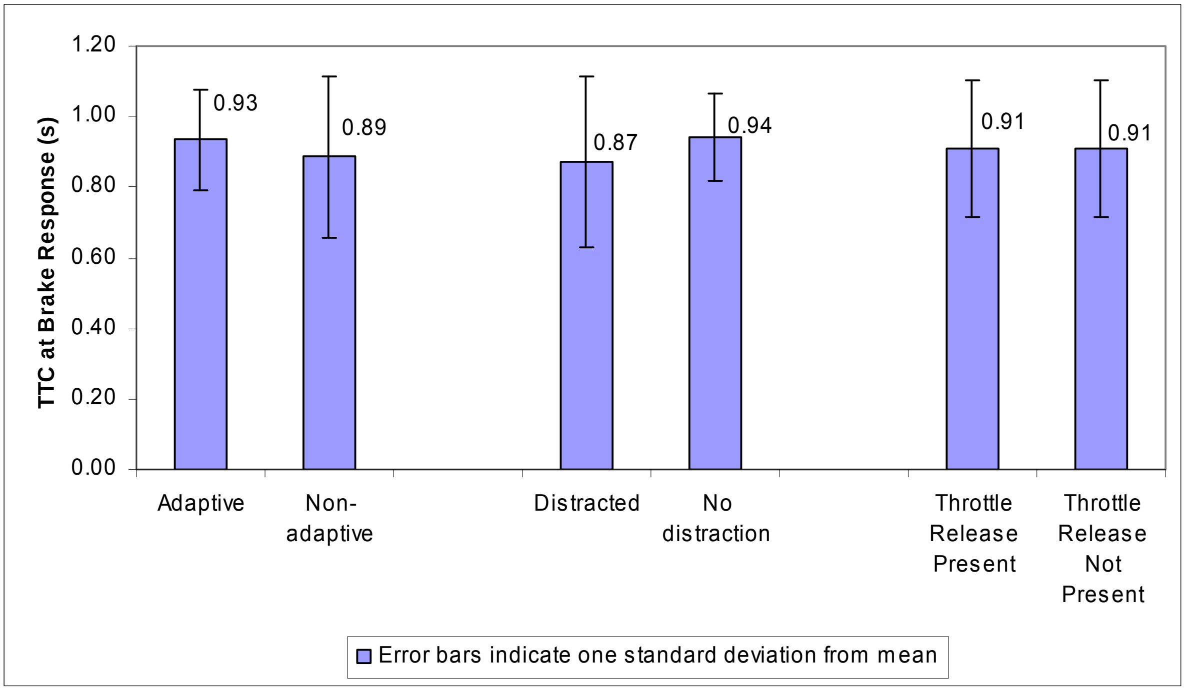

Figure 18. Time to collision at braking response for forward collision warning event

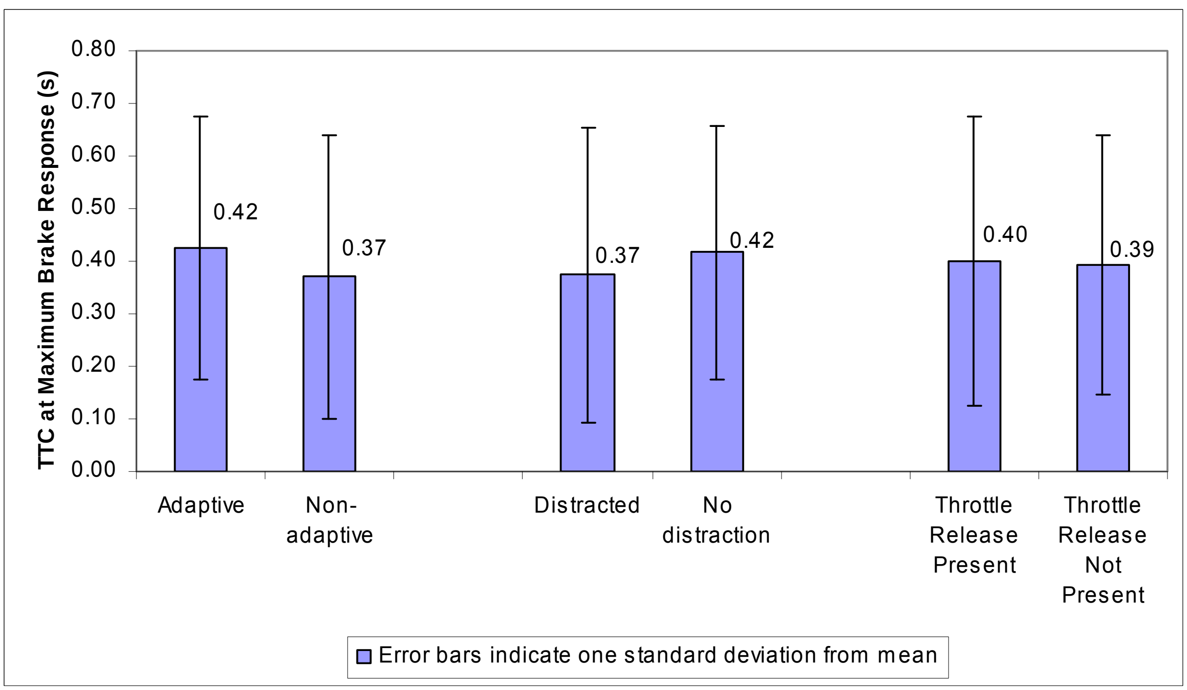

Figure 19. Time to collision at maximum brake response for forward collision warning event

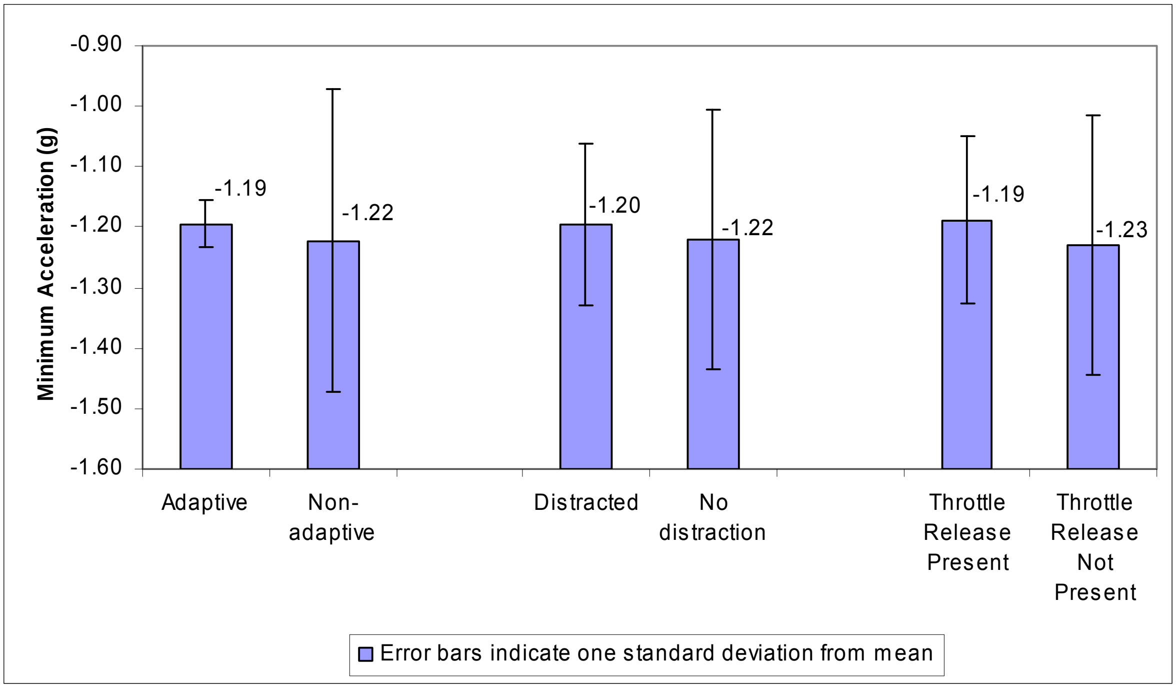

Figure 20. Minimum acceleration for forward collision warning event

A Chi-Square analysis was also run for whether or not participants had a braking response. A Fisher's Exact Test (p=1.0000) shows no difference between the adaptive and non-adaptive conditions for the braking response frequencies shown in **Table 24**.

Table 24. Frequency of braking response to forward collision warning event

Level of System Adaptation	No Braking Response	Braking Response	Total
Adaptive	1	30	31
Non-adaptive	1	31	32
Total	2	61	63

3.3.2 Lane Departure Warning

The independent measures included in this analysis were level of system adaptation and level of distraction. The results of the significance tests for the dependent measures related to safety are shown in **Table 25Table 25** and **Table 26**. As in the FCW analysis, only participants with their foot on accelerator at event onset were included in the analysis of accelerator release reaction time and time to collision at accelerator release, and only participants who had a braking response were included in the analysis of brake reaction time, maximum brake reaction time, time to collision at brake response, and minimum acceleration. **Table 27** shows the frequency table for accelerator release prior to event onset, and T**able 28** shows the frequency table for level of distraction from the Chi-square analyses. Fisher's Exact Tests did not indicate a difference between the adaptive and non-adaptive conditions (p=0.2737), nor for whether or not distraction was present (p=1.0000).

Table 25. Effect of system adaptation on driver response for lane departure warning event

Level of Adaptation	Mean		Standard Deviation		Sample Size		Significance
	Adaptive	Non-Adaptive	Adaptive	Non-Adaptive	Adaptive	Non-Adaptive	
Time to Steering Onset (s)	1.26	1.28	0.51	0.54	32	32	$F(1,60) = 0.02$ $p = 0.8903$
Time to Lane Crossing at Steering Onset (s)	2.85	-2.62	14.68	9.63	32	32	$F(1,60) = 3.03$ $p = 0.0867$
Maximum Steering Rate (deg./s)	190.78	157.97	195.64	128.01	32	32	$F(1, 60) = 0.62$ $p = 0.4359$
Maximum Lateral Acceleration (g)	31.41	29.36	6.82	6.80	32	32	$F(1, 60) = 1.44$ $p = 0.2341$
Maximum Lateral Jerk (g/s)	3107.42	3061.83	568.46	635.45	32	32	$F(1, 60) = 0.09$ $p = 0.7609$
Accelerator Reaction Time (s)	2.64	1.27	2.95	0.97	25	20	$F(1,41) = 3.86$ $p = 0.0562$
Time to Lane Crossing at Accelerator Release (s)	4.05	2.81	9.21	6.18	25	20	$F(1,41) = 0.24$ $p = 0.6257$
Brake Reaction Time (s)	4.31	3.92	2.62	2.25	18	16	$F(1,30) = 0.18$ $p = 0.6771$
Maximum Brake Reaction Time (s)	6.24	4.41	3.67	3.53	18	16	$F(1,30)=1.64$ $p = 0.2107$
Minimum Acceleration (g)	-0.29	-0.31	0.16	0.20	18	16	$F(1,30) = 0.06$ $p = 0.8011$
Time to Lane Crossing at Brake Response (s)	2.02	1.51	15.08	11.10	17	16	$F(1,30) = 0.00$ $p = 0.9777$

Table 26. Effect of distraction on driver response for lane departure warning event

Level of Distraction	Mean		Standard Deviation		Sample Size		Significance
	Distracted	Not Distracted	Distracted	Not Distracted	Distracted	Not Distracted	
Time to Steering Onset (s)	1.23	1.30	0.53	0.52	32	32	$F(1,60) = 0.27$ $p = 0.6073$
Time to Lane Crossing at Steering Onset (s)	-0.16	0.39	13.70	11.65	32	32	$F(1,60) = 0.03$ $p = 0.8599$
Maximum Steering Rate (deg./s)	182.24	166.51	184.28	145.31	32	32	$F(1, 60) = 0.14$ $p = 0.7081$
Maximum Lateral Acceleration (g)	31.40	29.37	6.73	6.89	32	32	$F(1,60) = 1.42$ $p = 0.2389$
Maximum Lateral Jerk (g/s)	3215.31	2953.94	556.55	618.88	32	32	$F(1,60) = 3.07$ $p = 0.847$
Accelerator Reaction Time (s)	2.49	1.56	2.94	1.51	23	22	$F(1,41) = 1.47$ $p = 0.2329$
Time to Lane Crossing at Accelerator Release (s)	3.36	3.64	9.52	6.09	23	22	$F(1,41) = 0.07$ $p = 0.5155$
Brake Reaction Time (s)	4.00	4.25	2.34	2.58	17	17	$F(1,30) = 0.06$ $p = 0.8109$
Maximum Brake Reaction Time (s)	4.16	6.60	3.80	3.19	17	17	$F(1,30)=3.41$ $p = 0.0747$
Minimum Acceleration (g)	-0.31	-0.28	0.21	0.16	17	17	$F(1,30) = 0.17$ $p = 0.6871$
Time to Lane Crossing at Brake Response (s)	0.88	2.61	6.41	17.41	16	17	$F(1,29) = 0.11$ $p = 0.7418$

Table 27. Frequency of accelerator release prior to event onset by level of system adaptation for lane departure warning event

Level of System Adaptation	Accelerator Depressed at Event Onset	Accelerator Released at Event Onset	Total
Adaptive	25	7	32
Non-adaptive	21	12	32
Total	46	19	64

Table 28. Frequency of accelerator release prior to event onset by level of distraction for lane departure warning event

Level of Distraction	Accelerator Depressed at Event Onset	Accelerator Released at Event Onset	Total
Distracted	23	9	32
Not Distracted	22	10	32
Total	45	19	64

There were no statistically significant results for the dependent measures in the lane departure warning event. The standard deviations are again large relative to the differences in the means. However, there are some differences large enough that they may be informative. The accelerator release reaction time for the adaptive condition was almost twice that for the non-adaptive condition (see **Figure 21**). If the system suppressed LDW warnings for participants glancing back and forth from the road to the system display, this could explain the higher reaction time for participants in the adaptive condition. The results for time to lane crossing at accelerator release (**Figure 22**) and maximum brake reaction time (**Figure 23**) are similar and could have also been affected by the suppression of LDW alerts.

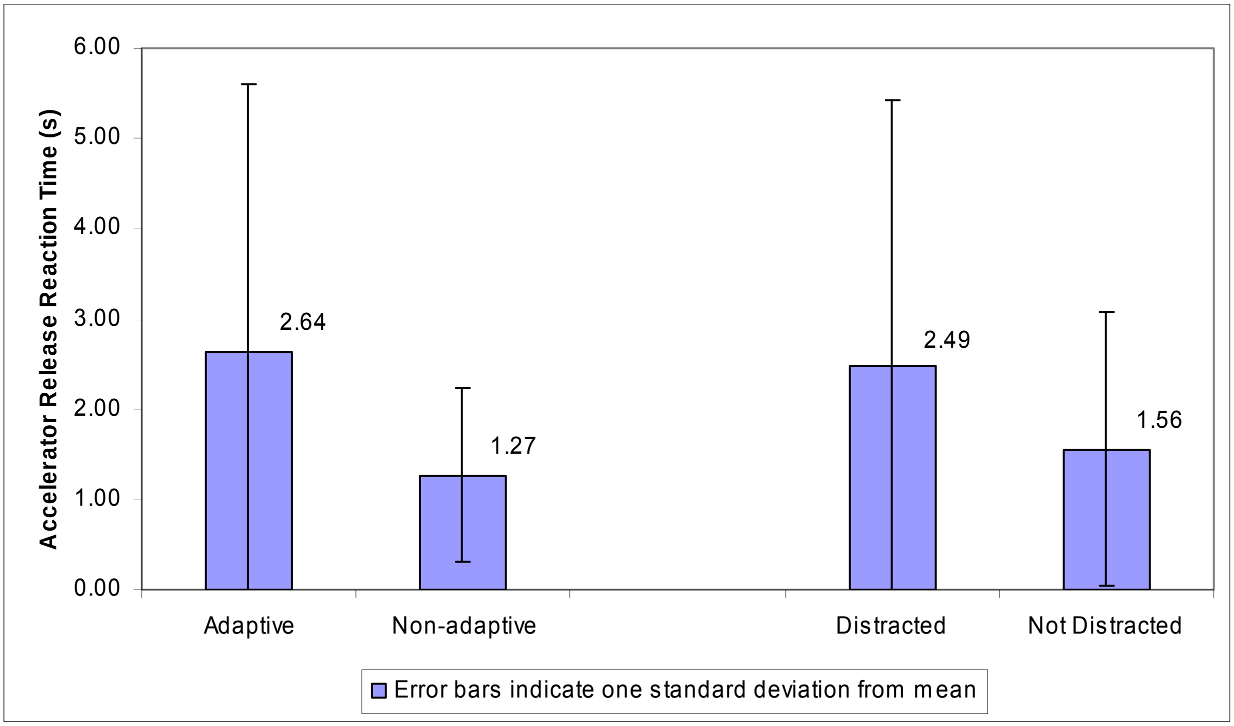

Figure 21. Accelerator release reaction time for lane departure warning event

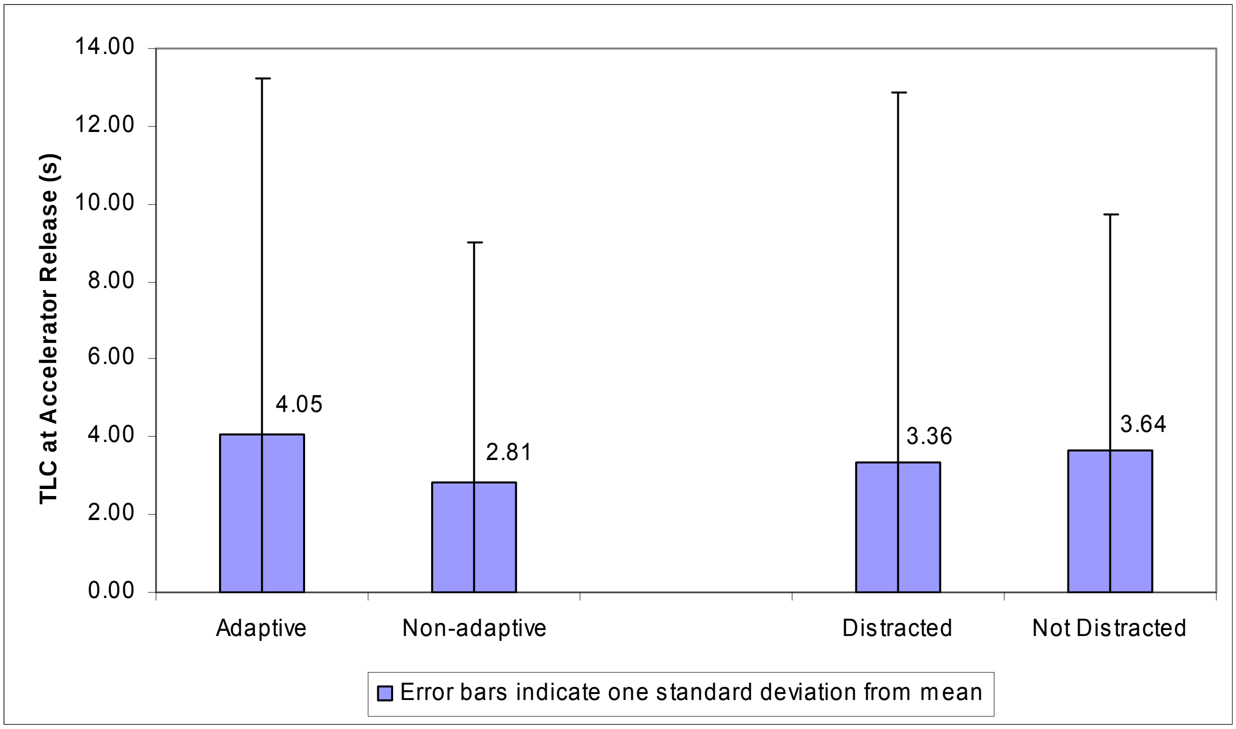

Figure 22. Time to lane crossing at accelerator release for lane departure warning event

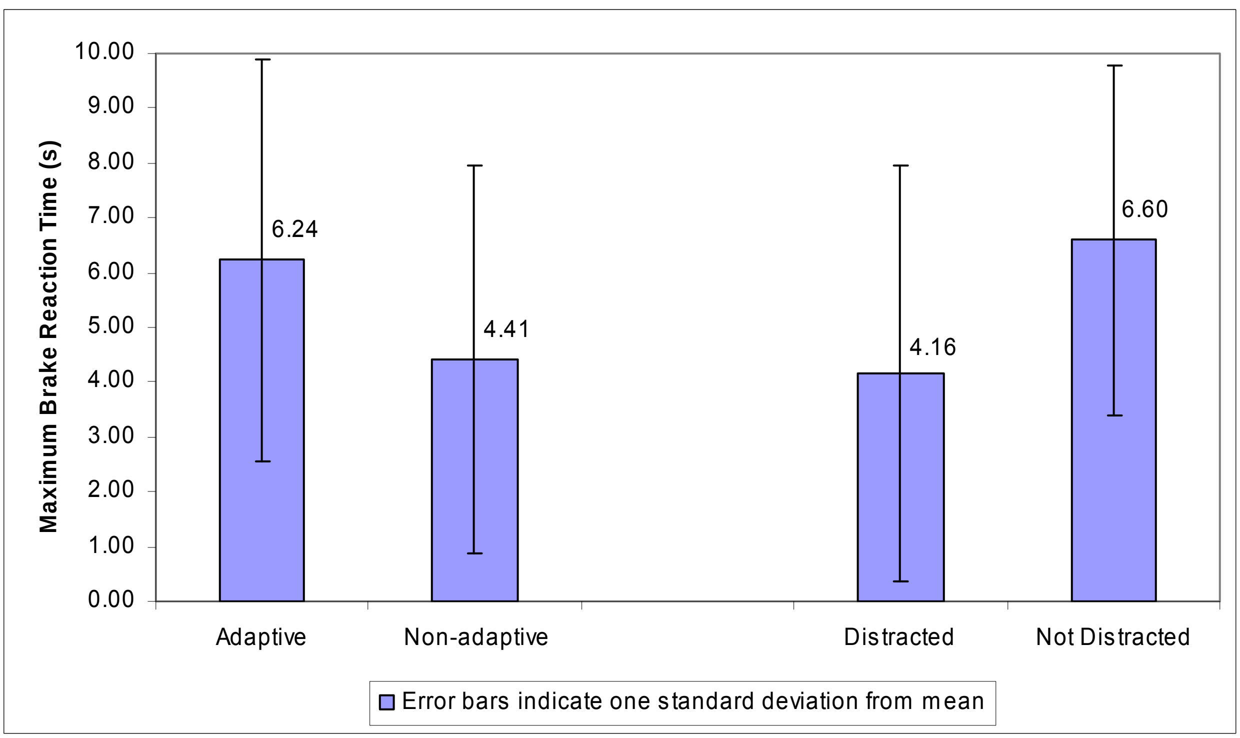

Figure 23. Maximum brake reaction time for lane departure warning event

Figure 24 through **Figure 31** illustrate that for the remaining dependent measures, adaptation and distraction level, there were only small differences between the means for each condition. It is important to note that the standard deviations continue to be large relative to the differences in the means.

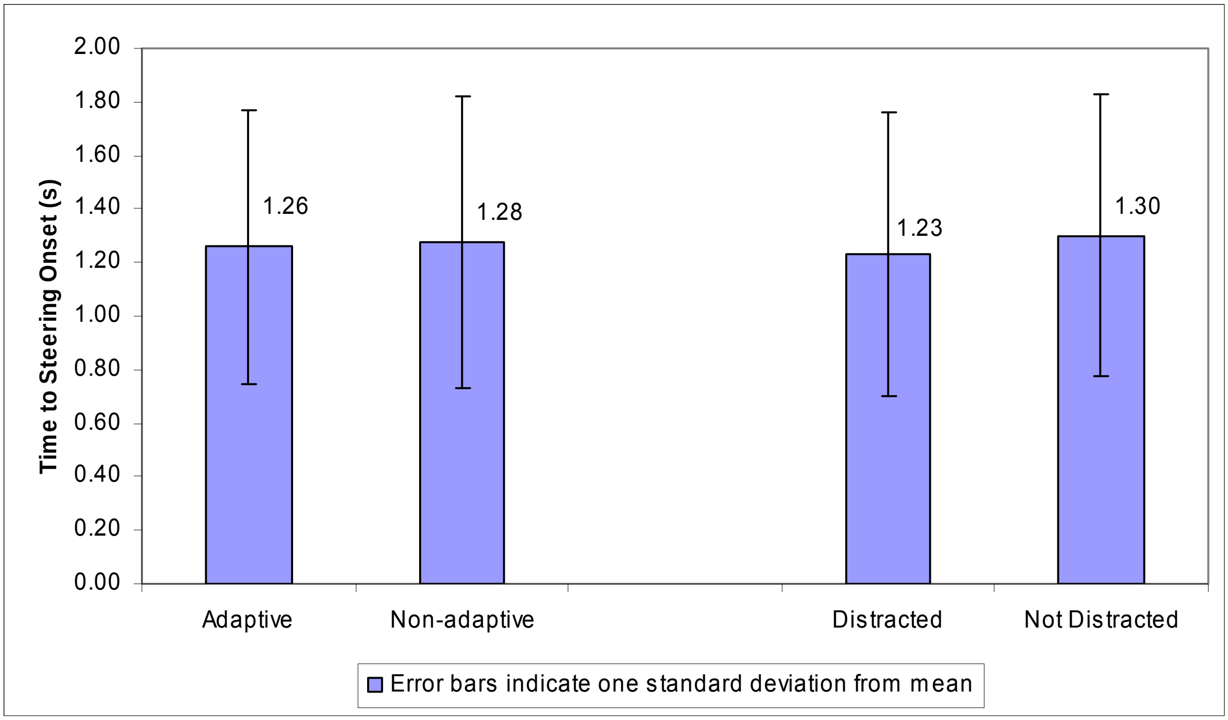

Figure 24. Time to steering for lane departure warning event

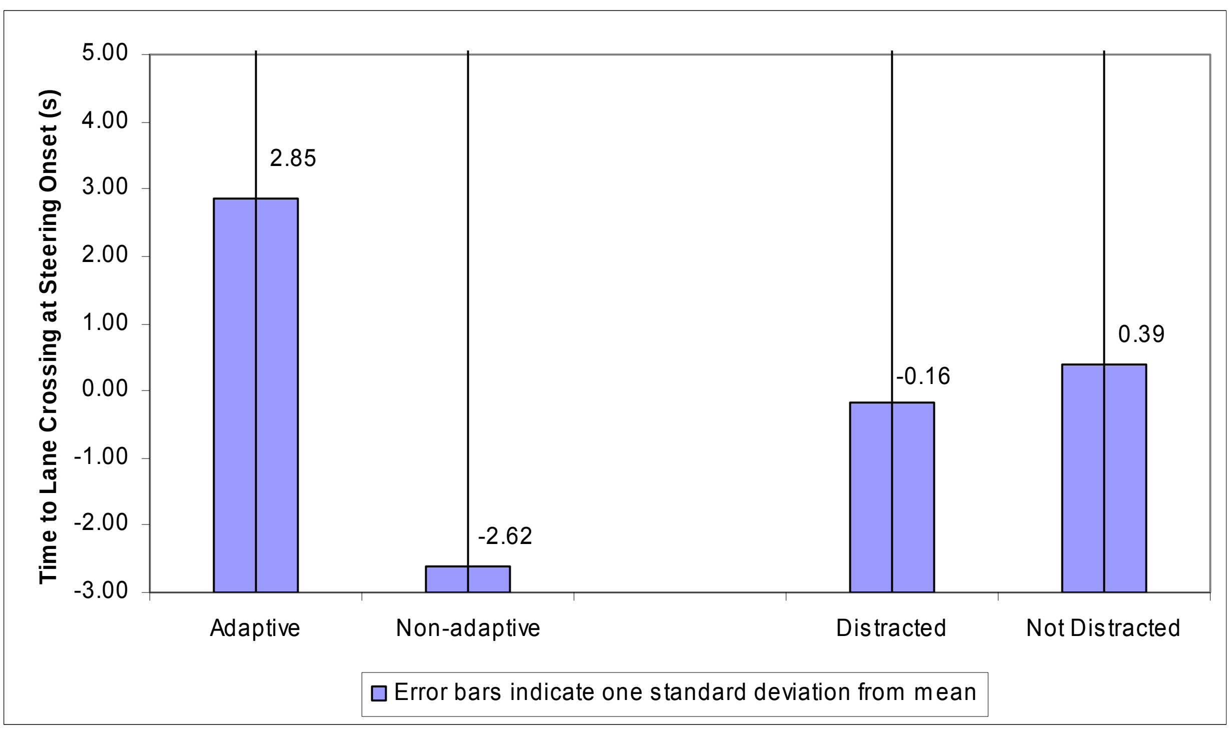

Figure 25. Time to lane crossing at steering onset for lane departure warning event

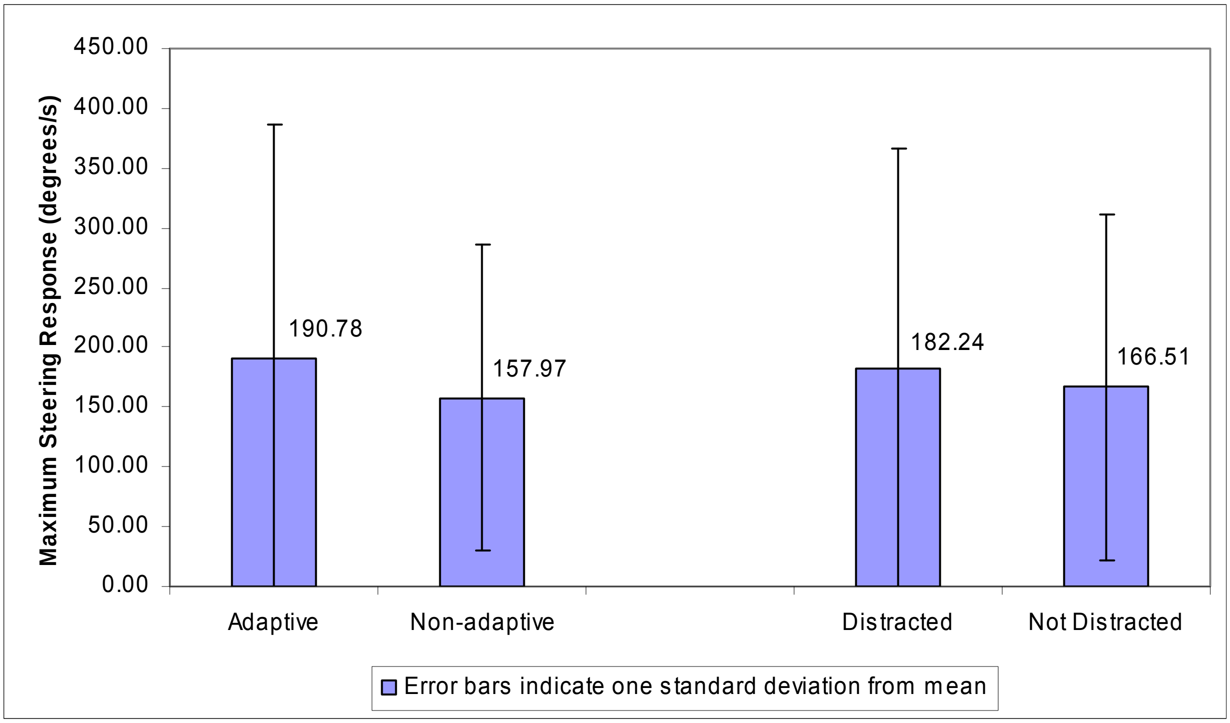

Figure 26. Maximum steering rate for lane departure warning event

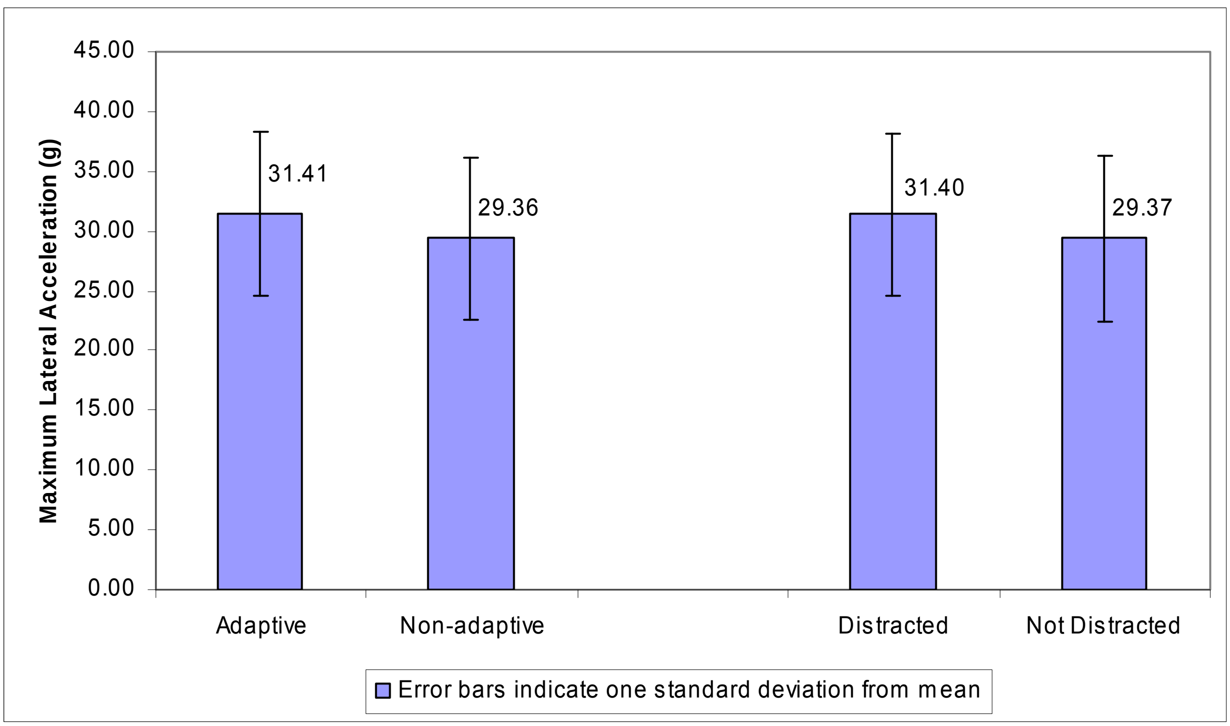

Figure 27. Maximum lateral acceleration for lane departure warning event

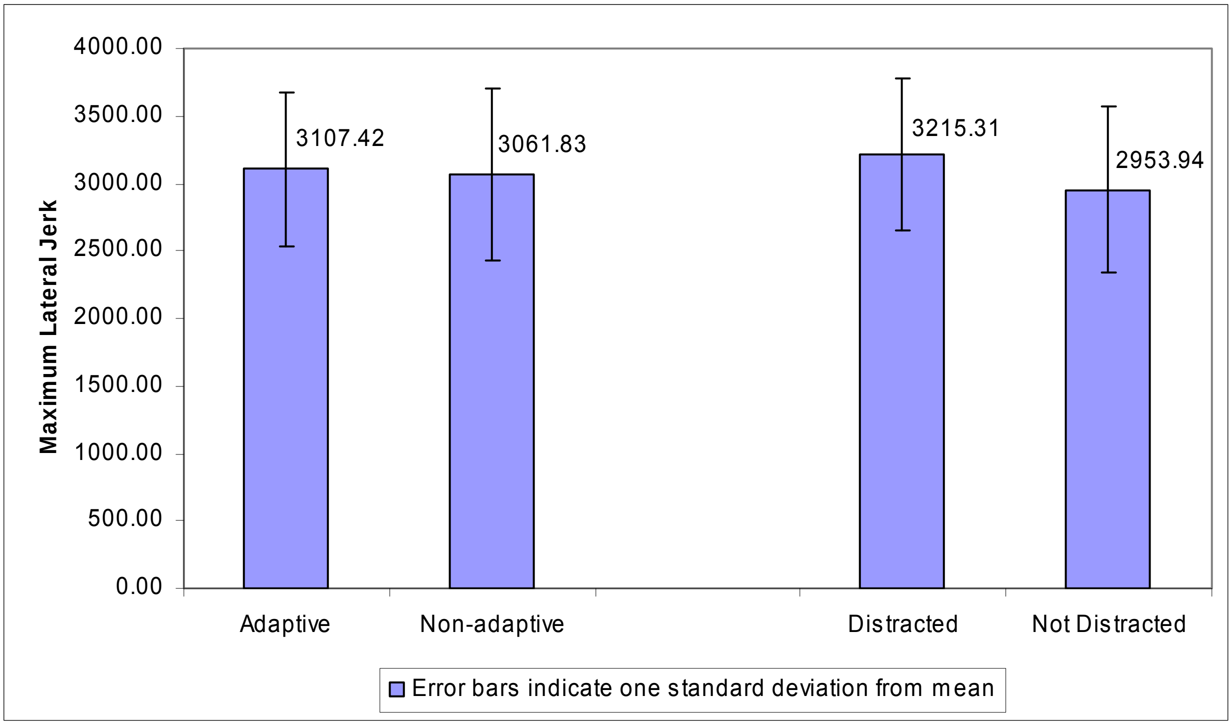

Figure 28. Maximum lateral jerk for lane departure warning event

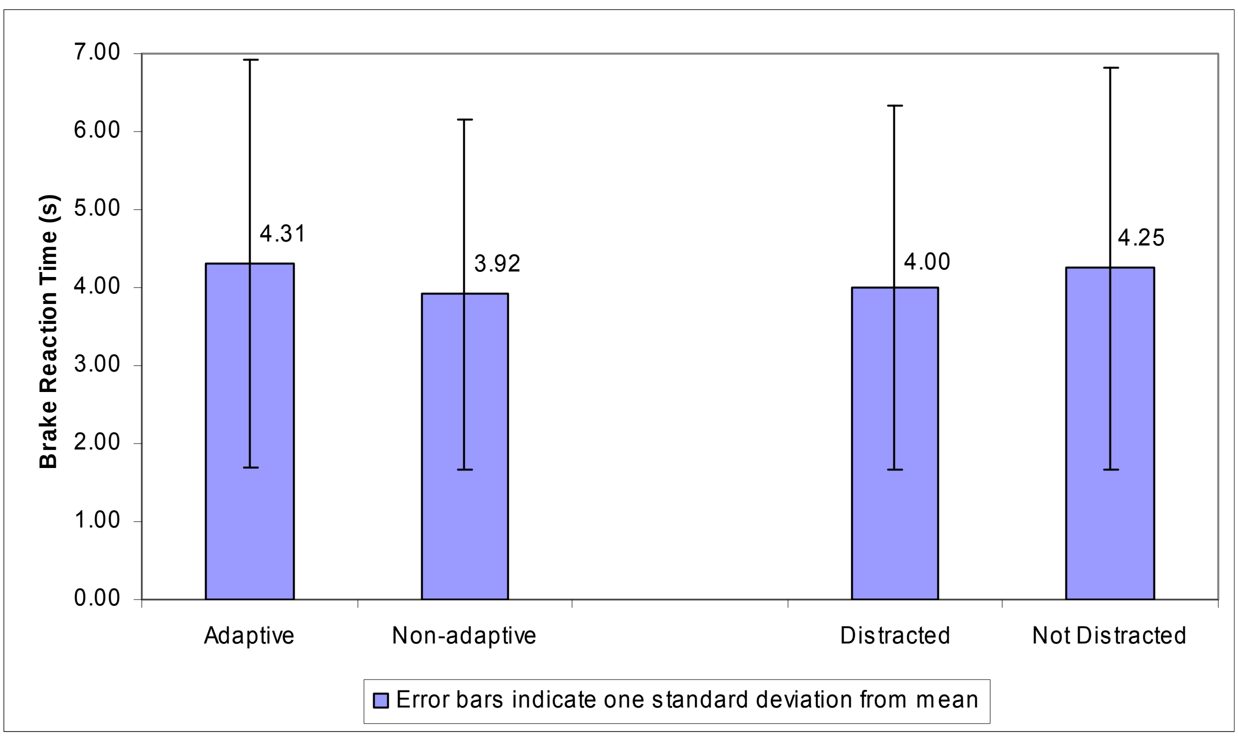

Figure 29. Brake reaction time for lane departure warning event

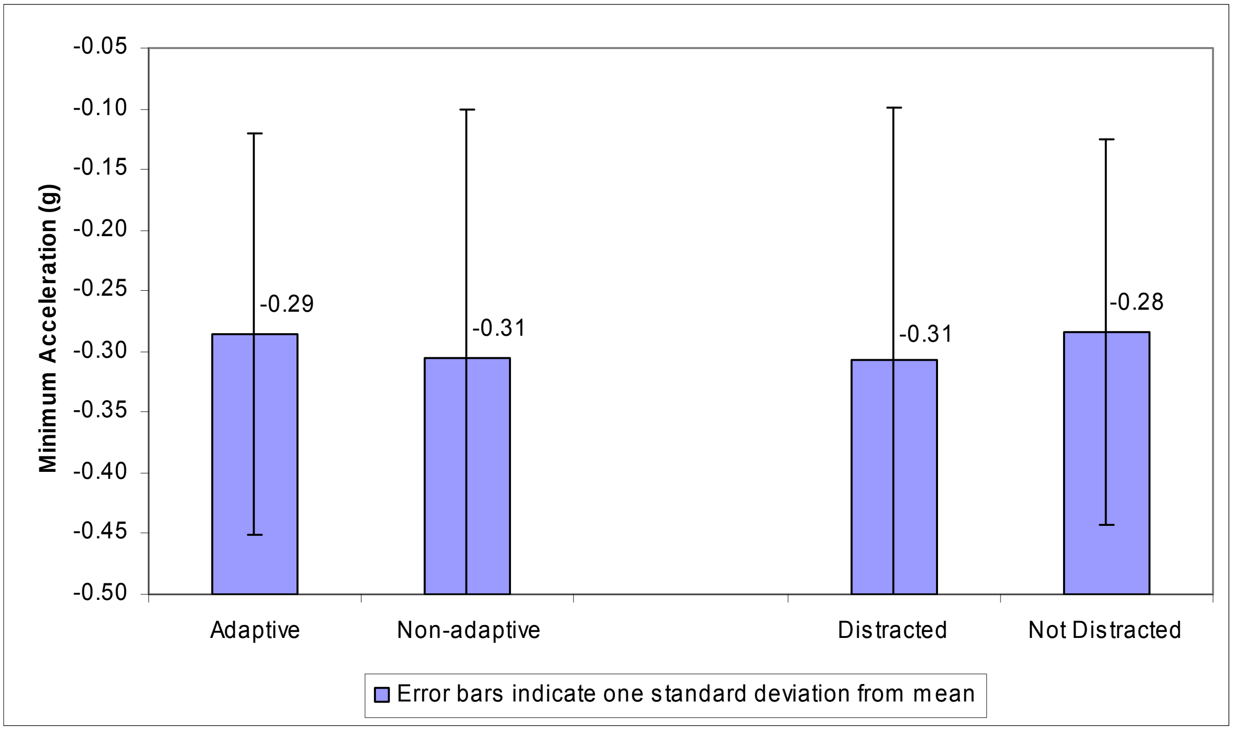

Figure 30. Minimum acceleration for lane departure warning event

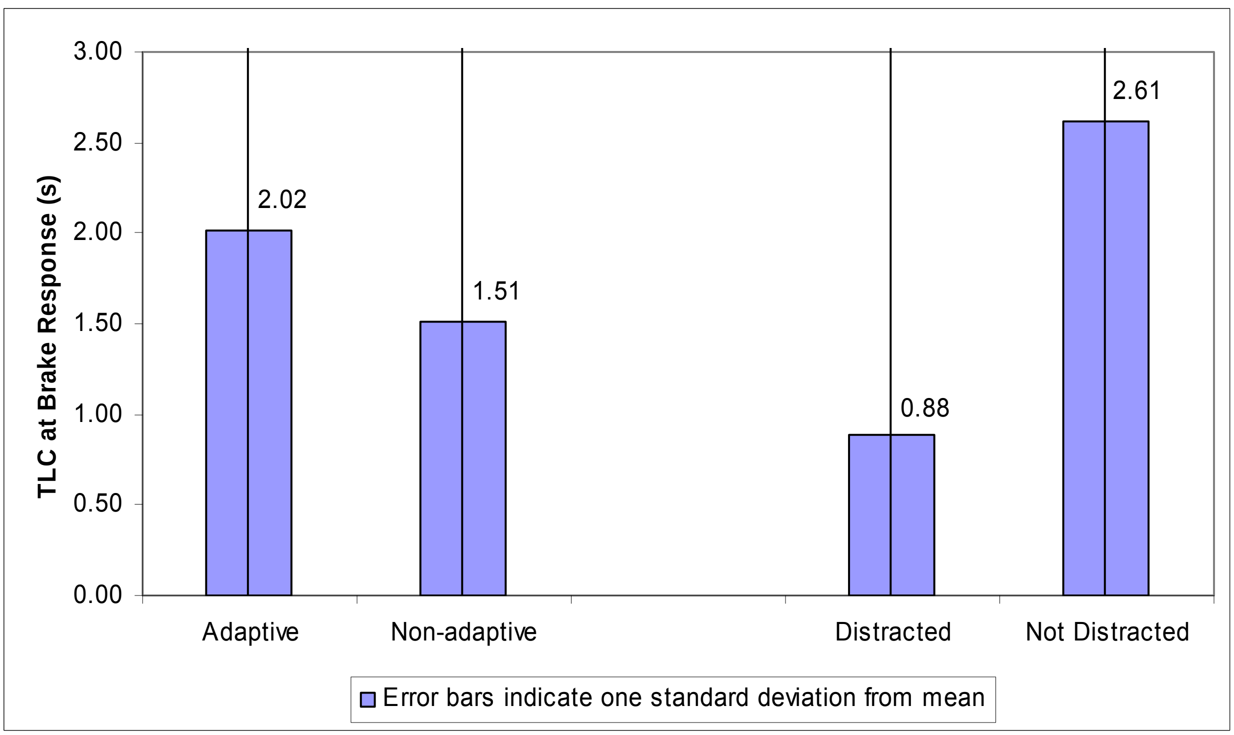

Figure 31. Time to lane crossing at brake response for lane departure warning event

3.3.3 Distraction Mitigation

The effect of distraction mitigation on driver response was evaluated in the context of the intersection incursion event at the end of Study Drive 3 and the distraction mitigation events during the first eight minutes of Study Drives 1 and 2. The within-subject independent variables are level of distraction (not distracted, distracted), level of demand (low, high), and level of mitigation (no mitigation, mitigation). As in the other analyses, only those participants with their foot on the accelerator at event onset were included in the analysis of accelerator release reaction time and time to collision at accelerator release, and only participants who had a braking response were included in the analysis of brake reaction time, maximum brake reaction time, time to collision at brake response, time to collision at maximum brake response, and minimum acceleration. The results of the significance tests for the distraction mitigation events are shown in

Table 29 through **Table 32**. Table 32 shows the frequency table for accelerator release prior to event onset, and **Table 33** shows the frequency table for level of distraction from the Chi-square analyses. Fisher's Exact Tests did not indicate a difference between the mitigation and no mitigation conditions (p=0.7092), nor for whether or not distraction was present (p=0.7092).

Table 29. Effect of mitigation on driver response for distraction mitigation events in drives 1 & 2

Level of Mitigation	Mean		Standard Deviation		Sample Size		Significance
	Mitigation	No Mitigation	Mitigation	No Mitigation	Mitigation	No Mitigation	
Accelerator Reaction Time (s)	0.63	0.61	0.39	0.38	168	179	F(1,331) = 0.93 p = 0.3363
Time to Collision at Accelerator Release (s)	1.15	1.12	0.67	0.34	168	179	F(1,331) = 0.08 p = 0.7747
Brake Reaction Time (s)	1.05	1.05	0.45	0.46	249	259	F(1, 492) = 0.00 p = 0.9444
Maximum Brake Reaction Time (s)	2.38	2.31	0.36	0.31	249	259	F(1, 492)= 4.40 p = 0.0365
Time to Collision at Brake Response (s)	1.11	1.08	0.59	0.38	249	259	F(492) = 0.51 p = 0.4769
Time to Collision at Maximum Brake Response (s)	0.98	0.96	0.65	0.41	249	259	F(1,492)= 0.41 p = 0.5233
Minimum Acceleration (g)	-0.52	-0.52	0.11	0.11	249	259	F(1,492) = 0.11 p = 0.7350

Table 30. Effect of demand on driver response for distraction mitigation events in drives 1 & 2

Level of Demand	Mean		Standard Deviation		Sample Size		Significance
	High	Low	High	Low	High	Low	
Accelerator Reaction Time (s)	0.62	0.63	0.40	0.38	172	175	F(1,331) = 0.01 p = 0.9197
Time to Collision at Accelerator Release (s)	1.01	1.26	0.16	0.71	172	175	F(1,331) = 16.86 p< .0001
Brake Reaction Time (s)	1.09	1.02	0.44	0.46	257	251	F(1,492) = 4.13 p = 0.0426
Maximum Brake Reaction Time (s)	2.37	2.32	0.29	0.37	257	251	F(1,492) = 3.23 p = 0.0727
Time to Collision at Brake Response (s)	0.96	1.22	0.28	0.62	257	251	F(1,492) = 36.98 p < .0001
Time to Collision at Maximum Brake Response (s)	0.81	1.13	0.33	0.65	257	251	F(1,492) = 50.22 p < .0001
Minimum Acceleration (g)	-0.52	-0.52	0.11	0.11	257	251	F(1,492) = 0.09 p = 0.7686

Table 31. Effect of distraction on driver response for distraction mitigation events in drives 1 & 2

Level of Distraction	Mean		Standard Deviation		Sample Size		Significance
	Distracted	Not Distracted	Distracted	Not Distracted	Distracted	Not Distracted	
Accelerator Reaction Time (s)	0.72	0.53	0.48	0.25	164	183	$F(1,331)=20.37$ $p <.0001$
Time to Collision at Accelerator Release (s)	1.15	1.12	0.50	0.55	164	183	$F(1,331) = 0.39$ $p = 0.5339$
Brake Reaction Time (s)	1.17	0.94	0.53	0.32	253	255	$F(1, 492) = 35.95$ $p <.0001$
Maximum Brake Reaction Time (s)	2.40	2.28	0.37	0.28	253	255	$F(1,492) = 16.96$ $p < .0001$
Time to Collision at Brake Response (s)	1.10	1.08	0.55	0.43	253	255	$F(1,492) = 0.35$ $p = 0.5521$
Time to Collision at Maximum Brake Response (s)	0.95	0.99	0.60	0.47	253	255	$F(1,492) = 0.42$ $p = 0.5155$
Minimum Acceleration (g)	-0.51	-0.52	0.11	0.11	253	255	$F(1,492) = 0.62$ $p = 0.4331$

Table 32. Frequency of accelerator release prior to event onset by level of mitigation for distraction mitigation events

Level of System Adaptation	Accelerator Depressed at Event Onset	Accelerator Released at Event Onset	Total
Mitigation	168	87	2255
No Mitigation	179	85	264
Total	347	172	519

Table 33. Frequency of accelerator release prior to event onset by level of distraction for distraction mitigation events

Level of Distraction	Accelerator Depressed at Event Onset	Accelerator Released at Event Onset	Total
Distracted	179	85	264
Not Distracted	168	87	255
Total	347	172	519

Maximum brake reaction time was significant for both mitigation and level of distraction in the mitigation events (means are shown in **Figure 32**), although the standard deviation is still large compared to the difference in the means. The higher mean for the distracted condition is as would be expected. The higher mean when mitigation was present was the opposite of what would be expected for a positive effect of mitigation on maximum brake reaction time. It could be speculated that the presence of mitigation allowed a less aggressive braking response, although this is not evident in the means for accelerator release time (**Figure 33**) or minimum acceleration (**Figure 34**), which were not statistically significant. The demand of the driving environment was significant for time to collision at accelerator release (Figure 35), time to collision at brake response (**Figure 36**), and time to collision at maximum braking response (**Figure 37**). As would be expected, the low driving demand environment had higher means for all three of these time-to-collision variables. Distraction was statistically significant for accelerator release reaction time (**Figure 33**), brake reaction time (**Figure 38**), and maximum brake reaction time (**Figure 39**). The means for the distracted condition were higher for all three measures.

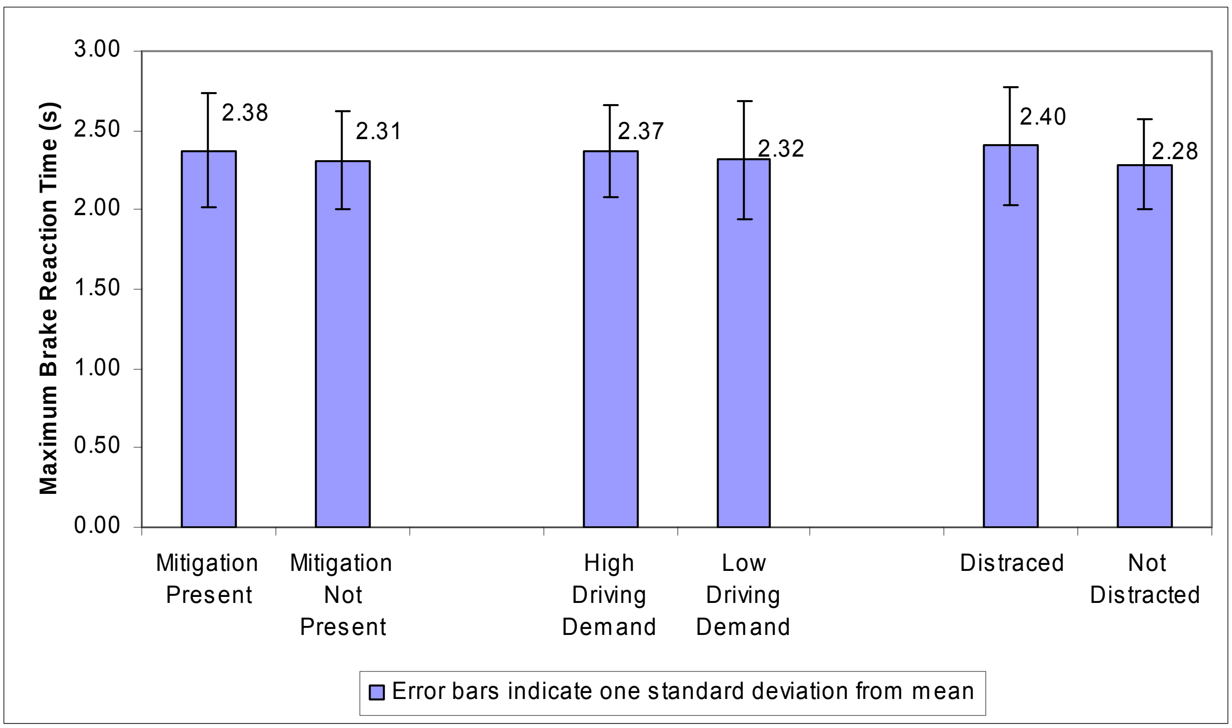

Figure 32. Maximum brake reaction time for distraction mitigation events

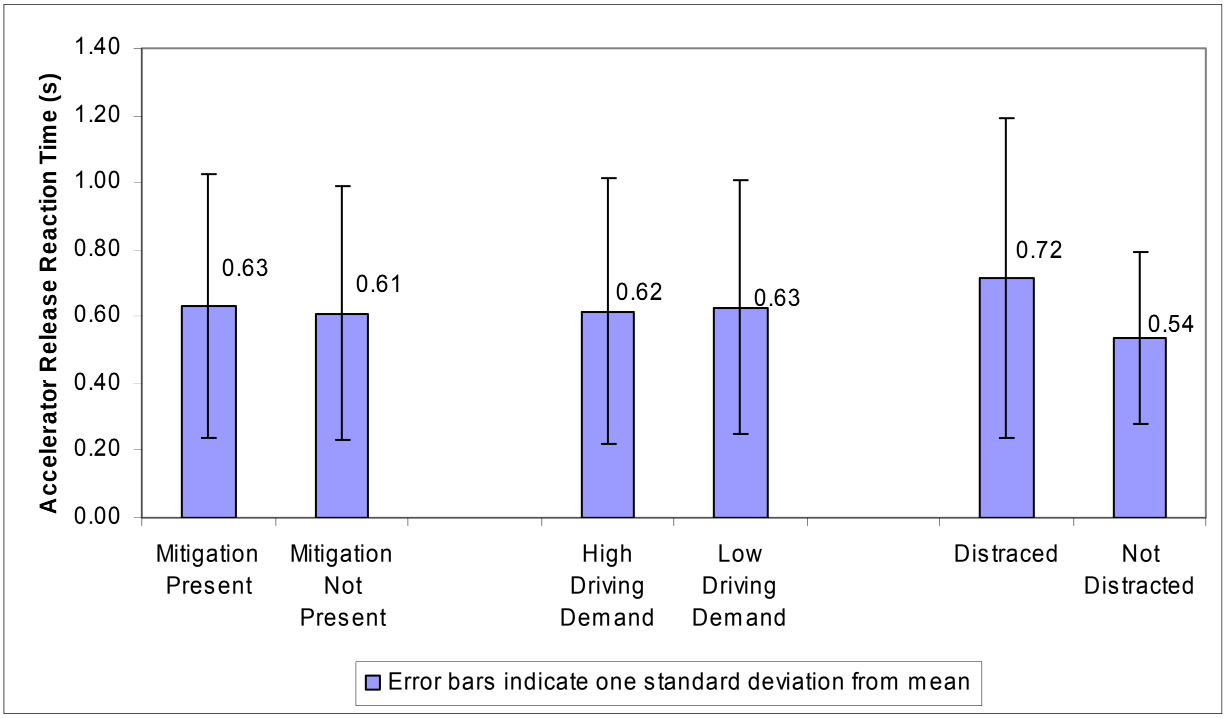

Figure 33. Accelerator release reaction time for distraction mitigation events

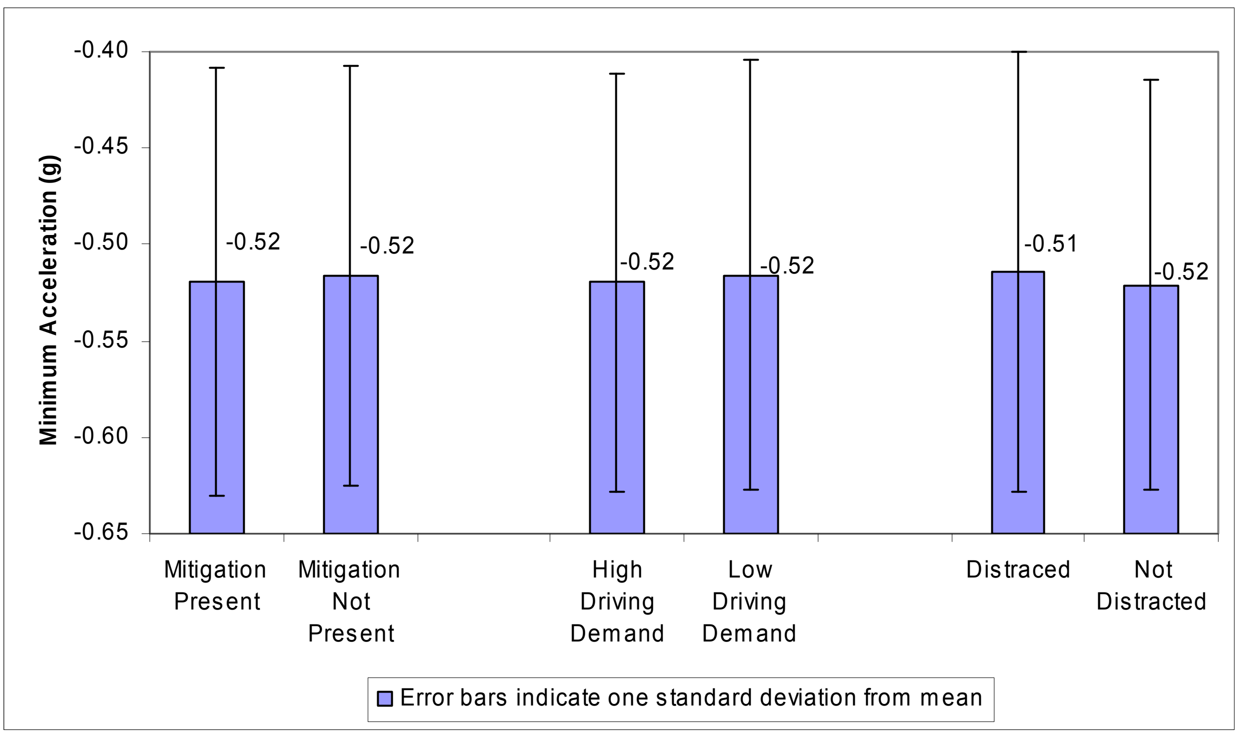

Figure 34. Minimum acceleration for distraction mitigation events

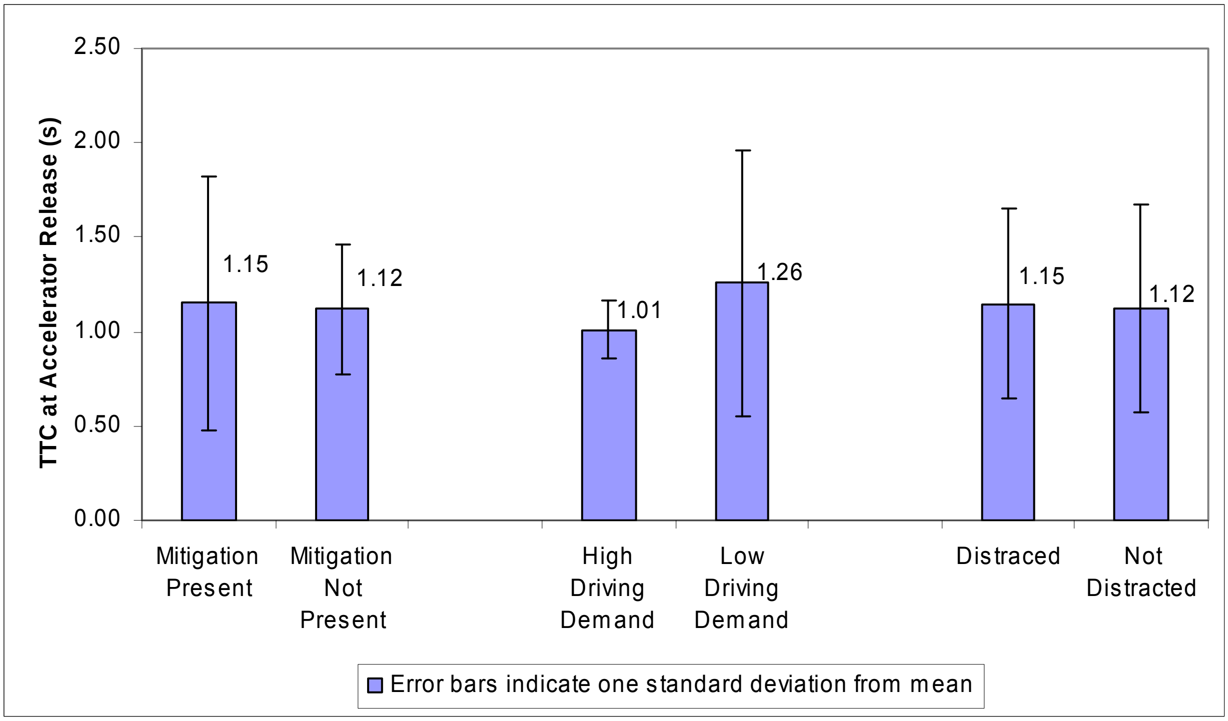

Figure 35. Time to collision at accelerator release for distraction mitigation events

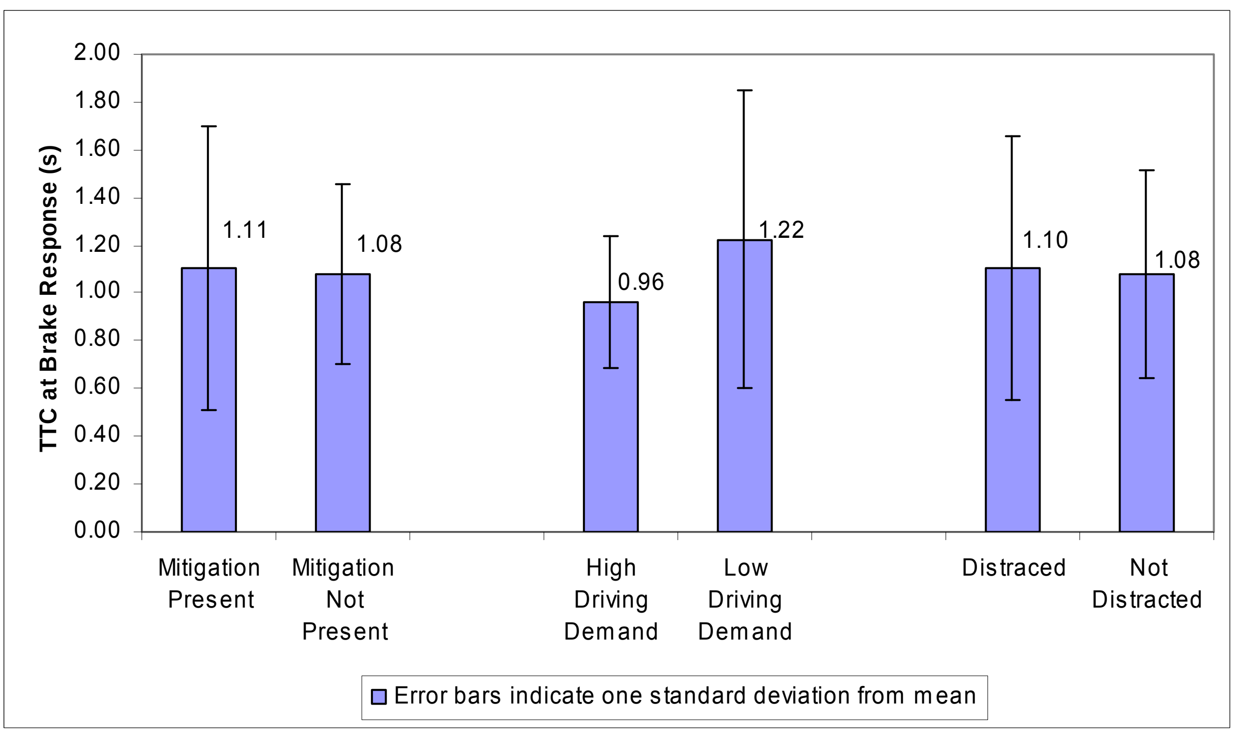

Figure 36. Time to collision at brake response for distraction mitigation events

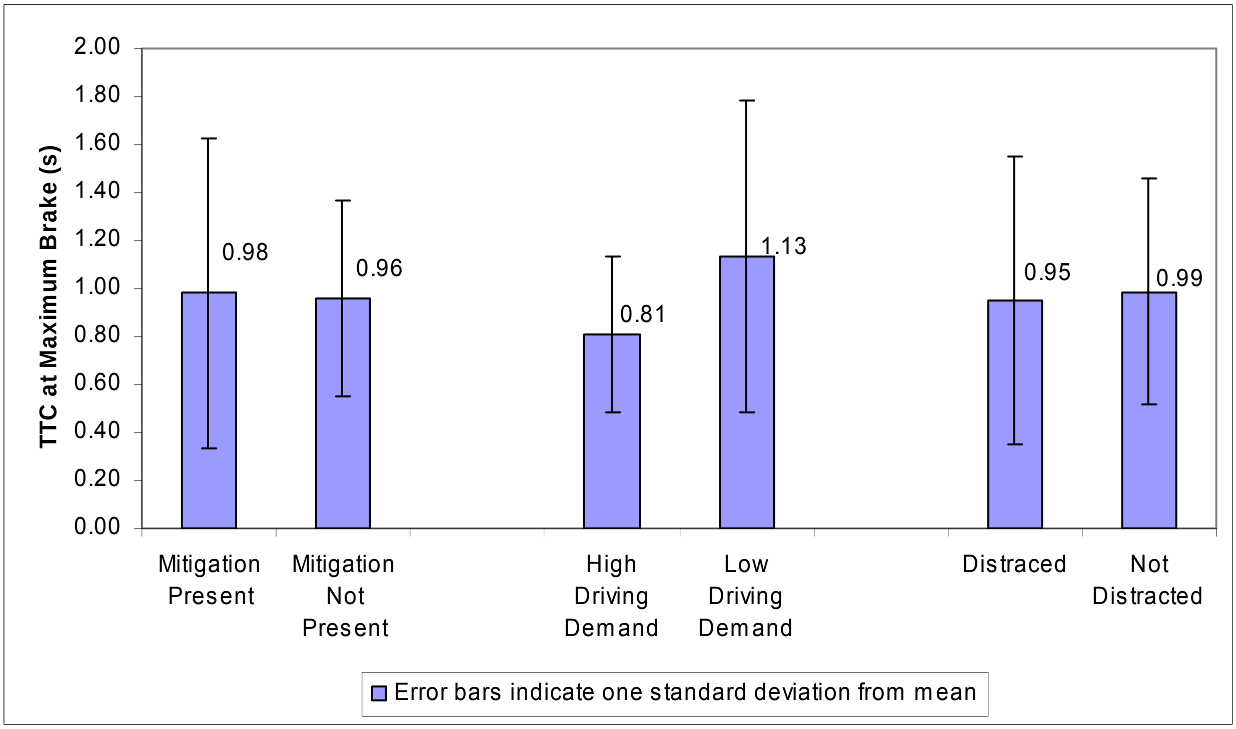

Figure 37. Time to collision at maximum brake for distraction mitigation events

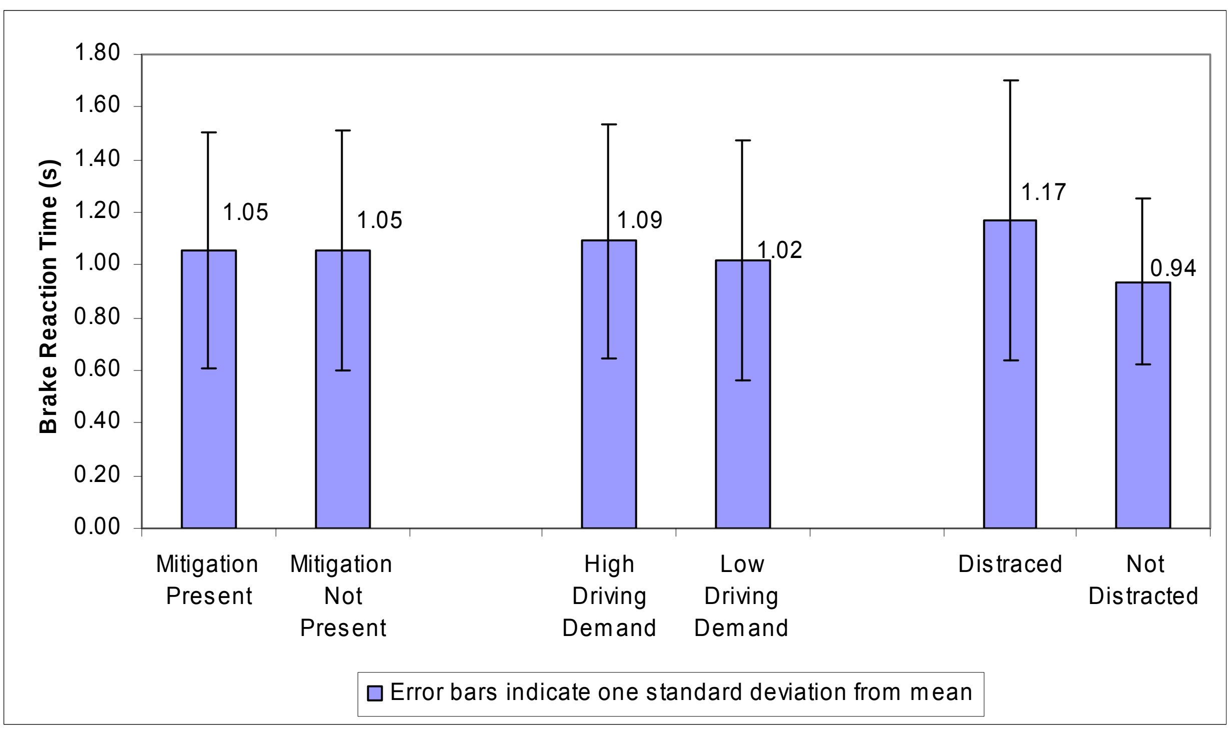

Figure 38. Brake reaction time for distraction mitigation events

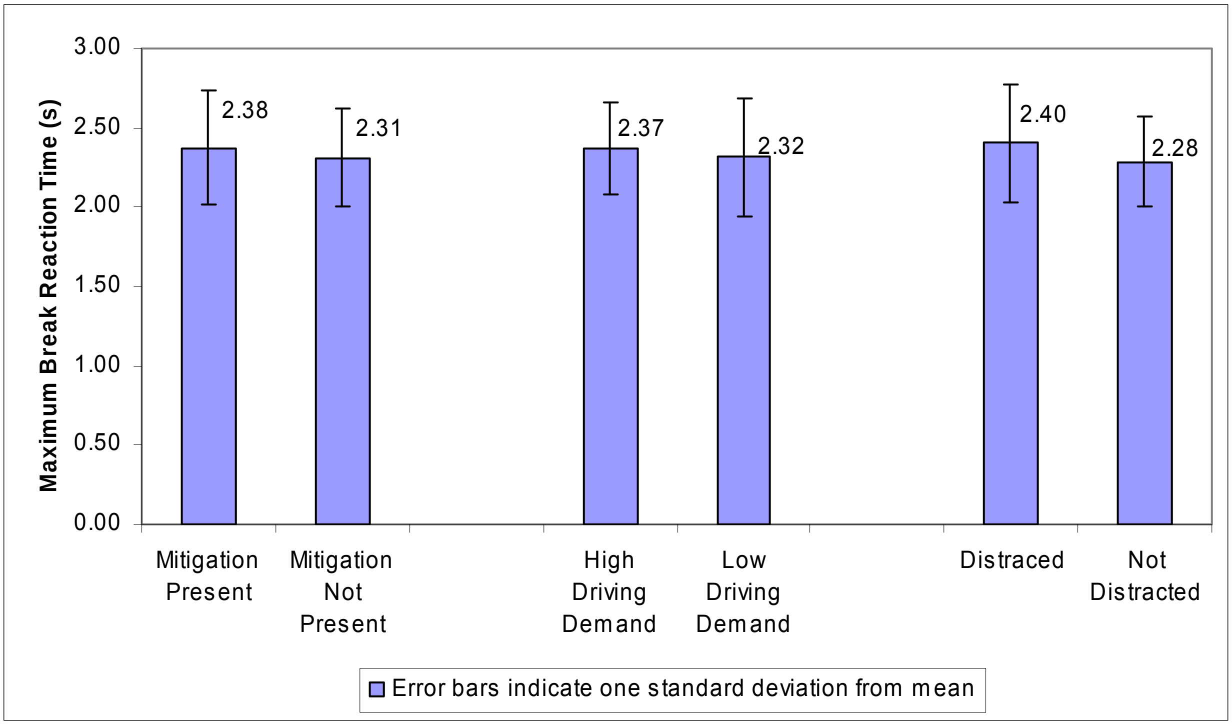

Figure 39. Maximum brake reaction time for distraction mitigation events

The results of the significance tests for the intersection incursion event are shown in

Table 34

Table 34 and **Table 35**. Level of demand was at a high level only for the intersection incursion event.

Table 36Table 36 shows the frequency table for accelerator release prior to event onset, and **Table 37** shows the frequency table for level of mitigation from the Chi-square analyses. Fisher's Exact Tests did not indicate a difference between the mitigation and no mitigation conditions (p=0.4155), nor for whether or not distraction was present (p=1.0000).

Table 34. Effect of mitigation on driver response for drive 3 intersection incursion event

Level of Mitigation	Mean		Standard Deviation		Sample Size		Significance
	Mitigation	No Mitigation	Mitigation	No Mitigation	Mitigation	No Mitigation	
Accelerator Reaction Time (s)	0.77	0.91	0.50	0.39	19	23	$F(1,38) = 1.04$ $p = 0.3131$
Time to Collision at Accelerator Release (s)	1.10	1.91	2.62	3.30	19	23	$F(1,38) = 0.87$ $p = 0.3571$
Brake Reaction Time (s)	1.38	1.32	0.41	0.28	26	30	$F(1,52) = 0.25$ $p = 0.6185$
Maximum Brake Reaction Time (s)	7.27	7.32	0.70	0.28	26	30	$F(1,52) = 0.26$ $p = 0.6103$
Time to Collision at Brake Response (s)	3.92	3.69	3.70	3.77	26	30	$F(1,52) = 0.06$ $p = 0.8062$
Time to Collision at Maximum Brake Response (s)	9.89	9.16	14.24	8.54	26	30	$F(1,52) = 0.13$ $p = 0.7229$
Minimum Acceleration (g)	4.95	4.58	7.12	4.27	26	30	$F(1,52) = 0.13$ $p = 0.7229$
Time to Lane Crossing at Brake Response (s)	-7.52	-10.97	46.46	48.49	26	30	$F(1,52) = 0.12$ $p = 0.7335$
Time to Steering Onset (s)	1.48	1.60	1.26	1.06	30	31	$F(1,57) = 0.19$ $p = 0.6626$
Time to Lane Crossing at Steering Onset (s)	2.69	-130.88	29.80	726.92	30	31	$F(1,57) = 0.95$ $p = 0.3346$
Maximum Steering Rate (deg./s)	145.44	110.86	130.69	129.33	30	31	$F(1,57) = 1.22$ $p = 0.2737$
Maximum Lateral Acceleration (g)	33.61	34.11	30.63	14.73	30	31	$F(1,57) = 0.01$ $p = 0.9433$
Maximum Lateral Jerk (g/s)	609.16	540.00	958.24	288.34	30	31	$F(1,57) = 0.14$ $p = 0.7051$
Accelerator Reaction Time (s)	0.77	0.91	0.50	0.39	19	23	$F(1,38) = 1.04$ $p = 0.3131$
Time to Lane Crossing at Accelerator Release (s)	16.69	1.56	63.27	6.83	19	23	$F(1,38) = 1.18$ $p = 0.2850$

Table 35. Effect of distraction on driver response for drive 3 intersection incursion event

Level of Distraction	Mean		Standard Deviation		Sample Size		Significance
	Distracted	Not Distracted	Distracted	Not Distracted	Distracted	Not Distracted	
Accelerator Reaction Time (s)	0.86	0.83	0.52	0.37	21	21	$F(1,38) = 0.09$ $p = 0.7692$
Time to Collision at Accelerator Release (s)	2.08	1.01	3.38	2.54	21	21	$F(1,38) = 1.65$ $p = 0.2069$
Brake Reaction Time (s)	1.46	1.23	0.33	0.32	29	27	$F(1,52) = 6.18$ $p = 0.0161$
Maximum Brake Reaction Time (s)	7.45	7.12	0.33	0.62	29	27	$F(1,52) = 6.41$ $p = 0.0144$
Time to Collision at Brake Response (s)	3.88	3.71	3.82	3.64	29	27	$F(1,52) = 0.01$ $p = 0.9092$
Time to Collision at Maximum Brake Response (s)	7.73	11.39	8.08	14.12	29	27	$F(1,52) = 1.79$ $p = 0.1864$
Minimum Acceleration (g)	3.87	5.70	4.04	7.06	29	27	$F(1,52) = 1.79$ $p = 0.1864$
Time to Lane Crossing at Brake Response (s)	-18.30	0.23	63.04	15.47	29	27	$F(1,52) = 2.24$ $p = 0.1409$
Time to Steering Onset (s)	1.40	1.68	0.42	1.59	31	30	$F(1,57) = 0.87$ $p = 0.3537$
Time to Lane Crossing at Steering Onset (s)	-131.83	3.67	726.74	29.68	31	30	$F(1,57) = 0.98$ $p = 0.3274$
Maximum Steering Rate (deg./s)	166.02	88.45	137.60	110.73	31	30	$F(1,57) = 6.09$ $p = 0.0166$
Maximum Lateral Acceleration (g)	35.70	31.97	24.21	23.43	31	30	$F(1,57) = 0.36$ $p = 0.5507$
Maximum Lateral Jerk (g/s)	593.55	553.82	680.77	725.59	31	30	$F(1,57) = 0.05$ $p = 0.8233$
Accelerator Reaction Time (s)	0.86	0.83	0.52	0.37	21	21	$F(1,38) = 0.09$ $p = 0.7692$
Time to Lane Crossing at Accelerator Release (s)	14.34	2.47	59.96	10.20	21	21	$F(1,38) = 0.85$ $p = 0.3628$

Table 36. Frequency of accelerator release prior to event onset by level of mitigation for intersection incursion event

Level of Mitigation	Accelerator Depressed at Event Onset	Accelerator Released at Event Onset	Total
Mitigation	19	11	30
No Mitigation	23	8	31
Total	42	19	61

Table 37. Frequency of accelerator release prior to event onset by level of distraction for intersection incursion event

Level of Distraction	Accelerator Depressed at Event Onset	Accelerator Released at Event Onset	Total
Distracted	21	10	31
Not Distracted	21	9	30
Total	42	19	61

Distraction was significant for brake reaction time, maximum brake reaction time, and maximum steering rate, as shown in Figure 40, Figure 41, and Figure 42, respectively. In all three cases, the mean for the distracted condition is greater than the not distracted condition, which is not surprising.

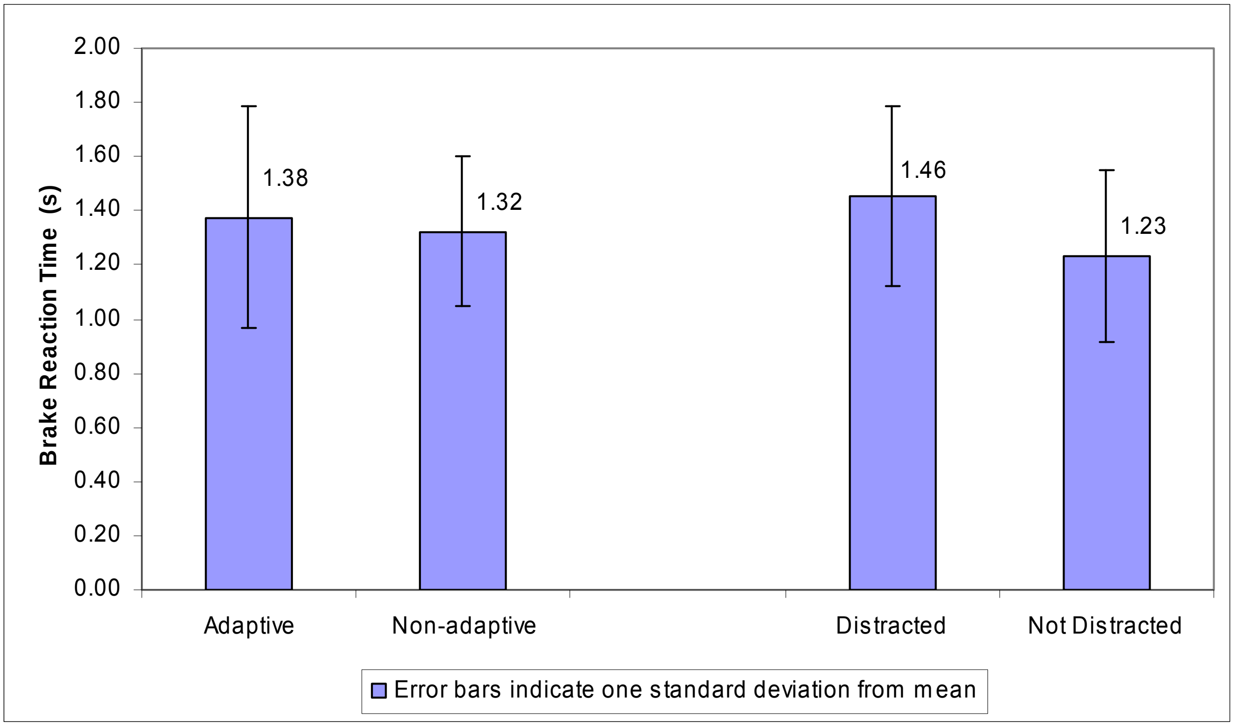

Figure 40. Brake reaction time for intersection incursion event

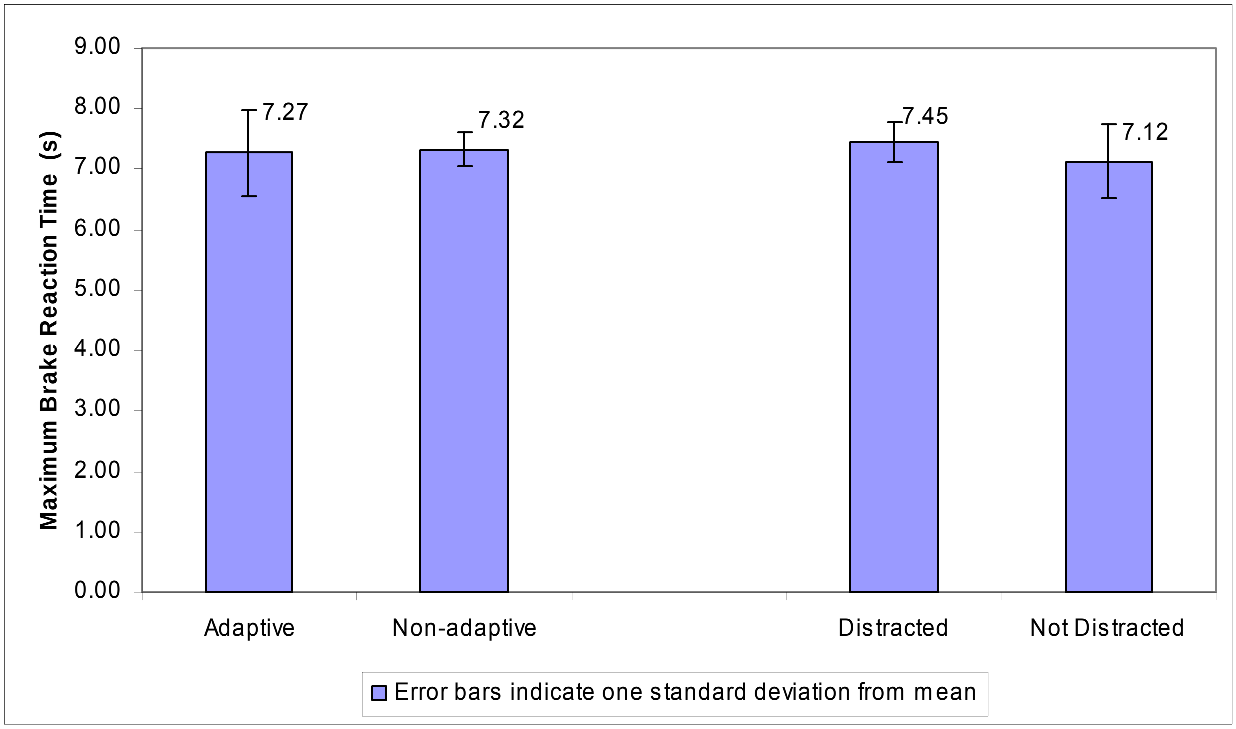

Figure 41. Maximum brake reaction time for intersection incursion event

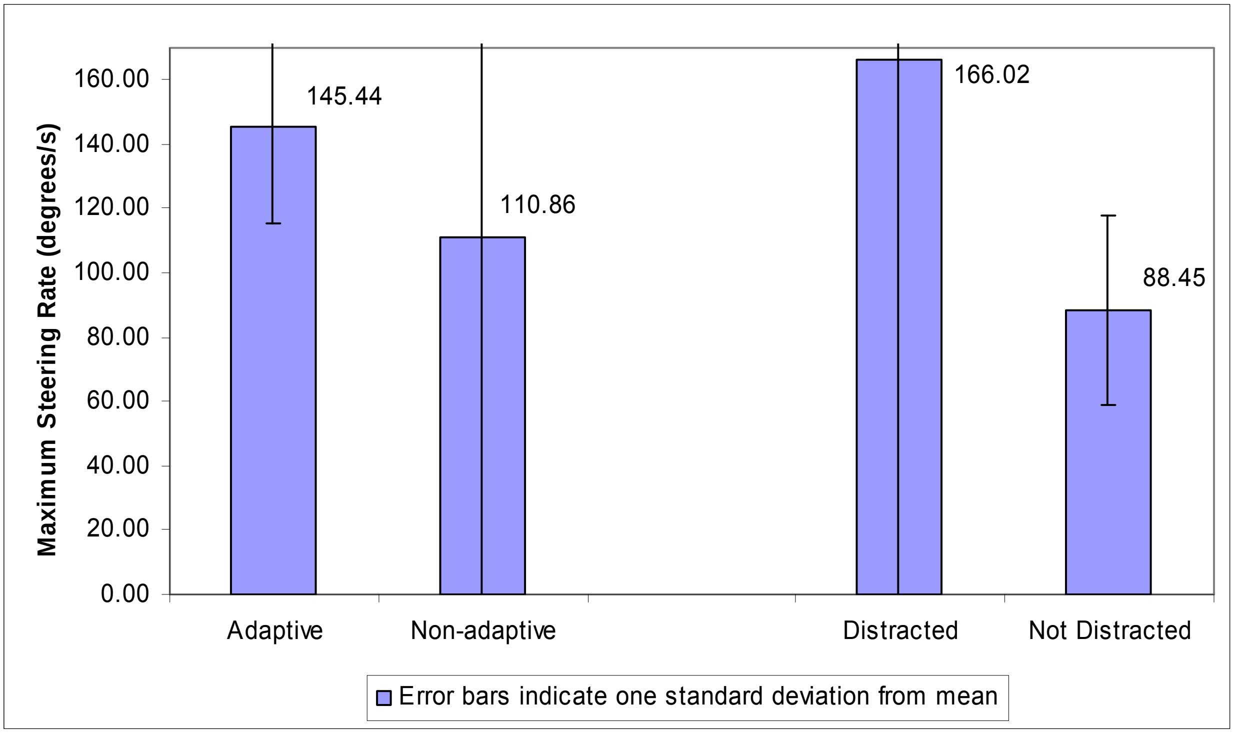

Figure 42. Maximum steering rate for intersection incursion event

There were no statistically significant results for the remaining variables. However, there were differences in the means between the adaptive and non-adaptive conditions that were larger than in other analyses and may be informative. Three variables stand out in this respect: time to lane crossing at brake response, time to lane crossing at steering onset, and time to lane crossing at accelerator release, as shown in Figure 48, Figure 50, and Figure 53, respectively.

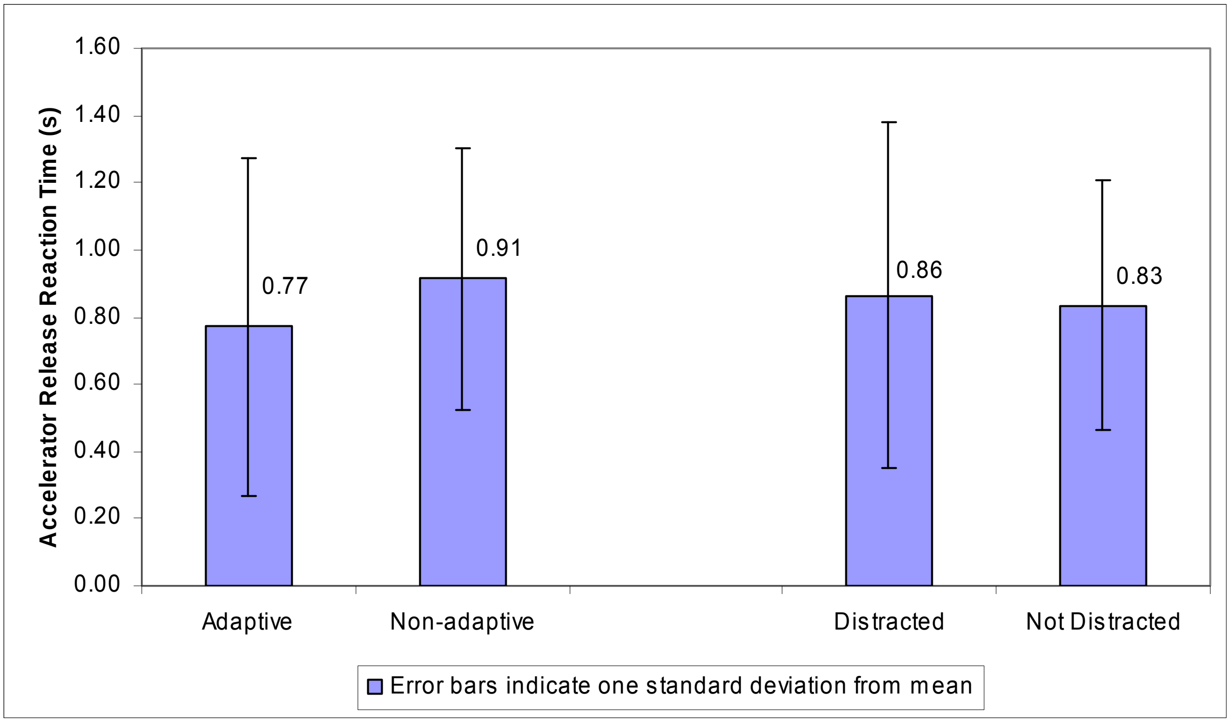

Figure 43. Accelerator release reaction time for intersection incursion event

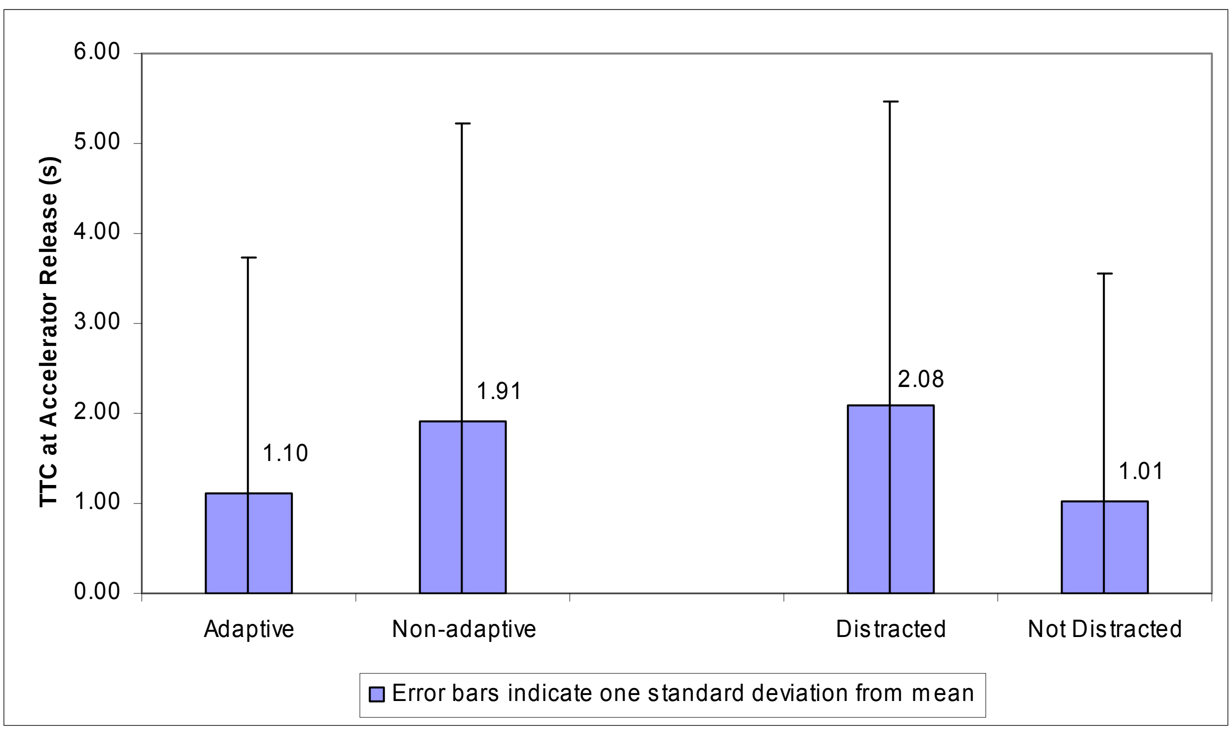

Figure 44. Time to collision at accelerator release for intersection incursion event

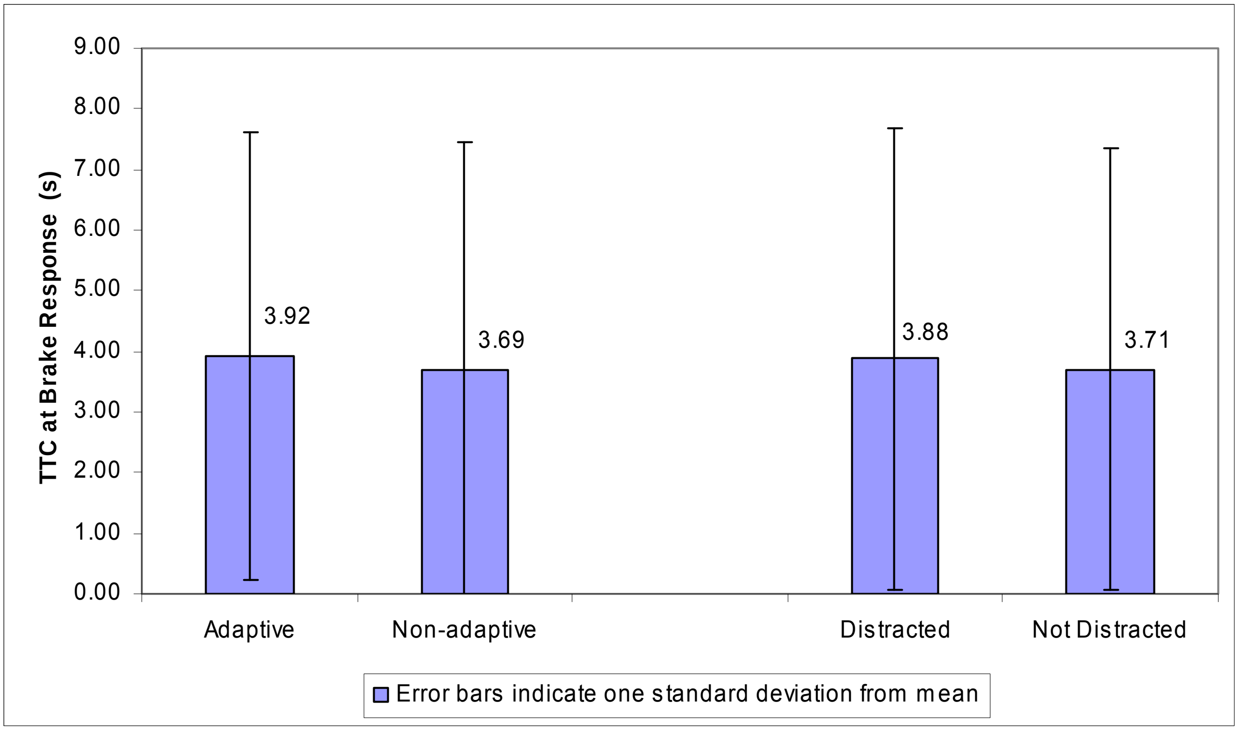

Figure 45. Time to collision at brake response for intersection incursion event

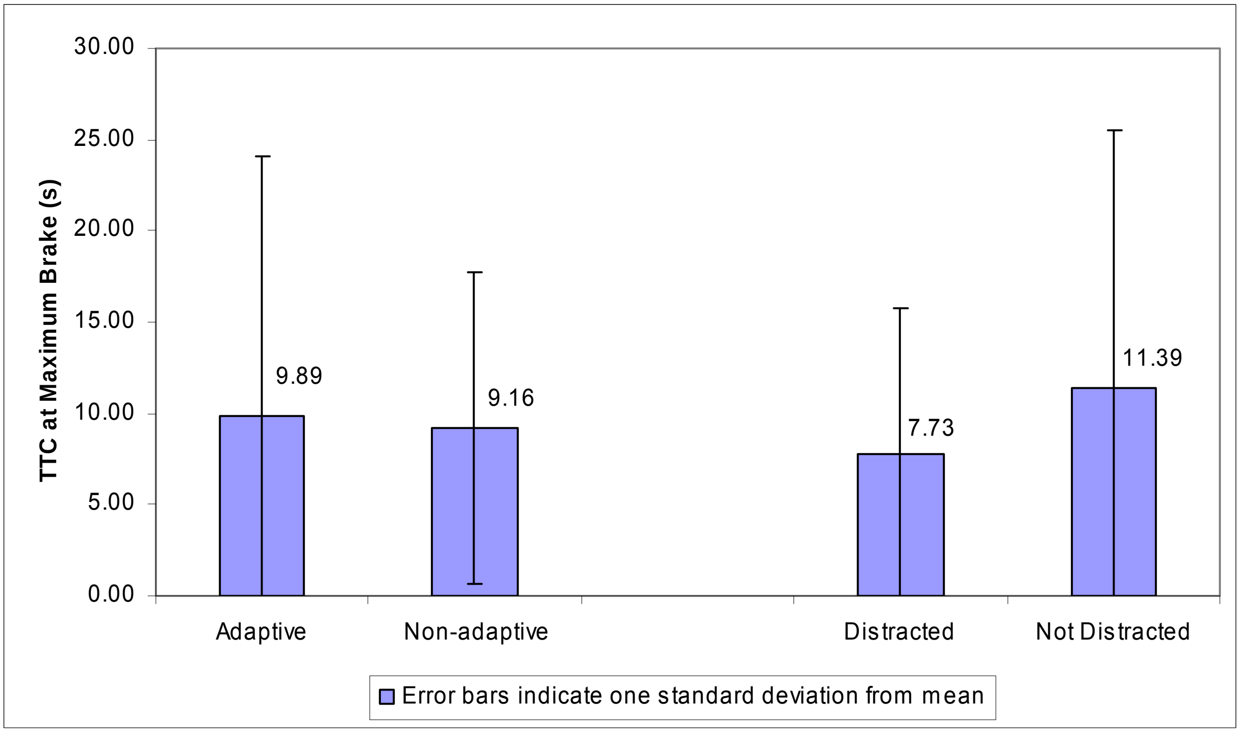

Figure 46. Time to collision at maximum brake for intersection incursion event

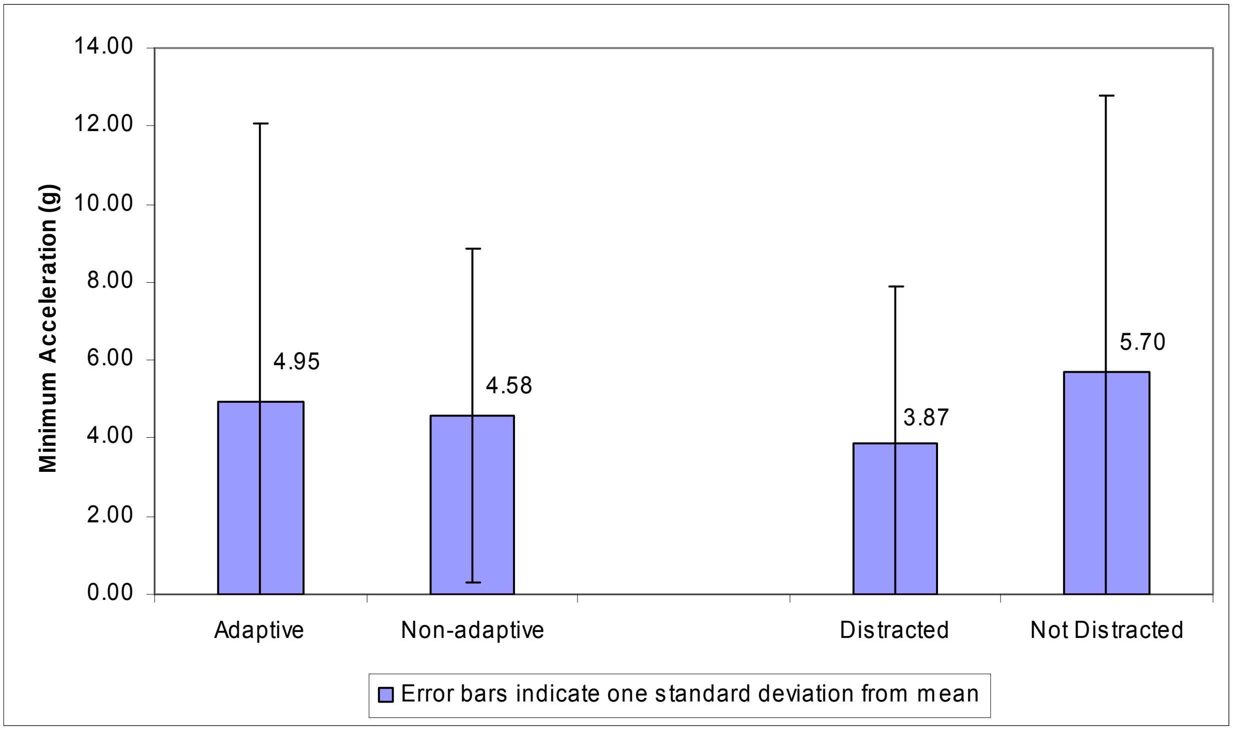

Figure 47. Minimum acceleration for intersection incursion event

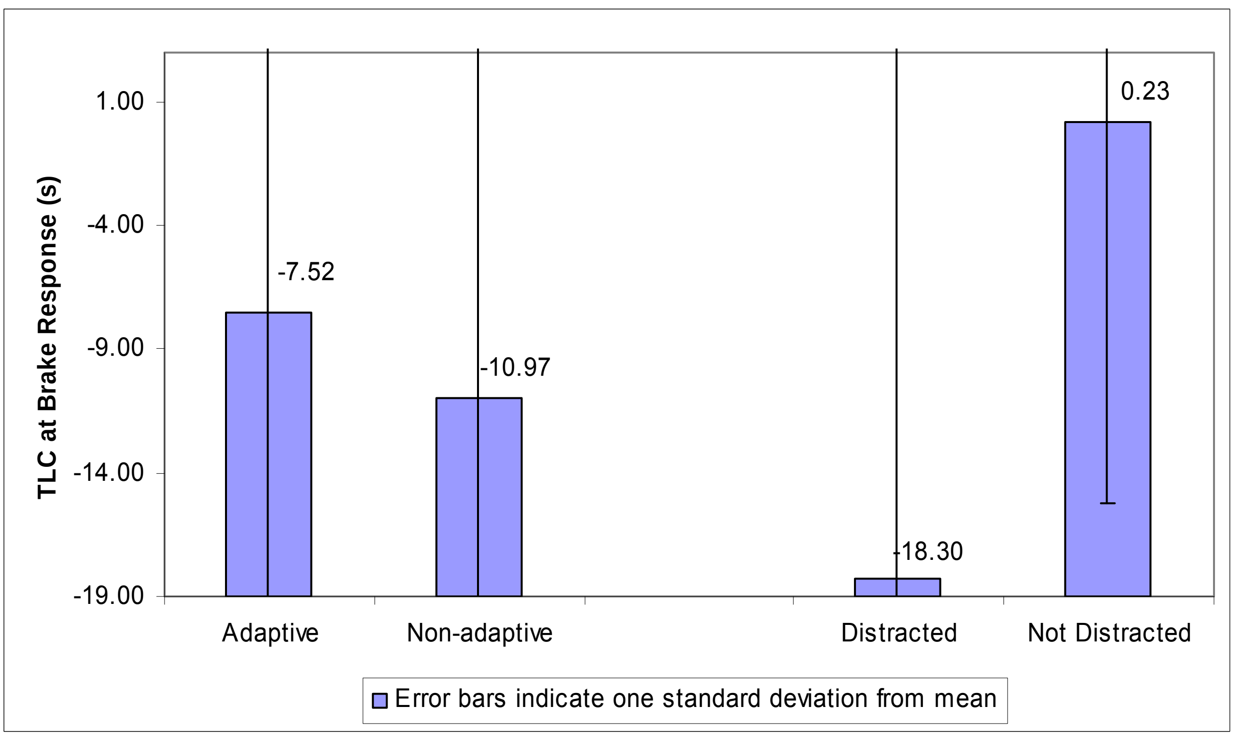

Figure 48. Time to lane crossing at brake response for intersection incursion event

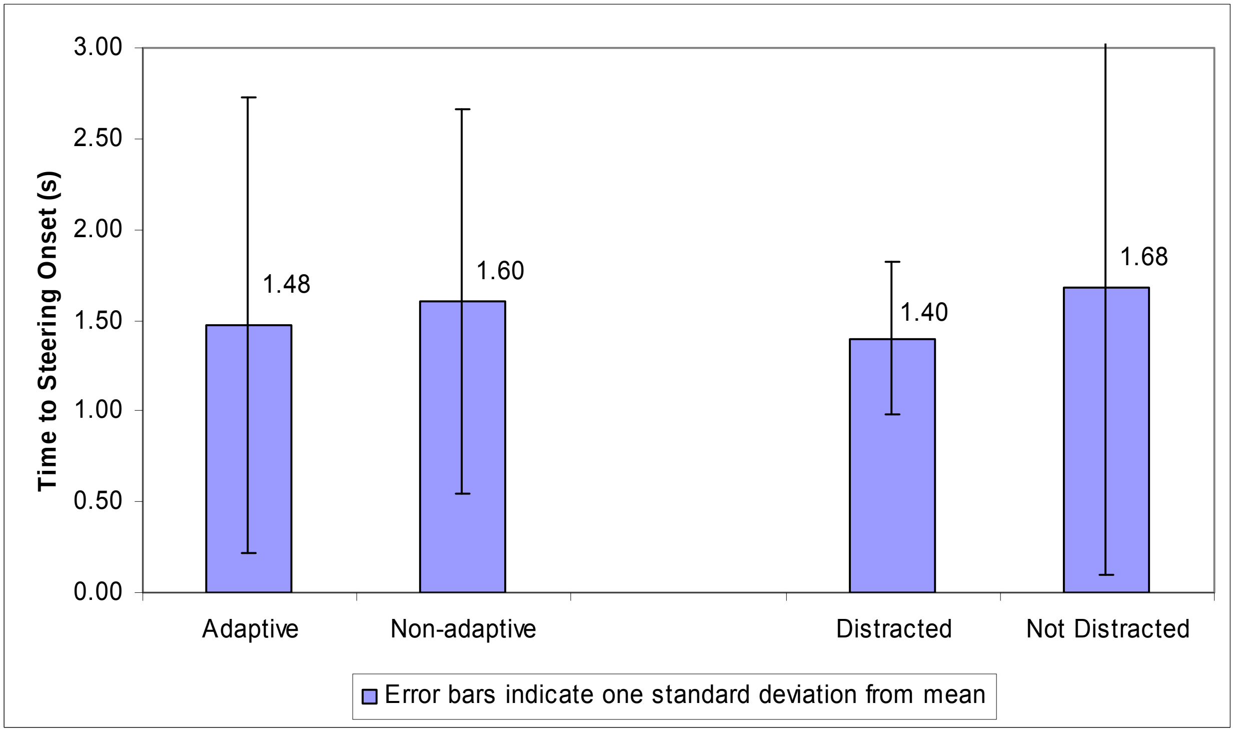

Figure 49. Time to steering response for intersection incursion event

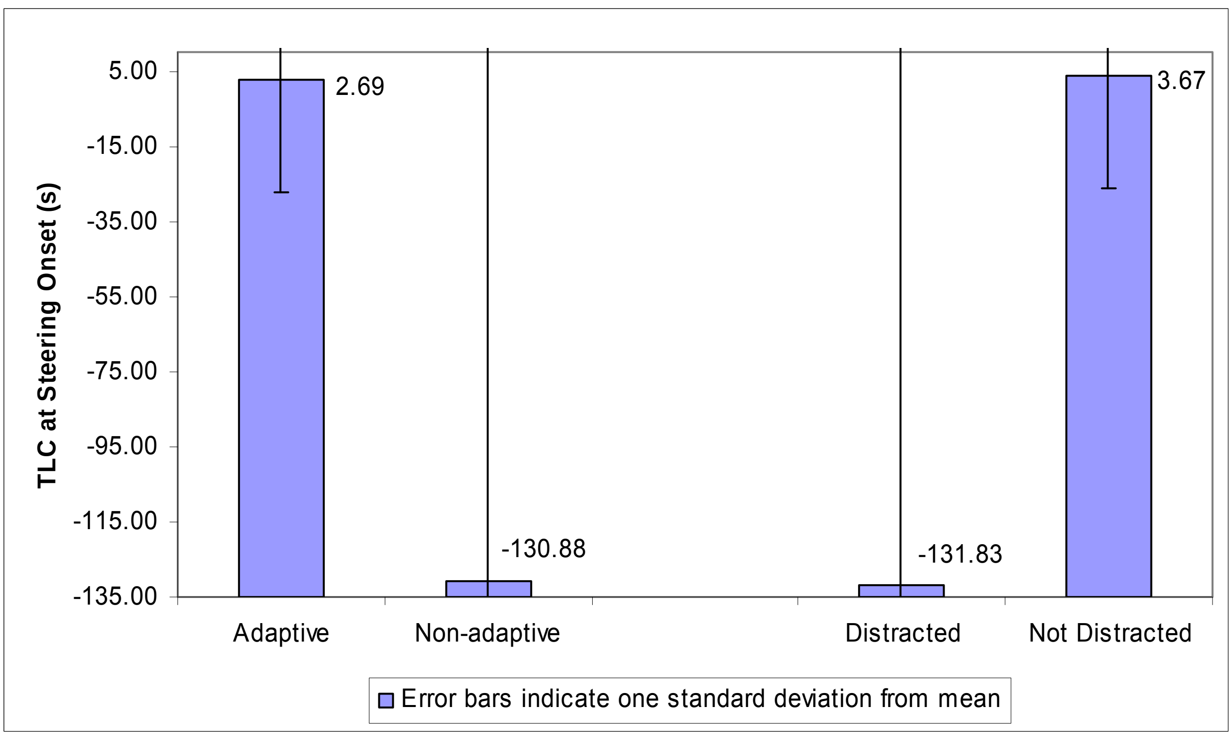

Figure 50. Time to lane crossing at steering onset for intersection incursion event

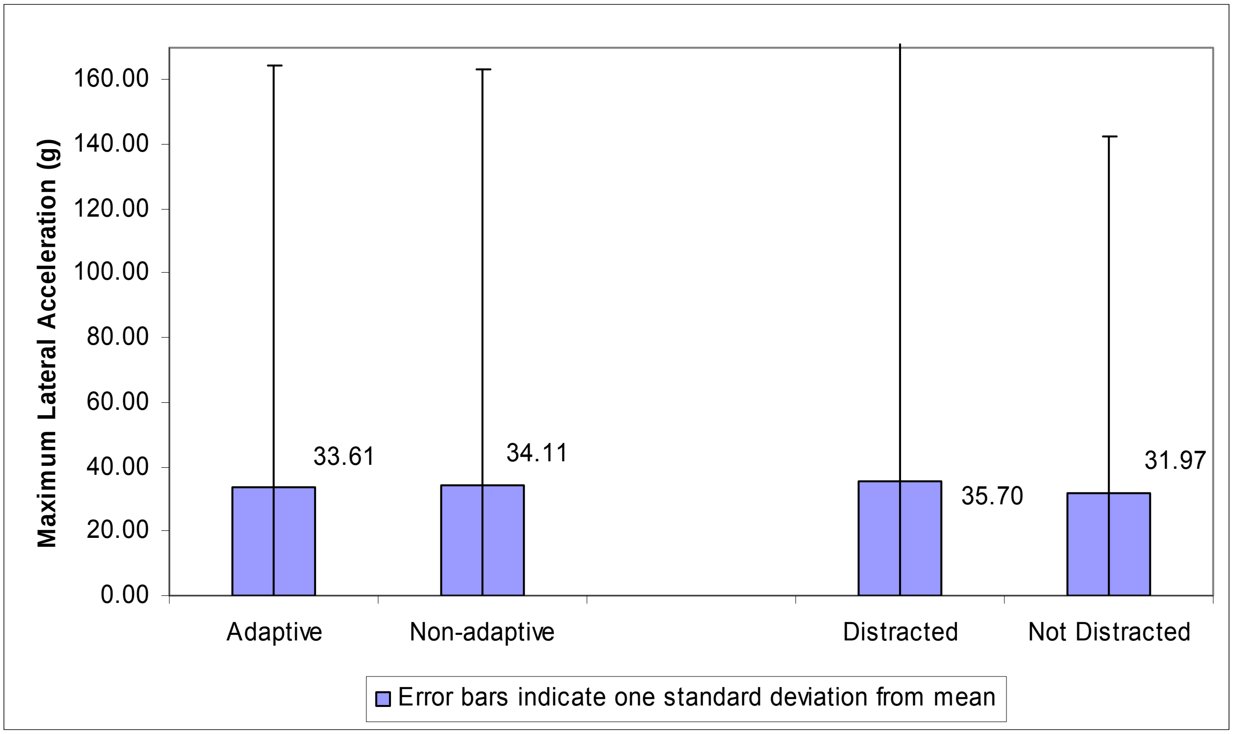

Figure 51. Maximum lateral acceleration for intersection incursion event

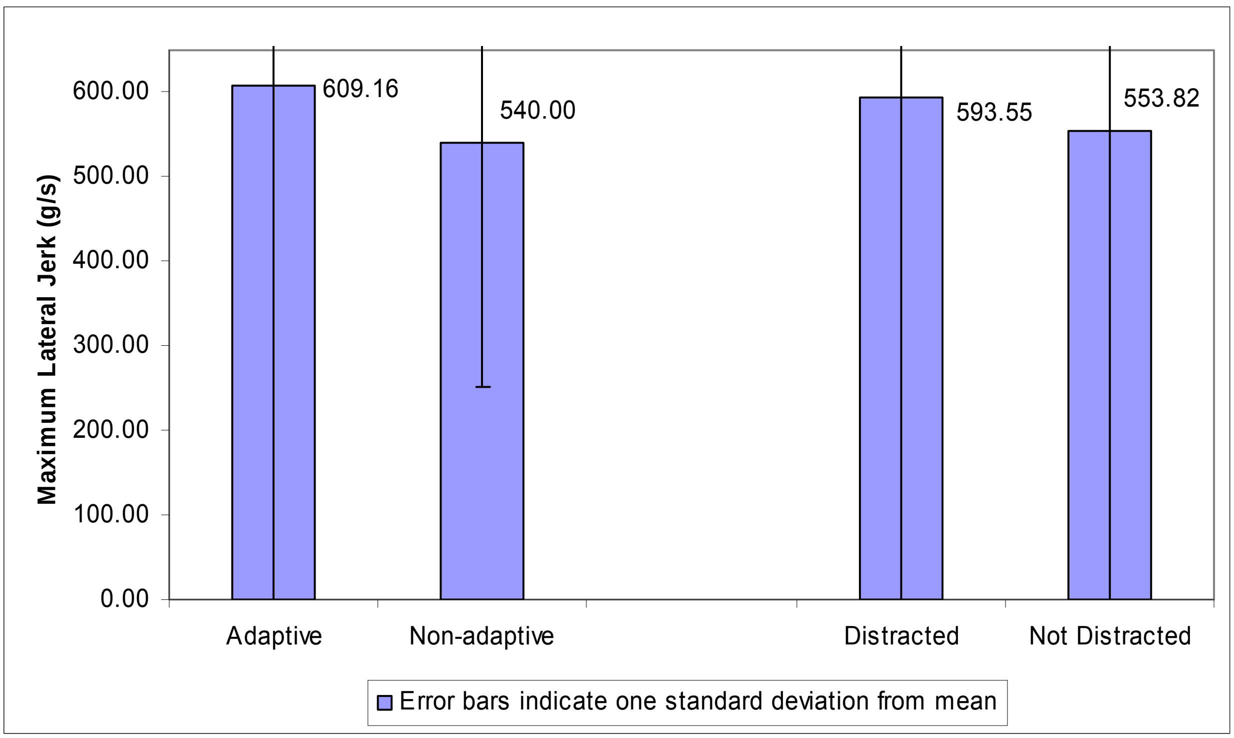

Figure 52. Maximum lateral jerk for intersection incursion event

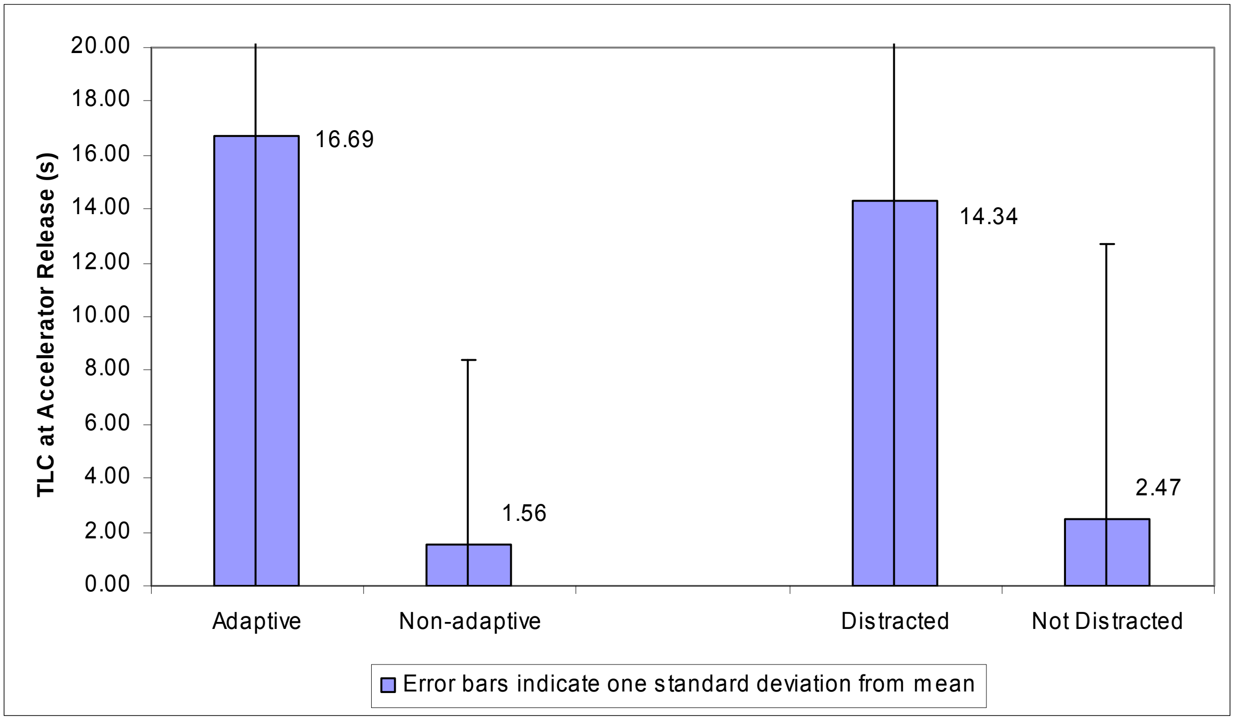

Figure 53. Time to lane crossing at accelerator release for intersection incursion event

3.3.4 Trip Report

Independent Variables

The within-subject independent variables are level of distraction (distracted, not distracted), level of demand (low, high), and mitigation (no mitigation, mitigation). The between-subjects independent variable is the trip report providing participants with mitigation feedback (none in previous trial, or mitigation feedback). This experimental design consists of only the first several minutes of the last two study drives.

As in the other analyses, only those participants with their foot on the accelerator at event onset were included in the analysis of accelerator release reaction time and time to collision at accelerator release, and only participants who had a braking response were included in the analysis of brake reaction time, maximum brake reaction time, time to collision at brake response, time to collision at maximum brake response, and minimum acceleration. **Table 41** shows the frequency table for accelerator release prior to event onset, and **Table 42** shows the frequency table for level of distraction from the Chi-square analyses. Fisher's Exact Tests did not indicate a difference between the adaptive and non-adaptive conditions (p=0.4698), nor for whether or not distraction was present (p=1.0000).

Table 38. Effect of trip report and mitigation on driver response

Level of Mitigation	Trip Report Present Y = Yes N = No	Mean		Standard Deviation		Sample Size		Significance
		Mitigation	No Mitigation	Mitigation	No Mitigation	Mitigation	No Mitigation	
Accelerator Reaction Time (s)	Y	0.48	0.60	0.34	0.41	79	71	F(1,270) = 3.70 p = 0.0556
	N	0.60	0.57	0.38	0.38	78	74	
Time to Collision at Accelerator Release (s)	Y	1.13	1.10	0.48	0.35	79	71	F(1, 270) = 0.00 p = 0.9570
	N	1.08	1.08	0.28	0.21	78	74	

Table 39. Effect of trip report and demand on driver response

Level of Demand	Trip Report Present Y = Yes N = No	Mean		Standard Deviation		Sample Size		Significance
		High	Low	High	Low	High	Low	
Accelerator Reaction Time (s)	Y	0.54	0.54	0.40	0.36	82	68	F(1,270) = 0.19 p = 0.6642
	N	0.61	0.54	0.38	0.37	86	66	
Time to Collision at Accelerator Release (s)	Y	1.02	1.22	0.14	0.60	82	68	F(1,270) = 0.57 p = 0.4519
	N	1.02	1.16	0.12	0.33	86	66	

Table 40. Effect of trip report and distraction on driver response

Level of Distraction	Trip Report Y = Yes N = No	Mean		Standard Deviation		Sample Size		Significance
		Distracted	Not Distracted	Distracted	Not Distracted	Distracted	Not Distracted	
Accelerator Reaction Time (s)	Y	0.72	0.41	0.50	0.17	62	88	F(1,270) = 1.55 p = 0.2142
	N	0.68	0.50	0.48	0.23	72	80	
Time to Collision at Accelerator Release (s)	Y	1.21	1.05	0.65	0.7	62	88	F(1,270) = 0.65 p = 0.4196
	N	1.12	1.05	0.34	0.09	72	80	

Table 41. Frequency of accelerator release prior to event onset by level of system adaptation for distraction mitigation events

Level of System Adaptation	Accelerator Depressed at Event Onset	Accelerator Released at Event Onset	Total
Adaptive	146	107	253
Non-adaptive	156	99	256
Total	347	172	519

Table 42. Frequency of accelerator release prior to event onset by level of distraction for distraction mitigation events

Level of Distraction	Accelerator Depressed at Event Onset	Accelerator Released at Event Onset	Total
Distracted	156	99	254
Not Distracted	147	107	254
Total	302	206	508

There were no statistically significant results for the presentation of the trip report. Figure 54 shows the means for accelerator release reaction time for the four combinations of trip report presentation and the presence of distraction, as does Figure 55 for time to collision at accelerator release. When distraction was present, the difference between participants who were and were not to be presented with the trip report is not as pronounced for accelerator release reaction time, and is similar for time to collision at accelerator release, as seen for minimum time to collision. When distraction was not present, the difference for acceleration reaction time is the opposite of that seen for minimum time to collision, and is quite small for time to collision at accelerator release.

As Figure 56 illustrates, for the four combinations of mitigation and presentation of trip report, the difference in accelerator release reaction time is the opposite of that seen so far; it is similar, although less pronounced, for time to collision at accelerator release.

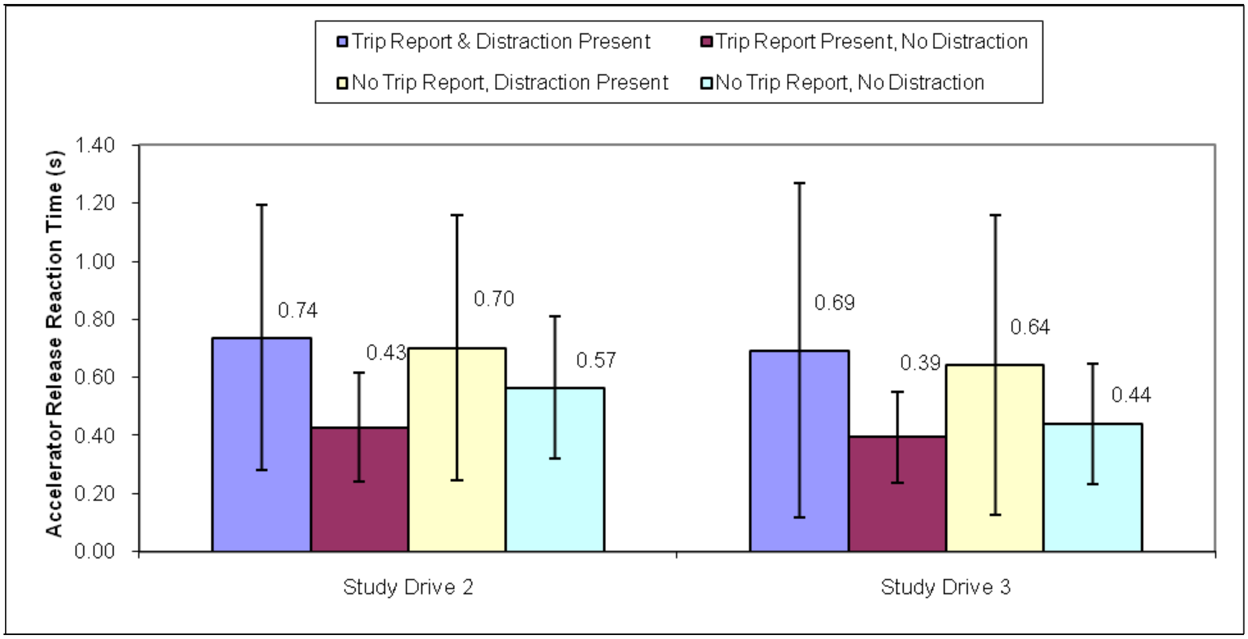

Figure 54. Accelerator release reaction time interaction between distraction and trip report

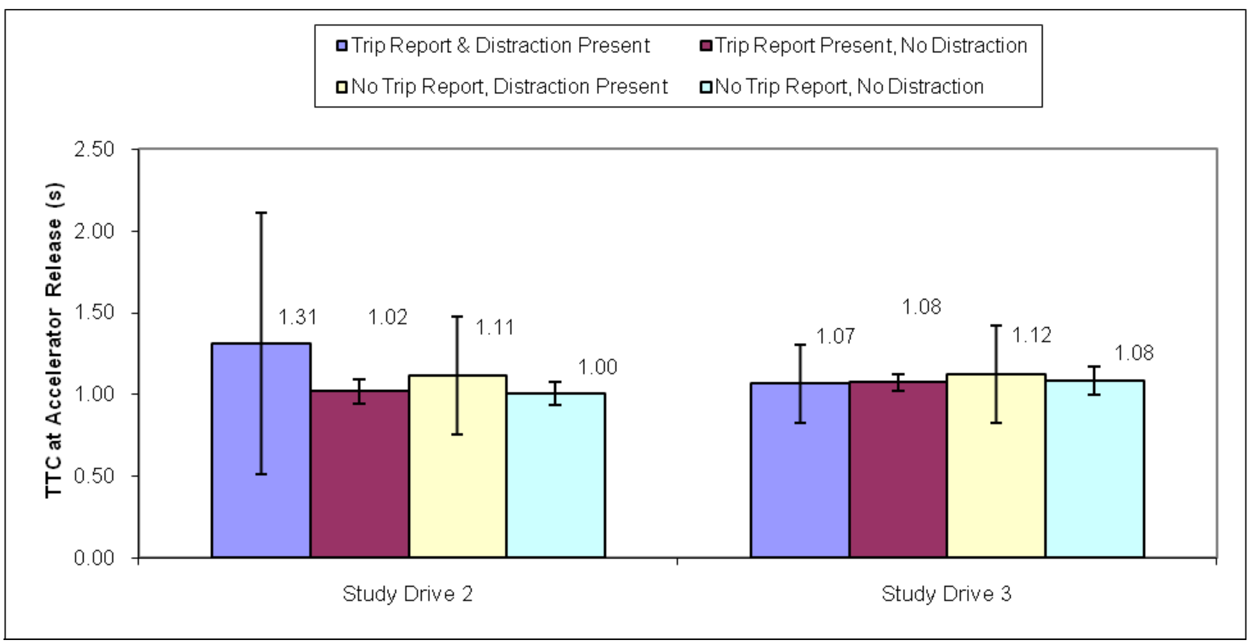

Figure 55. Time to collision at accelerator release interaction between distraction and trip report

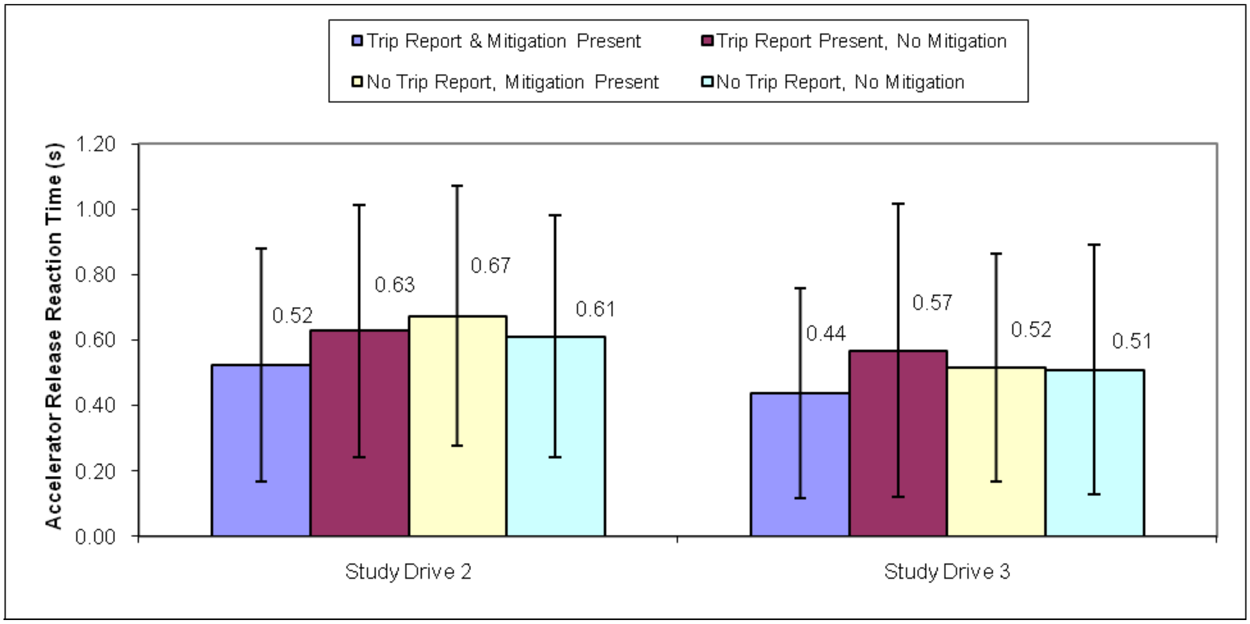

Figure 56. Accelerator release reaction time interaction between mitigation and trip report

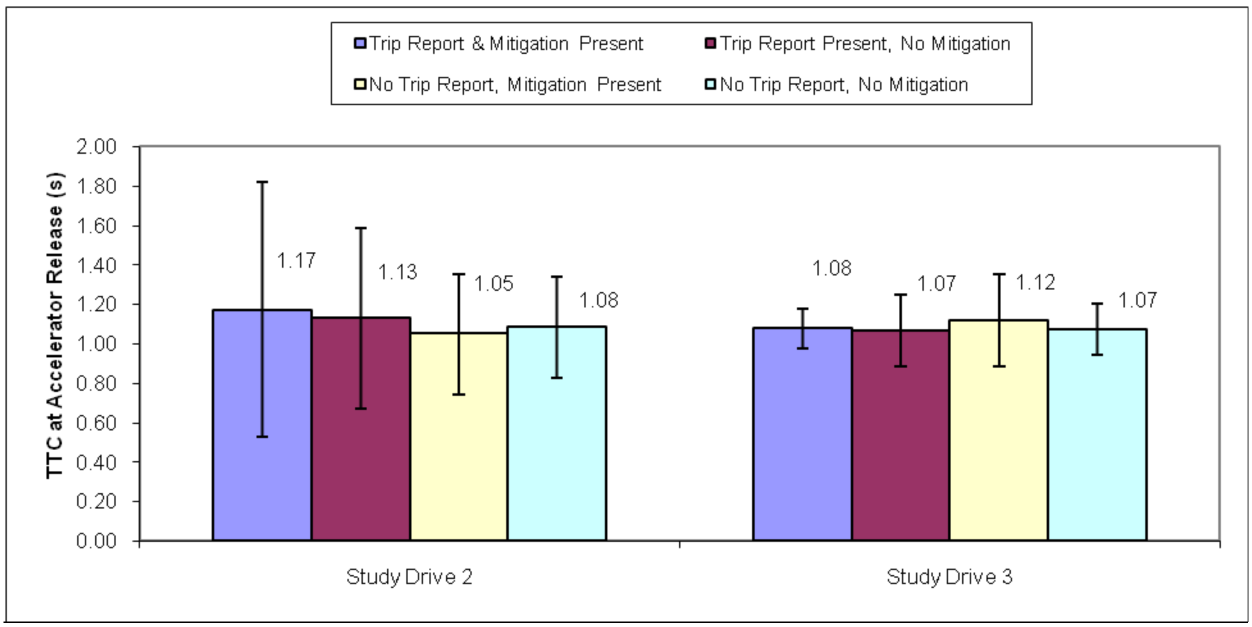

Figure 57. Time to collision at accelerator release interaction between mitigation and trip report

3.4 Driver Acceptance

Additionally, the NADS experiment addressed four experimental questions: driver acceptance of (1) adaptive compared with non-adaptive forward collision warning systems, (2) adaptive compared with non-adaptive lane departure warning systems, (3) a distraction mitigation warning system, and (4) a trip report.

3.4.1 Adaptive and Non-Adaptive Systems Compared

During the mental model interview, 59 percent of the participants remarked that they did not notice a difference between adaptive and non-adaptive alerts. Of the 39.3% of participants who stated that they did perceive a difference between adaptive and non-adaptive alerts, 45.8% believed the two alerting systems to be different, characterizing the difference between the two alerting systems in a range of responses, from those who believed that the difference referred to how the driver adapted to the alerts to those who noted that at certain times it felt like the system let the participant get closer to the lead vehicles than at other times.

After completing each study drive, participants rated their ability to safely respond to their driving environment based on the alerts' timing. **Figure 58** presents participants' responses to the timing of forward collision alerts across Study Drives 1 and 2, comparing the driver acceptance of the adaptive system with that of the non-adaptive system. Participant responses to the drives assigned to the adaptive alert condition fell into a bimodal distribution, with 34 percent mildly agreeing and 34 percent mildly disagreeing with the statement that the forward collision warning came too late for the driver to respond safely. Participant responses to the alert timing in drives assigned to the non-adaptive condition represented more of a unimodal distribution, with 34 percent mildly disagreeing that the forward collision alert came too late to respond safely to the driving environment.

Across Study Drives 1 and 2, 41 percent of participants were in agreement with the statement that the forward collision warning came too late in the adaptive condition, compared with 32 percent in the non-adaptive condition. The difference was less so for those who disagreed with the statement and therefore believed that the timing of the alert was appropriate; 41 percent of those in the adaptive condition and 44 percent of those in the non-adaptive condition disagreed with the statement. All participants reported experiencing a forward collision alert during Study Drives 1 and 2.

Participants' responses varied slightly when distraction at the final event was taken into account, as shown in **Figure 59** and **Figure 60**. Participants assigned to the adaptive warning system and who were distracted at the final event (severe lead vehicle braking) responded more favorably to the timing of the forward collision warning, with 40 percent mildly or strongly disagreeing that the warning came too late, compared with 33 percent of those participants in the non-adaptive condition. Conversely, 40 percent of participants with the non-adaptive warning system agreed that the forward collision warning came too late (13 percent in strong agreement), compared with 27 percent of participants in the adaptive warning condition.

When participants were not distracted during the final event, a slightly different trend emerges in their responses. Fifty-seven percent of participants with the adaptive warning system responded that they thought the timing of the forward collision alert was appropriate, whereas 40 percent of participants with the non-adaptive warning systems responded that the timing was appropriate. Twenty-six percent of participants with the adaptive system compared with 20 perecnt of those with the non-adaptive system agreed that the timing came too late.

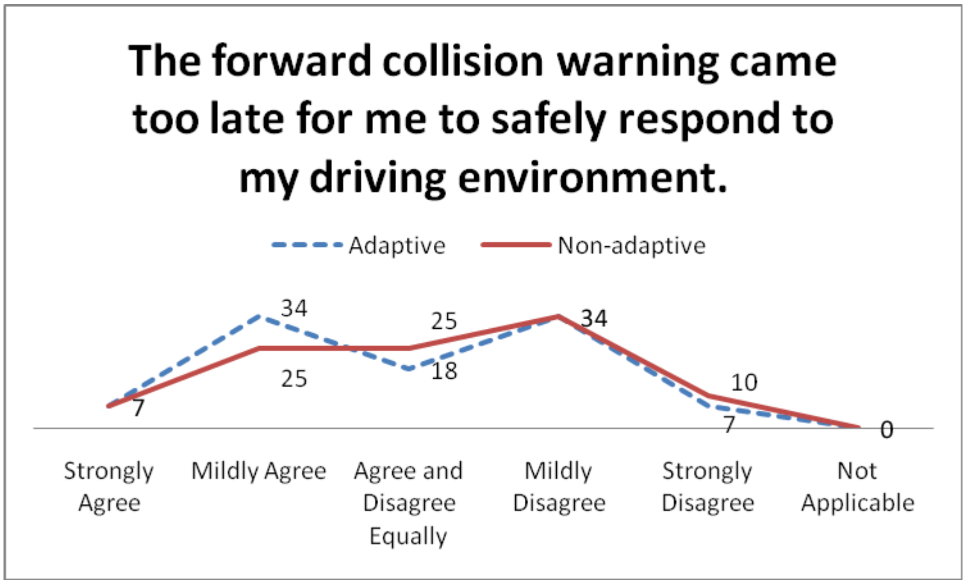

Figure 58.Forward collision warning, Study Drives 1 and 2 combined

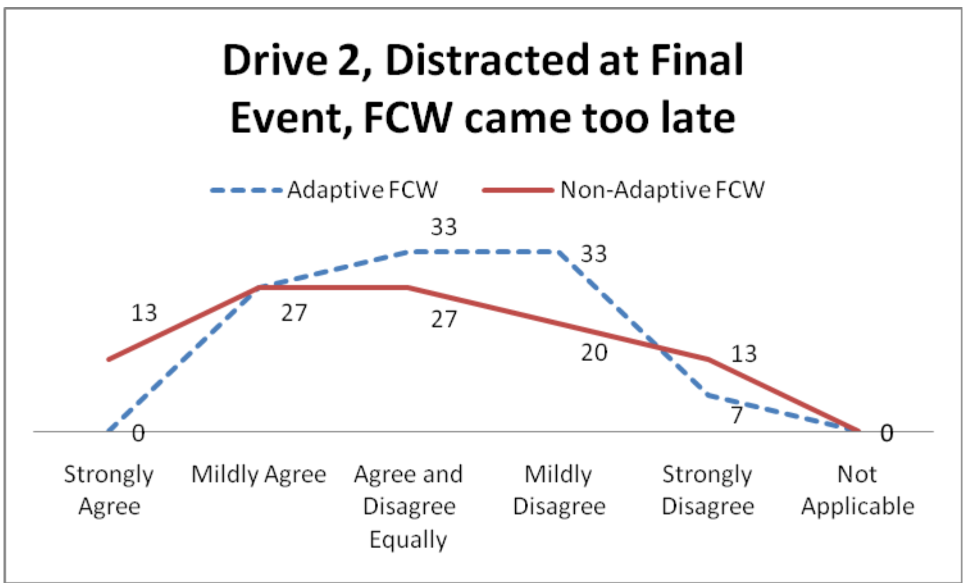

Figure 59. Study Drive 2, distracted at final event, adaptive and non-adaptive systems compared

Figure 61 presents participants' responses to the timing of lane departure alerts across Study Drives 1 and 2, again comparing the driver acceptance of the adaptive system with the non-adaptive system. Participant responses to the drives varied little between the adaptive and non-adaptive alert conditions. Both conditions are represented by a unimodal distribution, with roughly one-third of the participants in each condition marking a neutral response to the statement that the lane departure alert came too late for the driver to safely respond to the driving environment; roughly one-quarter of the participants in the adaptive condition and one-third in the non-adaptive condition mildly disagreed with the statement.

Whereas all participants responded that they received at least one forward collision alert in Study Drives 1 and 2, 21 percent of participants in the adaptive condition and 11 percent in the non-adaptive condition responded that they did not receive a lane departure alert in at least one of the two drives.

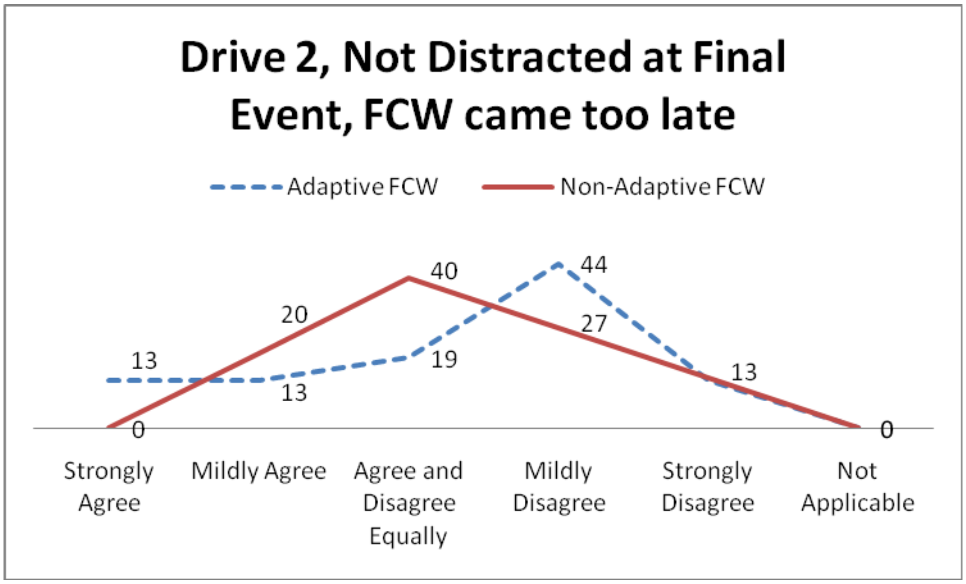

Figure 60. Study Drive 2, not distracted at final event, adaptive and non-adaptive systems compared

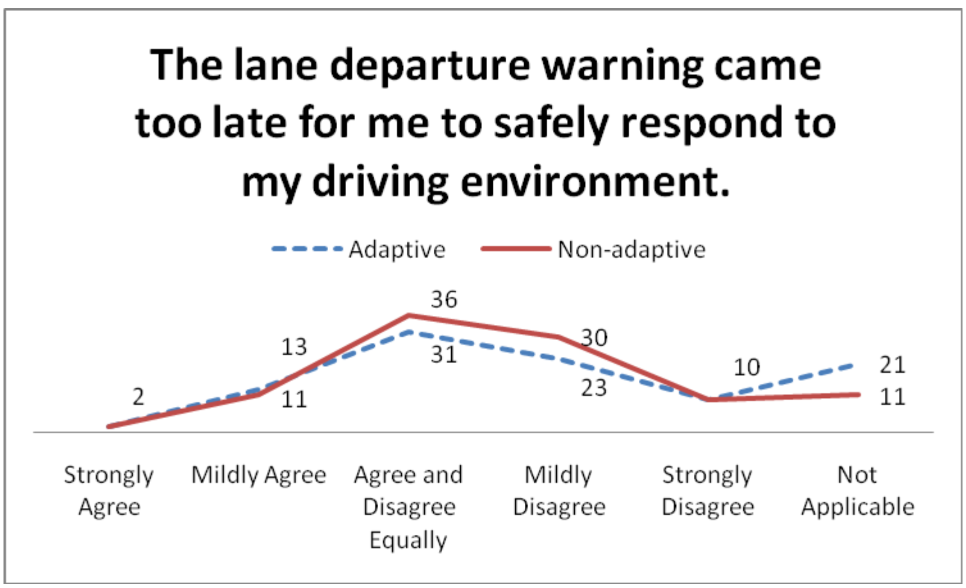

Figure 61. Lane departure warning, Study Drives 1 and 2 combined

When distraction at the final event was taken into account, participants' responses when distracted varied, although those who were not distracted presented little variation between the adaptive and non-adaptive conditions (see **Figure 63**). **Figure 62** displays the distribution of responses from participants who were distracted at the final event (wind gust from drivers' left to right, potentially pushing study vehicle off of the road). Participants in the adaptive condition were divided in their response to the alert system's timing; 34 percent responded that the timing was too late, while 40 percent believed that it was appropriate. Participants with non-adaptive systems, on the other hand, were more neutral in their impression of the alerts' timing than those with the adaptive system, with 33 percent agreeing and disagreeing equally, 20 percent believing that the timing was too late, and 27 percent believing that it was appropriate.

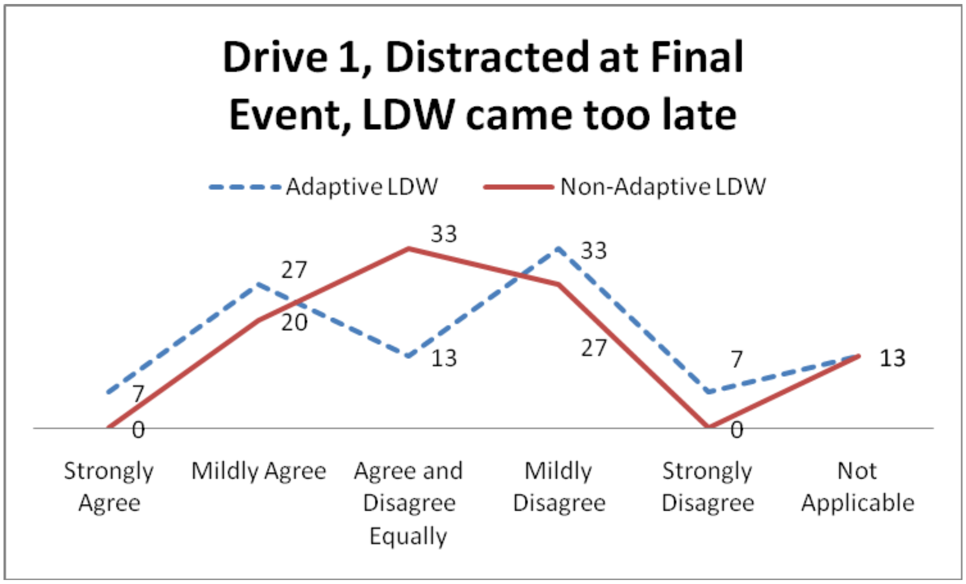

Figure 62. Study Drive 1, distracted at final event, adaptive and non-adaptive systems compared

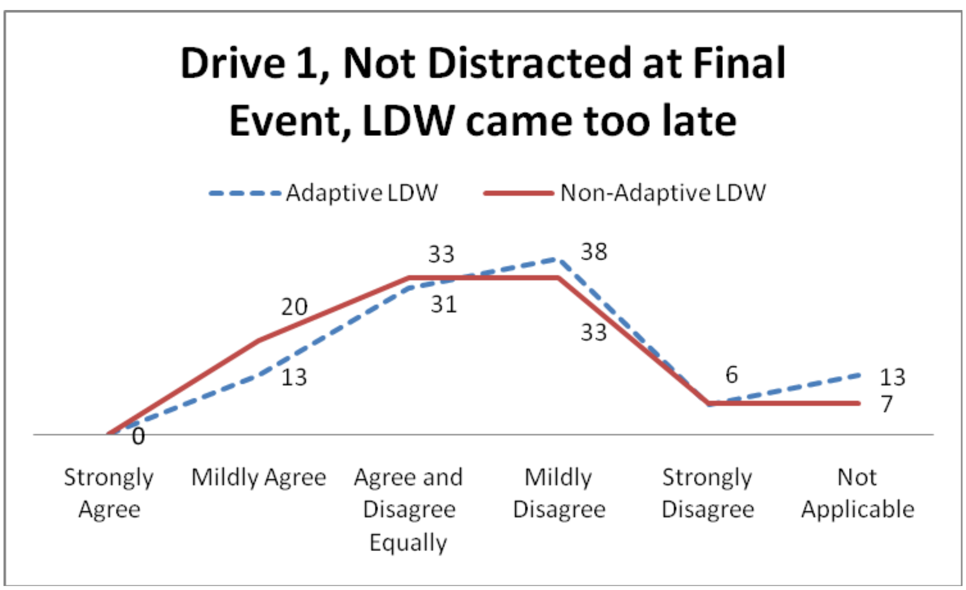

Figure 63. Study Drive 1, Not Distracted at Final Event, Adaptive and Non-Adaptive Systems Compared

3.4.2 Distraction Mitigation Warning

Participants' responses to the utility of the distraction mitigation alert comparing Study Drives 1, 2, and 3 are displayed in **Figure 64**. After Study Drive 1, three-quarters of participants were roughly divided between mild agreement, neutrality, or mild disagreement with the statement that the distraction mitigation alert came too late to safely respond to the driving environment. After Study Drive 2, the distribution of responses shifted, with a 6 percent increase in neutral responses (from 28 percent after Study Drive 1 to 34 percent after Study Drive 2) and an 11 percent decline in those who responded in mild disagreement with the statement (from 26 percent to 15 percent). After Study Drive 3, responses in mild agreement with the statement experienced a 12 percent decline (from 25 percent after Study Drive 2 to 13 percent), yet those in strong agreement increased from 2 percent to 8 percent. Generally, responses became more neutral as participants proceeded through the drives, in addition to a subtle increase in the number of participants who remarked that they did not receive distraction mitigation alerts.

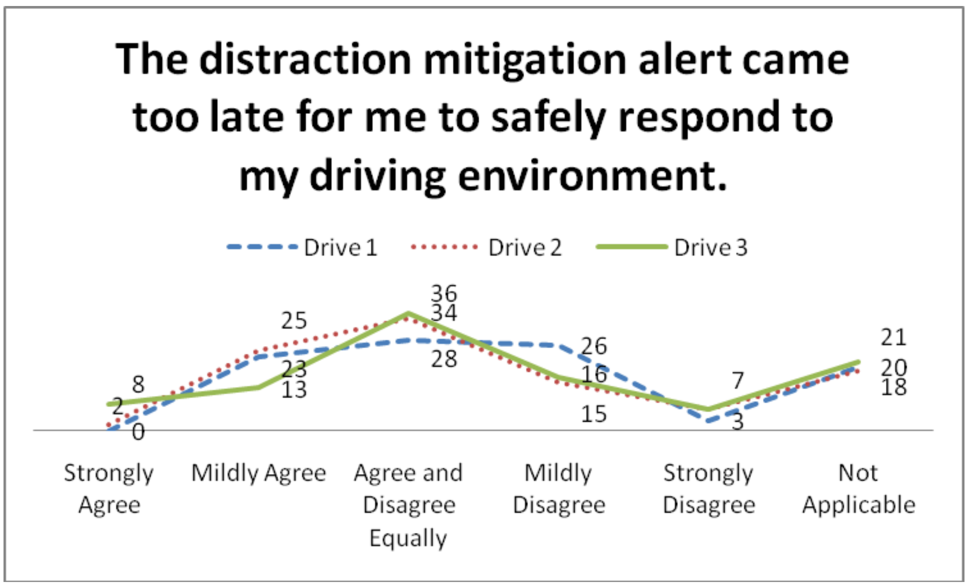

Figure 64. Responses to utility of distraction mitigation across the study drives

Study Drive 3 was designed to evaluate the potential safety benefits and acceptance of the distraction mitigation system. **Figure 65** displays the distribution of participants' responses after completing Study Drive 3 to the statement "The distraction mitigation alert came too late for me to safely respond to my driving environment," comparing those who were assigned to the distraction mitigation condition to those who were not. The participants who experienced distraction mitigation in the final study drive generally reported a more favorable response to the warning than those who did not have distraction mitigation activated, with 32 percent of those with distraction mitigation disagreeing with the statement compared to 13 percent of those without. Roughly one-third of the participants without distraction mitigation wrote in "NA," compared with 10 percent of the participants with distraction mitigation. This could indicate that participants without distraction mitigation were aware of the differences between the distraction mitigation alerts and the other alerts, as well as noticing when the system was active and when it was not. This is offset by the 30% of participants without distraction mitigation that believed the timing came too late; however, this too may indicate that participants expected to see the alert, and when they did not, they assumed it came too late instead of never occurring.

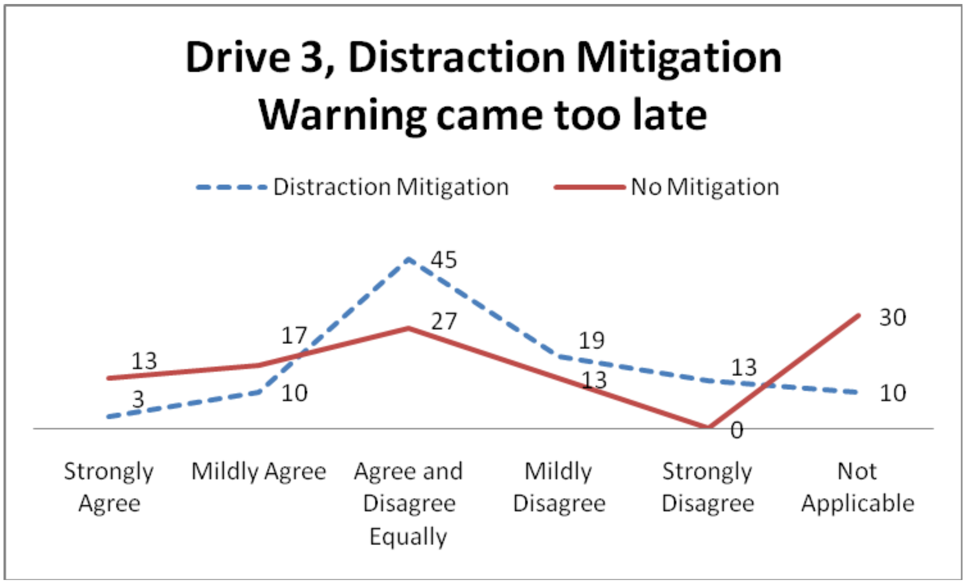

Figure 65. Study Drive 3, distraction mitigation and no distraction mitigation compared

Unlike Study Drives 1 and 2, some participants in Study Drive 3 were distracted during the final event. **Figure 66** displays responses for participants who were distracted at the final event, comparing distraction mitigation and no mitigation. Thirteen percent of participants who were distracted at the final event and did not have a distraction mitigation alert strongly agreed that the timing of the alert was too late for them to respond safely to their driving environment, compared with 7 percent of participants who did have a distraction mitigation alert. However, when agreement answers are grouped, 27 percent of participants with distraction mitigation compared with 20 percent of participants without mitigation responded that the timing was too late. These percentages remain the same for participants in disagreement with the statement; 27 percent of participants with distraction mitigation and 20 percent of those without had a more favorable opinion of the distraction mitigation system.

More variation between participants with distraction mitigation and those without occurred between participants who were not distracted at the final event, as shown in **Figure 67**. Even though there was no distraction task at the final event, participants with distraction mitigation responded more favorably to distraction mitigation than did those without mitigation (38 percent compared with 7 percent, respectively). No participants with distraction mitigation alerts were in agreement with the statement that the timing was too slow, compared with 40 percent of those without mitigation.

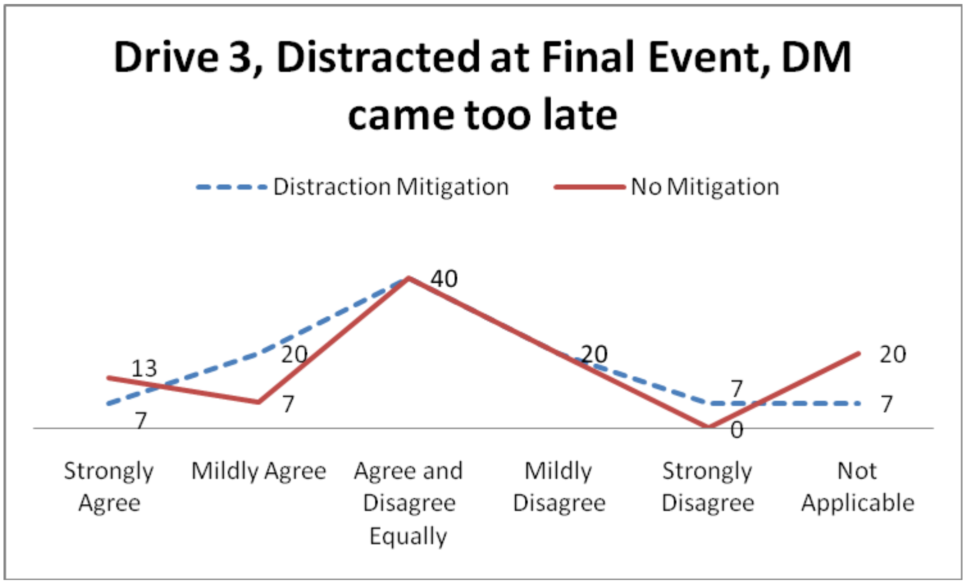

Figure 66. Study Drive 3, distracted at final event, distraction mitigation/no mitigation compared

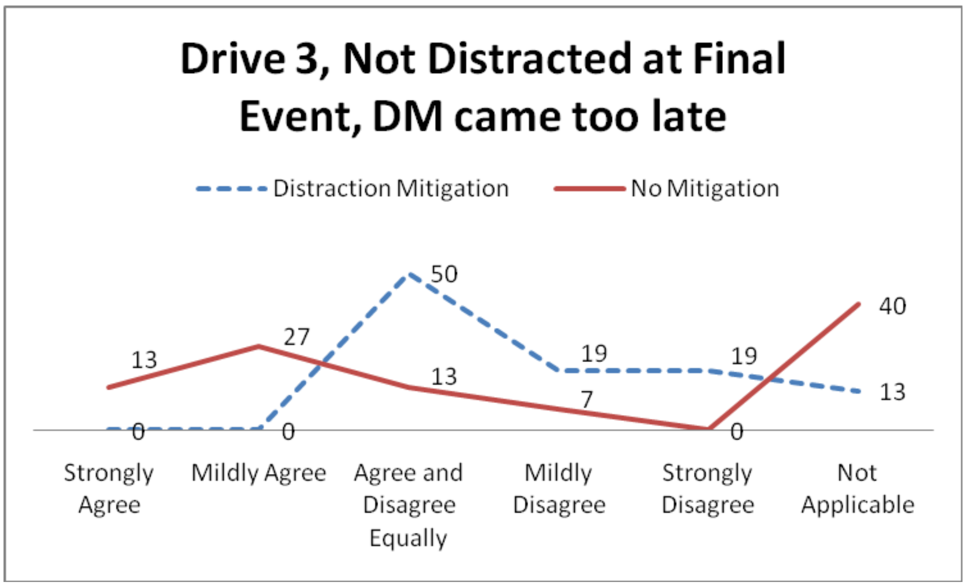

Figure 67. Study Drive 3, not distracted at final event, distraction mitigation/no mitigation compared

3.4.3 General Response to Alerts

Unlike the pattern of increasing neutrality in response to the distraction mitigation alert across the drives (see **Figure 64**), responses to the lane departure and forward collision alerts follow different acceptance trajectories. Charts summarizing the percentage of responses for the lane departure and forward collision alerts are presented in **Figure 68** and **Figure 69**, respectively. Participants provided the most favorable rating for the lane departure alert's timing after Study Drive 1; this drive culminated in the lane departure critical event, so it is expected that more participants experienced the alert and therefore provided a favorable, rather than neutral, response. Participants' ratings shifted to a more neutral response after Study Drive 2, and then stabilized after Study Drive 3, with 16% marking mild agreement, 23% equally agreeing and disagreeing, 23% mildly agreeing, and 18% in strong agreement.

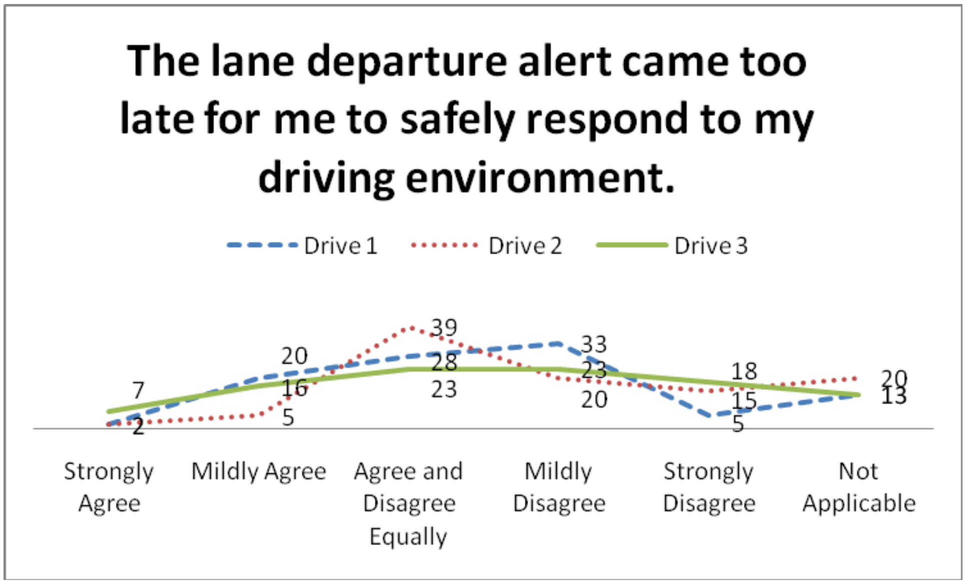

Figure 68. Responses to utility of the lane departure warning across study drives

Participants' responses to the timing of the forward collision alert after Study Drive 1 were divided; 38% of the responses were in mild agreement and 38% were in mild disagreement with the statement that the alert came too late to safely respond. After Study Drive 2, the bimodal response shifts to roughly one-third of responses adopting a neutral stance or mildly disagreeing with the statement. The final event in Study Drive 2 is an extreme braking event precipitated by a lead vehicle unexpectedly stopping in the roadway. While Study Drive 1 represented the most favorable (and unfavorable) rating for the forward collision alert, almost three-quarters of the responses after Study Drive 2 were neutral or favorable. Study Drive 2 also experienced the highest number of not applicable responses (16 percent) for forward collision alert timing of the three study drives. After Study Drive 3, those who strongly agreed with the statement that the alert came too late increased to 15 percent from 7 percent after Study Drives 1 and 2; neutral responses experienced a 12 percent decline from Study Drive 2 to Study Drive 3. Even accounting for these shifts, 63 percent of responses were neutral or favorable toward the timing of the forward collision alert.

When asked to provide a summarial response to the timing of the lane departure, forward collision, and distraction mitigation alerts in the study debriefing session, participants generally provided a favorable rating for the lane departure and forward collision alerts (51 percent and 50 percent, respectively, in disagreement), while providing a neutral rating to the distraction mitigation alert (46 percent). Response distribution is shown in **Figure 70**.

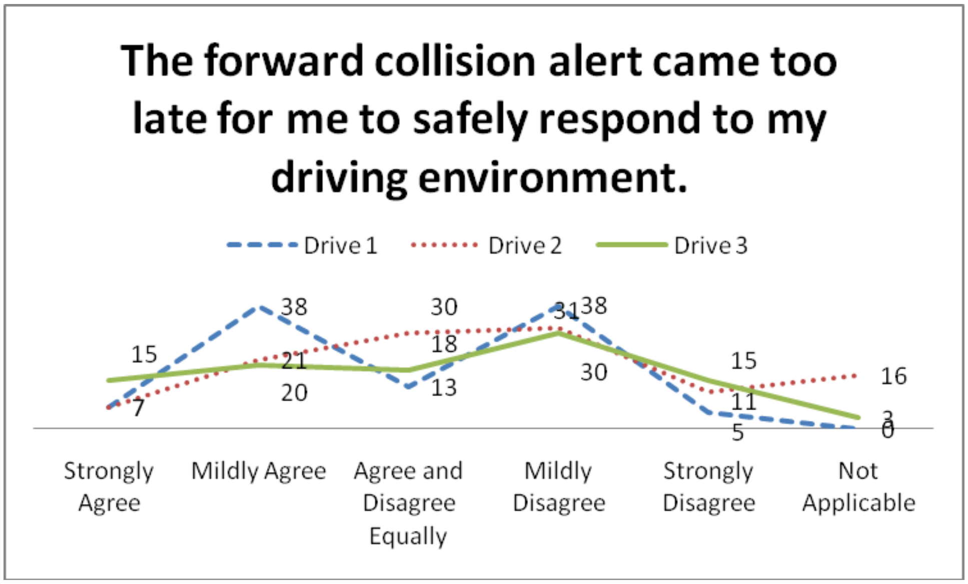

Figure 69. Responses to utility of the forward collision warning across study drives

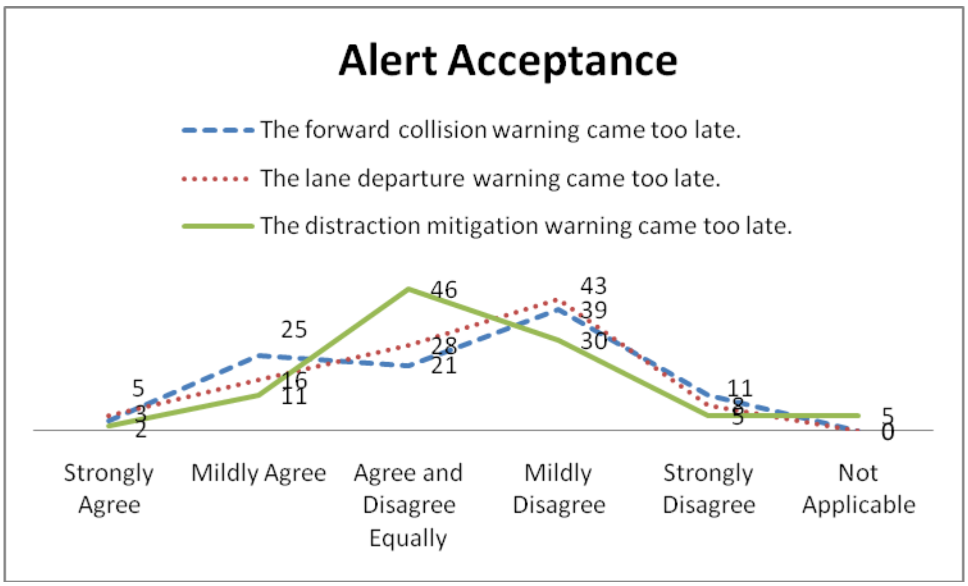

Figure 70. Summarial response to utility of all warning systems

Additionally, participants were asked to write suggestions to help improve the IVIS system based on their experience. **Table 43** provides a summary of the comments regarding the system's alerts (other comments included feedback on the placement of the display, the symbols and buttons used on the display, or the navigation or text-messaging tasks). Of the 15 respondents who provided feedback specific to the alerts, two remarked that the distraction alert was annoying or that it should be eliminated from the system. Others wrote that the alerts would be more effective if they were more distinct, with one specifically commenting that the forward collision and the distraction mitigation alerts were too similar.

Table 43. Summary of participant suggestions regarding alert style and function

Overall, what suggestions would you give to help improve the IVIS system? **Answers Addressing Alert System**	
Alert Style	Have voice attenuator actually state type of warning (e.g.: slow down, veer left, etc.).
	Voice instead of beeps, such as "Brake" or "Steer".
	Warning alerts that tell you which direction the alert is coming from, like stereo sound or lights on arrows.
	Allow customized tones/verbal warnings.
	The warnings could be a little more distinctive.
	Needs more specific warnings for each problem detected.
	More distinguished alerts (distraction and collision too similar), distraction alert is annoying, didn't feel comfortable with collision alert because was driving closer and faster than I felt safe.
Alert Function	Let you control which alerts you want on at different times for different conditions or drivers.
	Let the IVIS system be adjustable to individual's driving habits, or let it learn from the driver. System responses are much unpredictable and disconcerting.
	Warnings could be slightly earlier.
	Earlier forward collision alert.
	Increase collision warning time.
Overall Impression	No distraction warning.
	Thought it was distracting.
	Alert system useful.

3.4.4 Perceived Understanding

As has been intimated in the sections above, participants' understanding of how the system worked varied. Confusion between the alerts seemed to have led many participants to believe that an alert was present when it was not, and a small number of participants believed that there were additional features to the alert system, including blind-spot warnings or active braking when a forward collision is imminent. A majority of the participants could not detect changes in the alerts' timings in the adaptive condition compared with the non-adaptive condition. Some commented that alerts were too similar to distinguish while managing the distraction tasks and driving; this was particularly true for the distraction mitigation warning. Yet despite these and other misunderstandings, 85 percent of participants were in agreement with the statement that they understood the operation of the system, as shown in **Figure 71**.

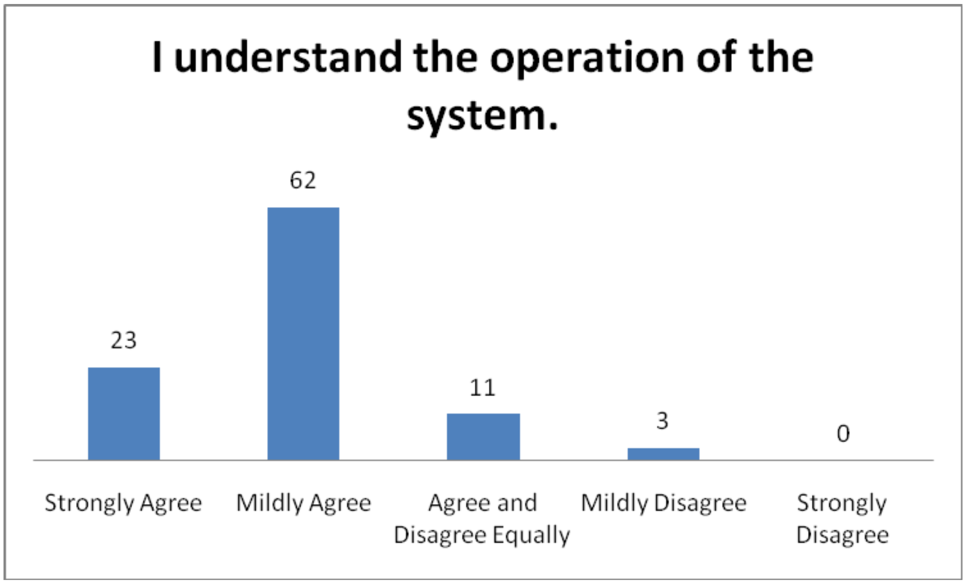

Figure 71. Participant response to system comprehension

Although participants were informed that the system monitors the driver and the driving environment during the IVIS training in the study briefing session, when they were asked in the mental model interview to describe how the safety system worked, 61 percent of participants did not think that the safety system monitored the driving environment and 72 percent did not think that it monitored the driver (see **Figure 72**).

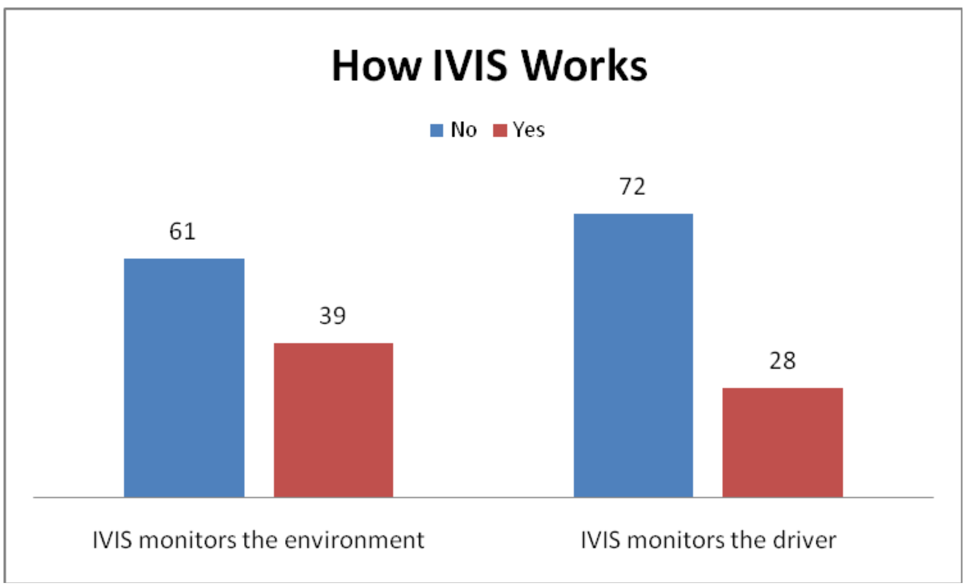

Figure 72. Participant response to IVIS operation

During the critical event and trip report interview, staff members reviewed the final event from the three study drives with each participant. After watching each video segment, participants were asked if they received a warning, what they thought triggered the warning, and what effect the warning had on their ability to handle the critical event. As shown in **Figure 73**, 33 percent of participants in Study Drive 1 and 30 percent of participants in Study Drive 3 stated that they received alerts during the lane departure and intersection incursion events, respectively, compared with 95 percent of participants who stated that they received a forward collision warning during the final event in Study Drive 2. While instances did occur when alerts were not triggered, there also were cases where participants, after reviewing video of the final event, reported that they did not receive a warning despite the auditory alerts clearly playing on the video.

Whereas **Figure 72** shows participants' general impression of how the system worked, **Figure 73** provides participants' understanding of how the warnings were triggered for each drive[1]. Of the participants who reported receiving an alert at the final event, the majority of participants believed that the trigger for the alert was in the driving environment, as opposed to activities performed by the driver inside the vehicle, or a combination of the driver's state and the driving environment. Five percent of participants who recalled receiving an alert in Study Drives 1 and 2 understood the alert to be triggered by both the driver's state and the driving environment. One-quarter of the participants in Study Drive 1 attributed the trigger to the driver's state, compared with 16 percent of participants in Study Drive 2, and no participants in Study Drive 3. Sixty-five percent of the participants in Study Drive 1, 71 percent in Study Drive 2, and 83 percent in Study Drive 3 attributed the alerts to the driving environment.

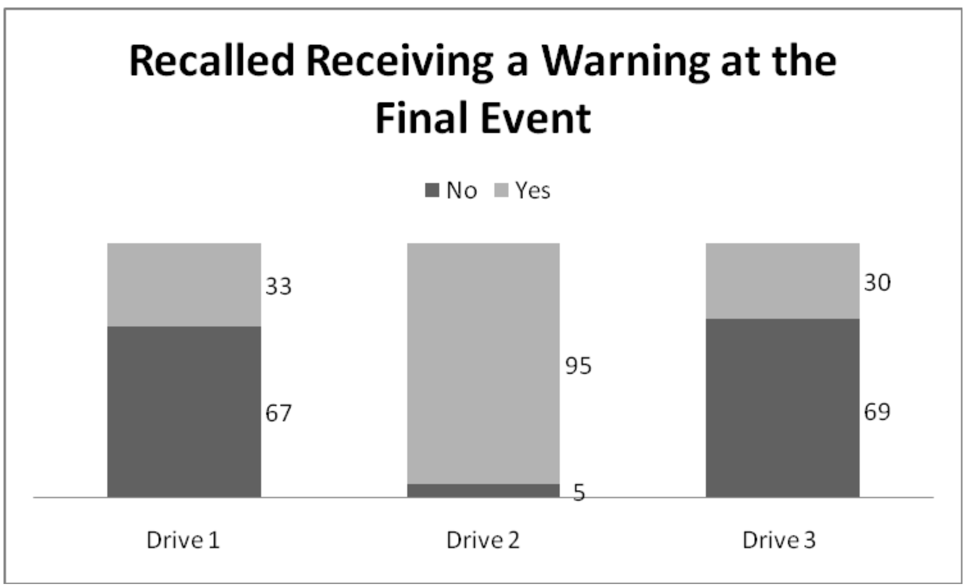

Figure 73. Recollection of warning at final event

These findings, while not statistically significant, suggest that while participants believed that they understood how the system operated, most did not draw a connection between the driver's state and the alerts. Several examples from the data support this theory: the low number of participants who detected a difference in the alerts' timing associated with adaptive and non-adaptive conditions, as well as their general lack of understanding of the difference between the two conditions; the low percentage of participants who believed that IVIS monitored the driver as part of its alerting system; the disparate recollections of alerts between those in Study Drives 1 and 3 and those in Study Drive 2; and the attribution of the alert in Drive 3 solely to the driving environment.

[1] Percentages do not equal 100 because of missing data.

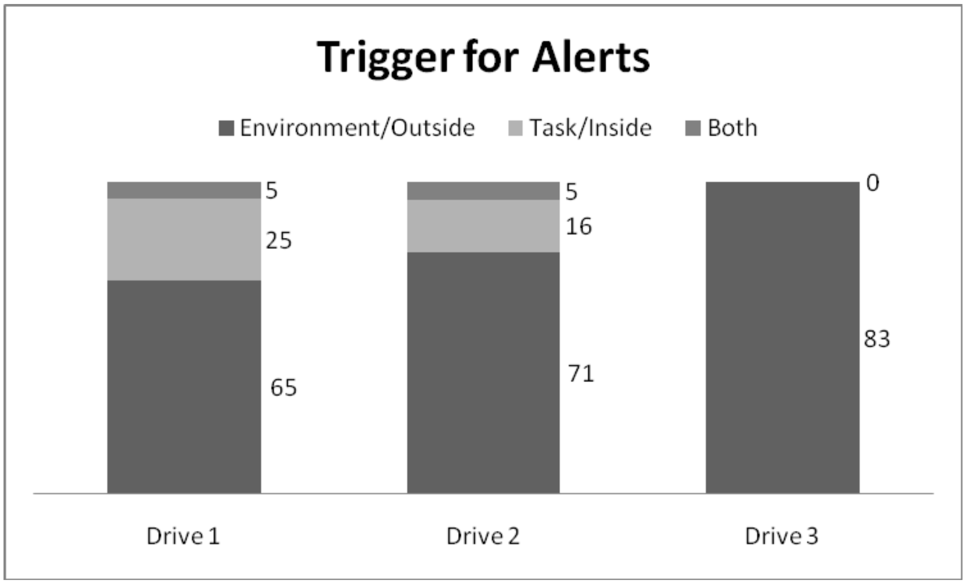

Figure 74. Participant perception of alert triggers

The final two examples deserve further elaboration. Many participants commented that they were unclear as to the source of the final event in Study Drive 1, mistaking the wind gust for an earthquake, a blown tire, or driving over an object on the roadway. It is likely that the higher percentage of responses associating the driver's state with the alert in Study Drive 1 compared with the other drives is in part because a clear environmental trigger was difficult to decipher, and the participants who did receive a lane departure warning were often involved in a distraction task at the time of the final event. Unlike the visually nondescript wind gust, the final event in Study Drive 2, an imminent forward collision with the lead vehicle, is visually apparent and therefore its accompanying alert is perhaps more easily associated with its environmental trigger. Interestingly, participants attributed the alerts experienced in Study Drive 3 solely to environmental triggers, although the design of the system does not allow for forward collision or lane departure alerts in intersections. It was expected that if participants understood the operation of the system, those who were assigned to the distraction with mitigation condition would distinguish this alert from the other alerts and tie the distraction mitigation alert to the drivers' state instead of to the driving environment.

3.4.5 User Reliance

In the study, user reliance was examined through participants' level of trust in the system (including how reliable they believed the system to be) and the effect of IVIS on participants' level of confidence in relationship to specific driving tasks, maneuvers, and driving environments. Generally, as shown in **Figure 75**, 52 percent reported that they mildly to strongly trusted the system, and 62 percent reported that they thought the system was reliable. Despite these favorable responses, 91 percent of participants remarked that they were confident with their ability to drive safely without the system. The difference between the mean responses to the question "I trust the system" among participants who experienced two drives with the adaptive system compared with those that experienced one drive with the adaptive system was negligible (2xadaptive mean=2.61 with 1.15 stdev, 1xadaptive mean=2.57 with .9 stdev).

Although the overwhelming majority of participants reported that they were confident in their ability to drive safely without IVIS, only 21 percent remarked that they disregarded the system's warnings while driving. When asked why they did not disregard the warnings, participants noted that while they prioritized their ability to interpret the driving environment and react accordingly based on past driving experience, the extra assistance provided by the warning system was helpful, even for participants who thought that the alerts themselves were distracting. Interestingly, 30 percent reported that they came to rely on the system as their primary source of information about potential hazards while driving when distracted rather than using the system as a secondary source (see **Figure 76**). This presents a potential danger of the warning systems; some participants were willing to relinquish control to the vehicle and/or the safety system so that they could more readily engage in the incentivized distraction tasks.

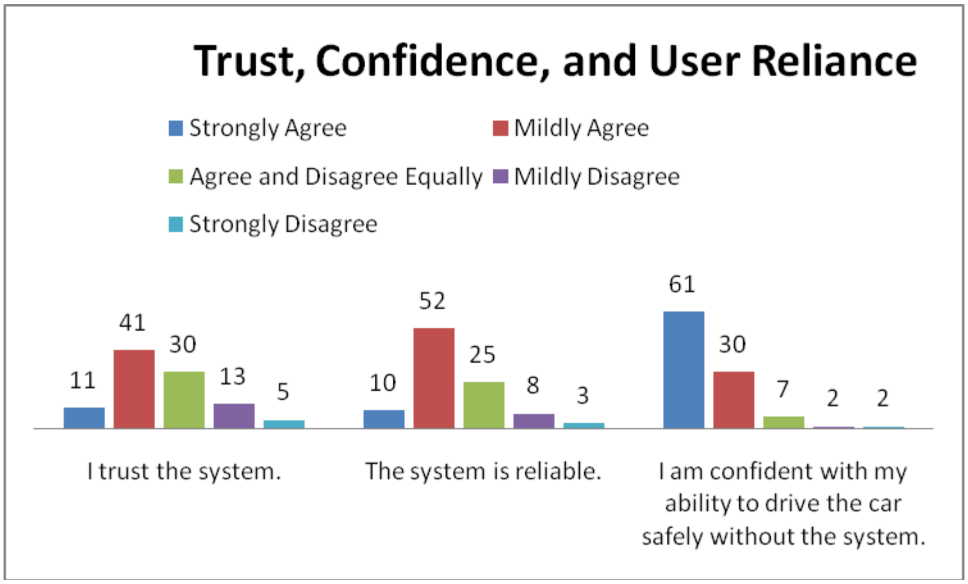

Figure 75. Trust, confidence, and user reliance in the warning system

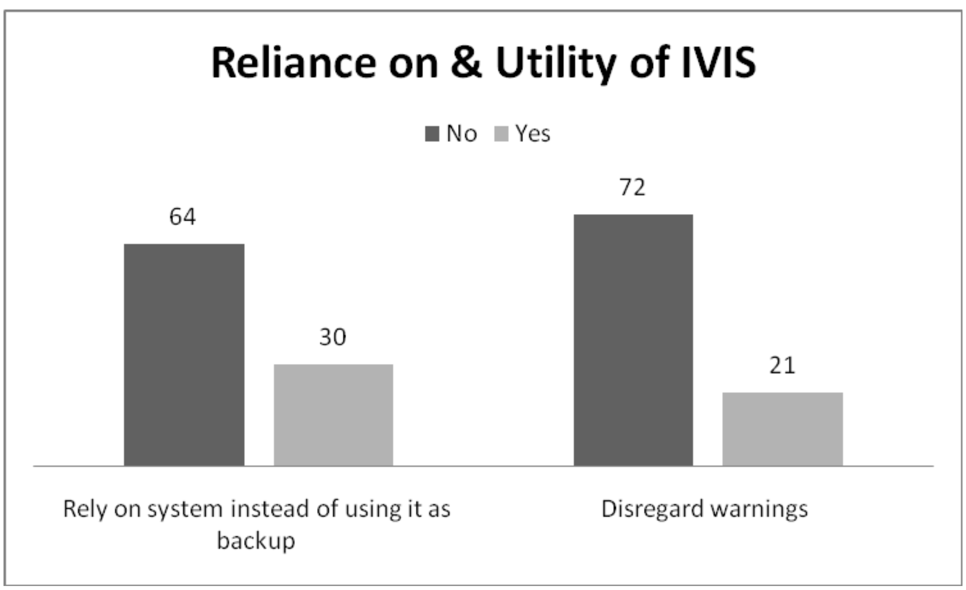

Figure 76. Reliance on and utility of IVIS

Participants also were asked to report how frequently they perform certain tasks and maneuvers while driving, as well as to rate their level of confidence in performing these tasks/maneuvers with and without IVIS. Prior to the study drives, participants were asked to report how frequently they performed certain tasks or maneuvers while driving; **Table 44** displays the number of infrequent, frequent, and not applicable/no answer responses. The first five tasks/maneuvers address driving conditions that may impact or be impacted by IVIS. These include driving in heavy traffic, keeping up with traffic on a two-lane highway, exceeding the speed limit, veering unintentionally from the lane, and maintaining an unsafe following distance. The last five tasks/maneuvers address activities that potentially distract or otherwise impair the driver, including fatigue, driving with children, adjusting radio settings, reading a map, using a navigation system, or using a wireless phone while driving.

Table 44. Summary of self-reported task and maneuver frequency

When driving, how frequently do you perform the following tasks/maneuvers? N=61				
		Infrequent	Frequent	Not Applicable/ No Answer
Conditions	Drive in heavy traffic	7	54	0
	Keep up with traffic on two-lane highway	0	61	0
	Exceed speed limit	12	48	1
	Veer from your lane	53	7	1
	Keep less than the suggested following distance between you and the car in front of you	44	16	1
Activities	Drive when tired	24	36	1
	Drive with children	19	42	0
	Adjust your radio settings	9	52	0
	Read a map	39	19	3
	Use an in-vehicle navigation system	50	3	8
	Use a wireless phone	25	36	0

Generally, 75 percent or more of participants reported frequently driving in heavy traffic, being able to keep up with traffic on two-lane highways, and exceeding the speed limit[2], while infrequently veering from their lane or keeping an unsafe following distance between their vehicle and that in front of them. The frequency of activities or driver's state for which there is a possibility of impairment are less definitive, with the exception of adjusting radio settings (85 percent frequently do so) and using in-vehicle navigation systems (roughly 5 percent frequently use). Roughly 70 percent drive with children, 60 percent reported that they frequently drive when tired or use a cell phone while driving, and only 30 percent report frequently reading a map while driving. Paring the list down to those elements that directly apply to the IVIS, then, suggests that our sample infrequently veer from their lane, drive at an unsafe following distance, or use an in-vehicle navigation system, but more than half

[2] Participants reported that they average a speed of 59 miles per hour when the posted speed limit is 55 (range=55-70, SD=2.9), and 69 miles per hour when the posted limit is 65 (range=65-75, SD=2.7).

frequently use a cell phone, and well over 75 percent of participants report frequently adjusting the radio settings while driving.

The percentage of responses that gauge the level of confidence for those with and without IVIS are displayed in **Figure 77** through **Figure 80**. The 4-point scale ranged from very hesitant to very confident, with not applicable as the fifth option. For this analysis, very and slightly hesitant were combined in the category “hesitant,” and moderately and very confident were combined into the category “confident.”

Generally, participants’ hesitance and confidence responses had an inverse relationship, with the exception of the use of in-vehicle navigation systems. The high rate of never or rare use of navigation systems precipitated a large number of “not applicable” responses to how confident they felt performing this task with or without IVIS, which could explain this variation. Participants reported that they felt more confident veering from their lane (p=<.0001) and keeping an unsafe following distance with IVIS than they did without; conversely, they reported feeling more confident driving in heavy traffic, keeping up with the speed of traffic on two-lane highways (p=0.0425), and exceeding speed limits without IVIS.

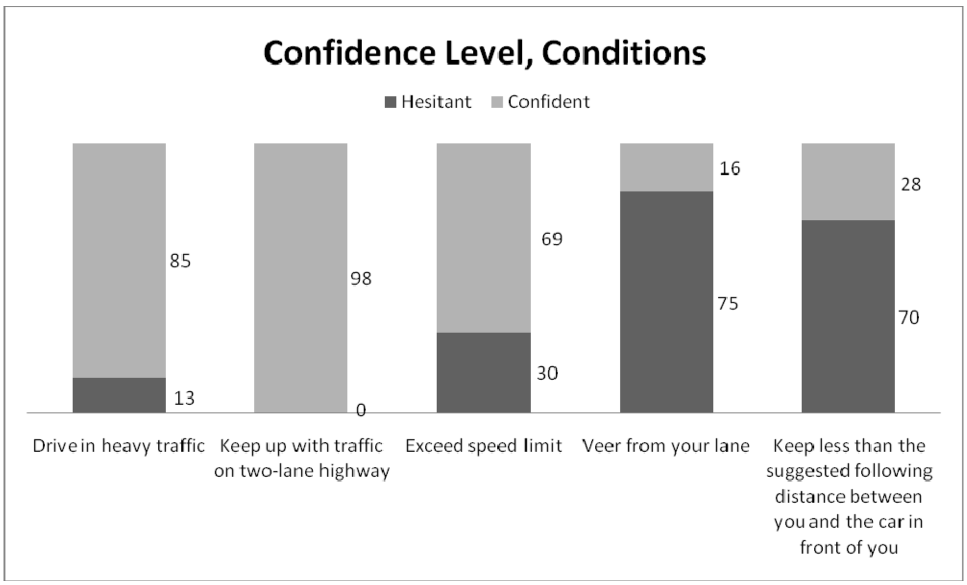

Figure 77. Confidence level driving in various conditions

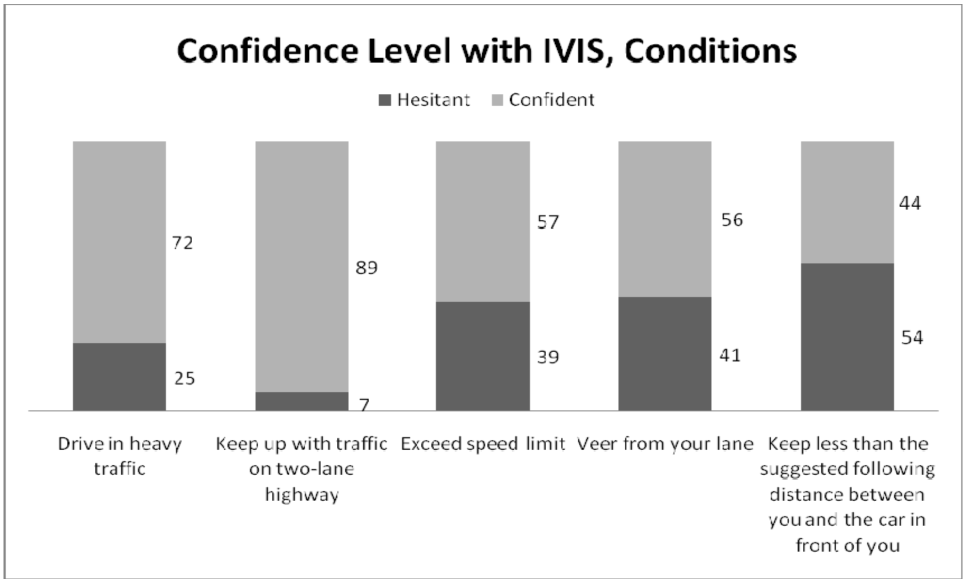

Figure 78. Confidence level driving in various conditions with IVIS

When asked about activities performed inside the vehicle and about the driver's state, participants reported that they felt more confident driving when tired, reading a map (p=0.0343), using a navigation system (p=<.0001), or using a cell phone with IVIS; this trend was not the case, however, for driving with children or adjusting radio settings, both of which participants felt less confident doing with IVIS. One explanation for this pattern is that participants did not translate the potential distraction mitigation safety benefits to other, non-technology-based distracters, such as interacting with children while driving. Because changing radio settings is so commonplace for the majority of this sample, the inherent dangers of distraction associated with the task may go unrecognized; therefore, the potential safety benefit of IVIS may be likewise disregarded.

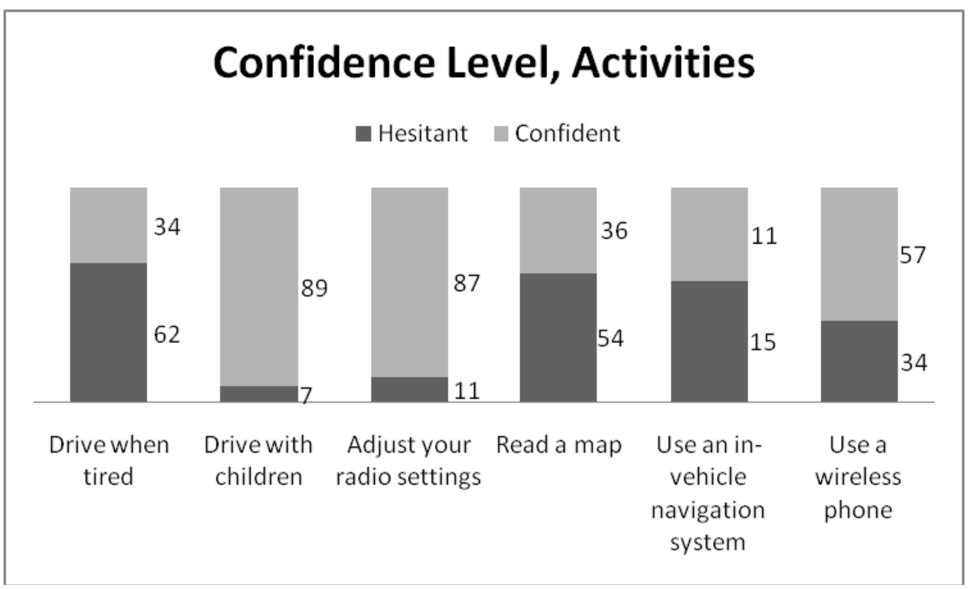

Figure 79. Confidence level performing various activities while driving

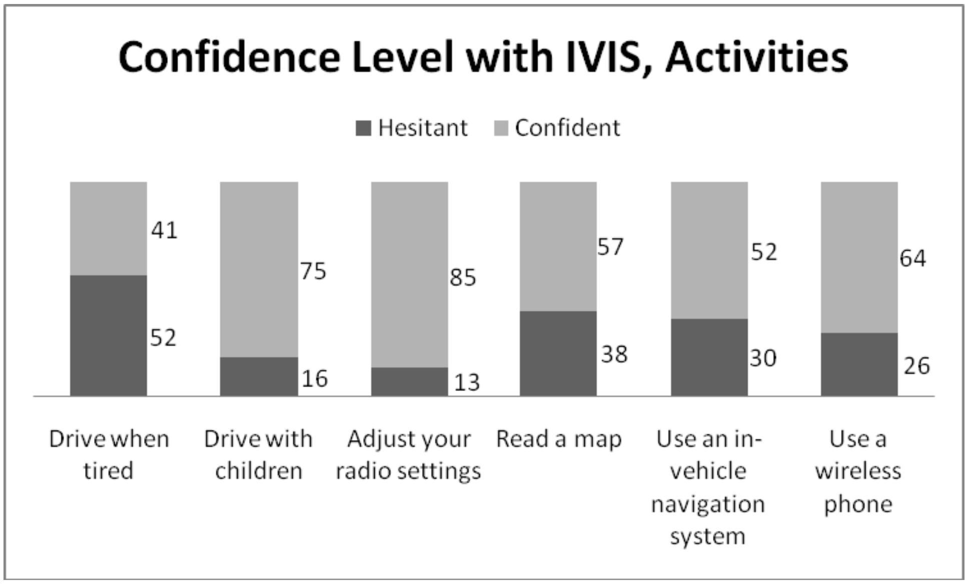

Figure 80. Confidence level performing various activities while driving with IVIS

3.4.6 System Utility

Driver acceptance also was evaluated through questionnaire and interview questions regarding the user's perceived utility of the system, including the perceived safety benefits of the system, the value the driver places on the system, as well as the limits of the system's usefulness.

Connections can be drawn between participants' understanding of the system and the perceived effect of the warning on participants' ability to manage the event. **Figure 81** displays the percentage of help, hinder, and neither responses for each drive for the participants who reported receiving an alert in the final event. As may be expected from participants' ability to relate the forward collision warning to the imminent event in the driving environment, 69 percent of participants who received this warning reported that it helped them manage the critical event. Contrary to participant responses to the forward collision warning, participants in Study Drives 1 and 3 were relatively ambivalent about the warnings' impact on the lane departure and intersection incursion events, with 40 percent and 61 percent of participants, respectively, replying that the warnings neither helped nor hindered their driving. More remarkable, considering the distraction potential of the alerts themselves, are the low percentages of participants who responded that the warnings hindered their ability to respond to the event.

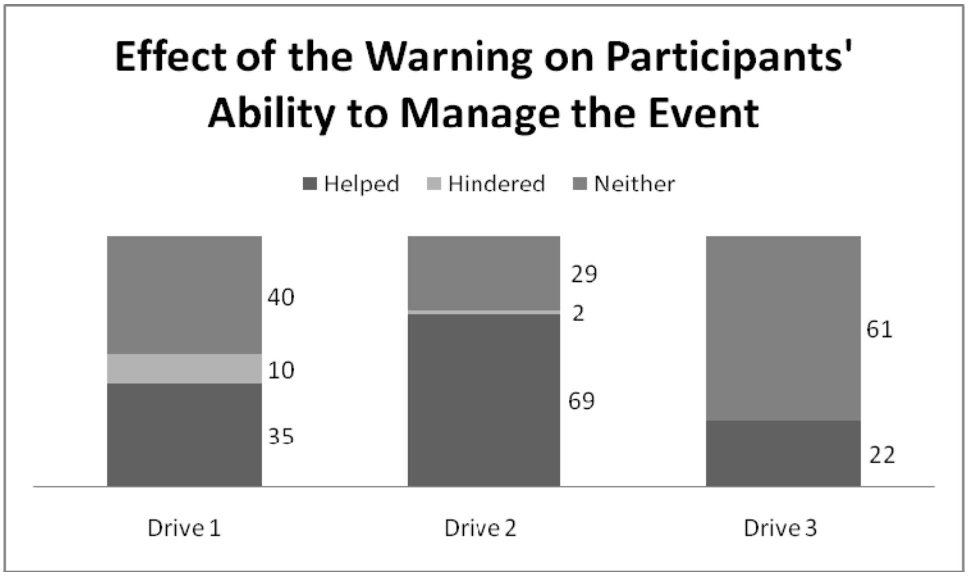

Figure 81. Effect of warning on participants' ability to manage final events

Participants were asked a series of questions on a debriefing questionnaire regarding the safety benefits of the system as a whole. Responses are displayed in **Figure 82**. Although 38 percent of participants reported that IVIS would not help them drive more carefully than they normally would in typical daily driving, when specifically asked about their ability to avoid potential crashes and to avoid potential collisions faster than they would have without the system, the negative responses dropped dramatically (11 percent and 21 percent, respectively). Across these questions, those in mild agreement were relatively constant, with the increase in positive responses attributed to sharp increase in strong agreement to the statements that IVIS helped the driver to avoid a crash (33 percent) and to do so in less time than it would have taken without the system (28 percent).

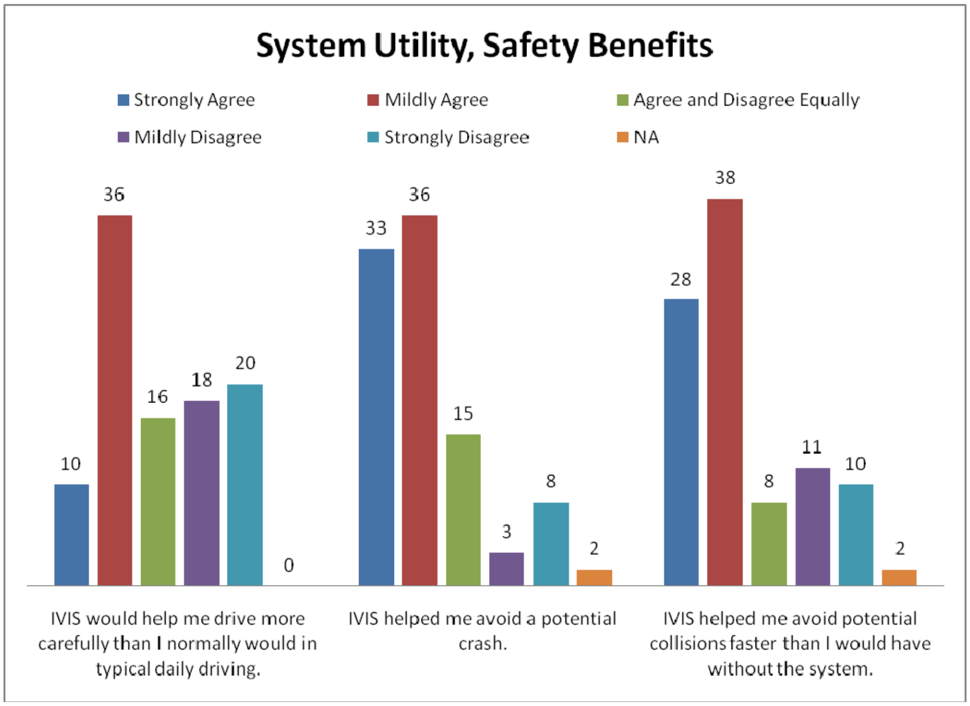

Figure 82. Responses regarding safety benefit of the system

Figure 83 displays participants' level of annoyance with the three alerting systems. Fifty-one percent responded that the lane departure warning was not annoying, and 64% responded that the forward collision warning was not annoying. The percentage of responses drops for the distraction mitigation warning, with 46% reporting that they did not think this alert was annoying.

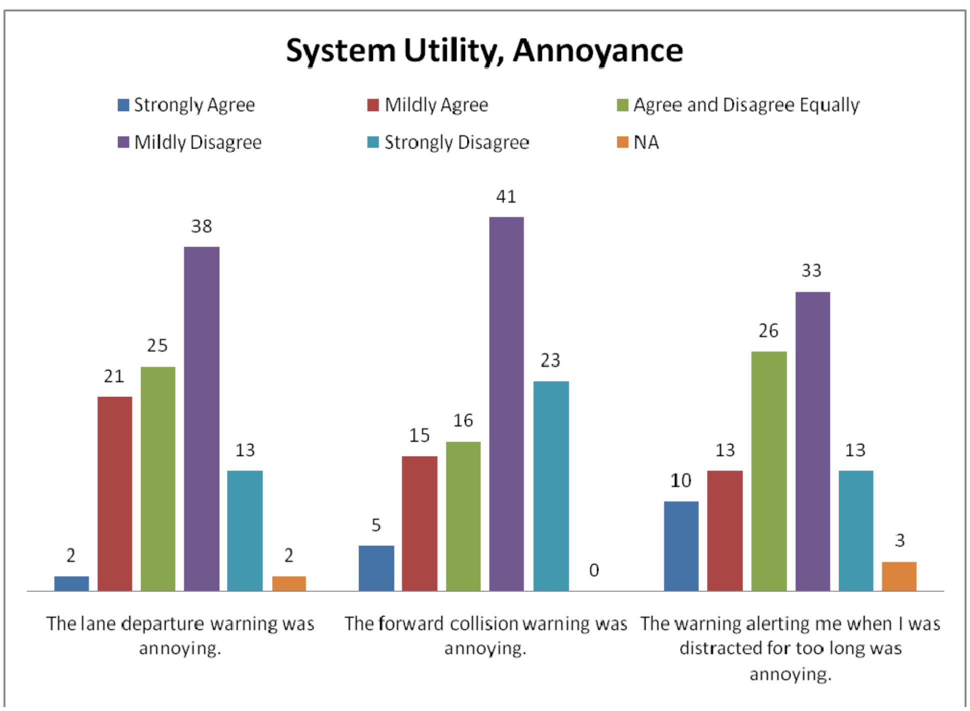

Figure 83. Participants' level of annoyance with the warnings

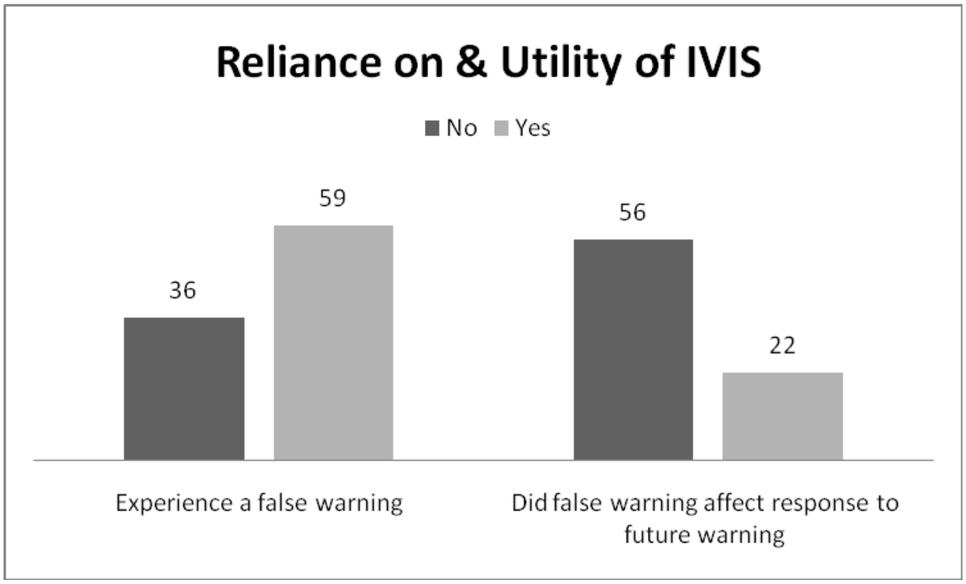

Figure 84. Effect of perceived false warnings on response to future warnings

The limitations of the system were also examined through interview questions regarding whether or not the participants thought that they experienced a false warning, and what effect the false warning had on participants' responses to future warnings. Roughly 60 percent of participants reported experiencing a false warning; of those participants, 22 percent responded that receiving the false warning impacted how they responded to future warnings. For some, the effect was limited to closer scrutiny of the driving environment before providing a steering or braking response to the signaled critical event. For others, their confidence in the system was compromised, leading them to more frequently disregard warnings (see **Figure 76**).

Only 16 percent of participants thought that they might purchase a vehicle with IVIS, compared with 42 percent who reported that they would not and 36 percent who were ambivalent (see **Figure 85**). Roughly one-quarter of the responses were in strong or mild agreement, one-third were neutral, and 38 percent mildly or strongly disagreed with the statement that the participant themselves would not use the system but another driver in his/her household would benefit from its use. In this sample, participants reported 46 adult-aged (25 or older) partners or children (one senior, 65+ years of age), thirteen 15- to 24-year-old males, and ten 15- to 24-year-old females who share or own their own vehicles with the participants.

Participants' willingness to purchase IVIS and the monetary value they place on the system is represented in **Figure 86**. Twenty-one percent reported that they would not purchase IVIS, 53 percent would purchase the system if it were priced under $1000, while 20 percent would purchase it if priced between $1000 and $2000. No participants were willing to pay above $2000 for the system.

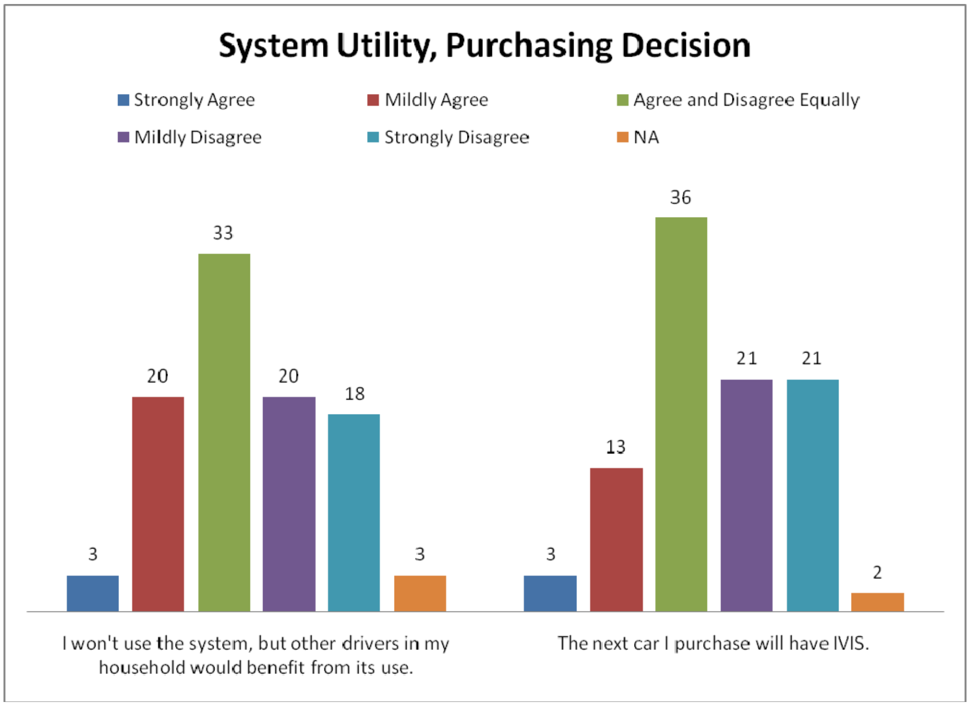

Figure 85. Purchasing decision as a measure of utility

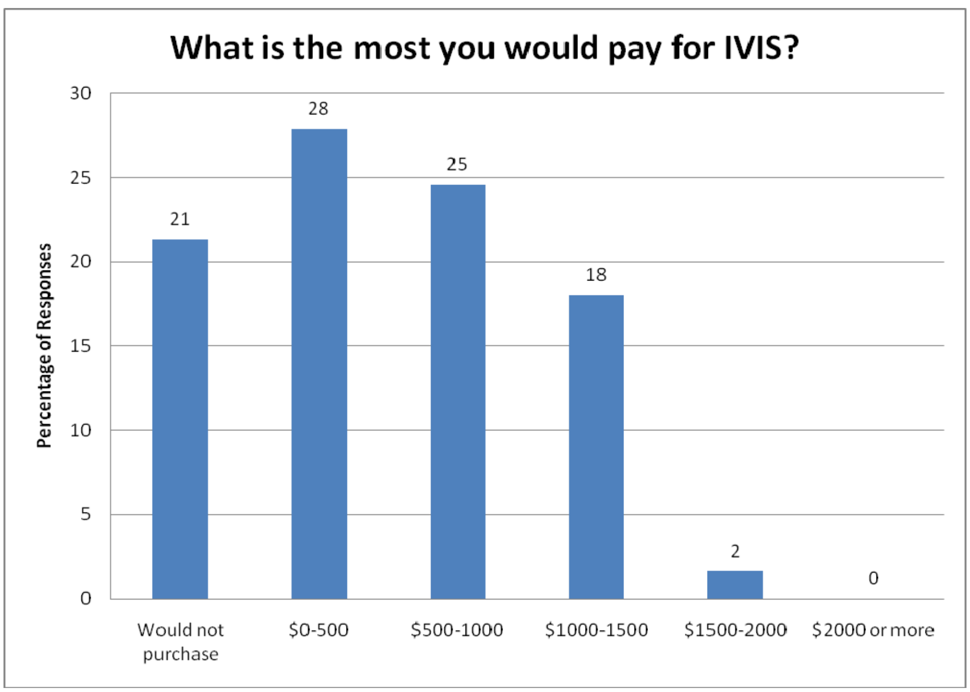

Figure 86. Cost participants willing to pay for the system

3.4.7 Trip Report

Roughly 46 percent of participants reported receiving a trip report after the completion of the second study drive (three participants who were assigned that condition did not recall receiving a report). Of those participants who reported receiving a trip report, over half (54 percent) remarked that they did not consciously change their driving behavior based on the feedback provided in the trip report. Reasons for not changing driving behavior were collected for 13 of the 15 participants. Reasons included not understanding the report or that the information communicated was not meaningful (40 percent); prioritizing alternative approaches (20 percent), which ranged from choosing to prioritize driving at the 45-miles-per-hour speed limit in order to receive the incentive to choosing to prioritize one's own rules for safe driving over those communicated by the report; believing that nothing was wrong with their driving behavior, even if the report presented contradictory evidence (13 percent); and other reasons, such as not being able to read the report or interpreting the feedback as only relevant to the past, and therefore not useful in applying to future, unknown driving situations (13 percent).

For the 46 percent of participants who, after receiving the trip report, remarked that they changed their driving behavior based on its feedback, motivations varied. Some commented that they were made more aware of and therefore paid more attention to speed adherence, following distance, and eyes off of the road after reviewing the trip report. Others commented that they became more "self-conscious" of their driving, with one characterizing the trip report's effect as a layer of surveillance akin to driving in close proximity to a police officer. One participant felt more secure knowing that the system was monitoring her driving and that the warnings were there for her protection. Some participants commented that they attempted to anticipate when the alerts would be triggered, often in order to minimize the amount of annoyance they experienced due to the auditory alerts. One commented that he decided to shift his priority from earning the incentive by performing various distracting tasks while driving, while another attempted to drive more cautiously but to balance this shift with his desire to continue performing the incentive tasks.

Figure 87 compares participant responses to the trip report based on the distraction mitigation condition. Fifty-seven percent of participants who received the trip report and who had distraction mitigation for the final drive remarked that they changed their behavior based on the report's feedback, compared with 36 percent of participants who had no mitigation. This may suggest that the trip report is more effective when used in conjunction with warning systems.

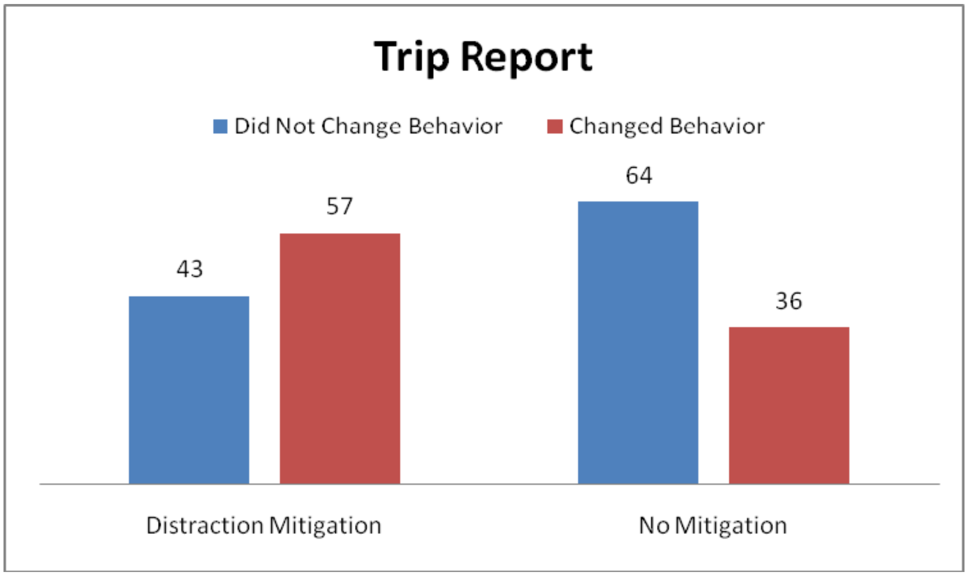

Figure 87. Trip report effect on driving behavior, mitigation and no mitigation compared

The trip report did not appear to affect participants' perception of the distraction mitigation alert, as shown in **Figure 87**.

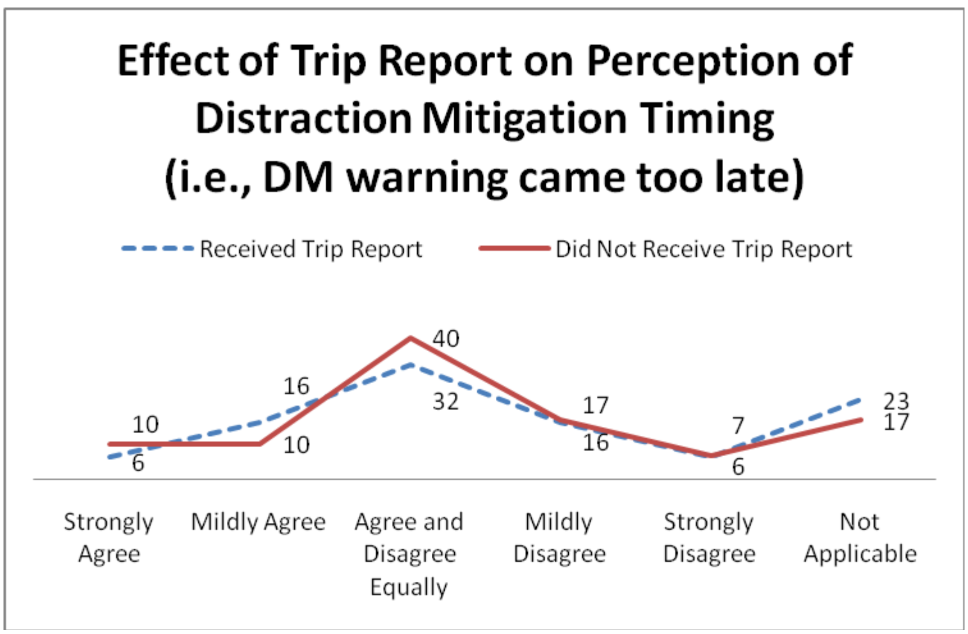

Figure 88. Effect of trip report on acceptance of distraction mitigation warning

4 CONCLUSIONS

The few statistically significant results found are listed in **Table 45**Table 45. The variability present in the data, evidenced by the high standard deviations, was a contributor to the lack of statistically significant results. A possible explanation for the high variability in the data was the complexity of the experimental design. Participants were presented with a great deal (alerts for lane departure, forward collision, and distraction mitigation warnings) in a short amount of time (three 10-minute drives) by a system they had just become familiar with. While the experimental conditions were balanced across participants and participants were trained on the system, all experimental conditions were confounded. The experimental design may reasonably approximate short periods of interaction with an in-vehicle system; however, the close temporal proximity of those interactions may have affected participant's response to the system.

Table 45. Summary of significant results

Independent Variable	Analysis	Dependent Variable	Description of Result
Distraction	Distraction Mitigation Safety Benefit	Minimum Time to Collision	shorter when mitigation present
		Length of Excursion	shorter with no distraction
		Extent of Excursion	shorter with no distraction
		Duration of Excursion	shorter with no distraction
Distraction	Forward Collision Warning Driver Response	Brake Reaction Time	shorter with no distraction
Distraction	Distraction Mitigation Event Driver Response	Accelerator Release Reaction Time	shorter with no distraction
		Brake Reaction Time	shorter with no distraction
		Maximum Brake Reaction Time	shorter with no distraction
Distraction	Distraction Mitigation in Intersection Incursion Event	Brake Reaction Time	shorter with no distraction
		Maximum Brake Reaction Time	shorter with no distraction
		Maximum Steering Rate	smaller with no distraction
Demand	Distraction Mitigation Event Driver Response	Time to Collision at Accelerator Release	longer in low-demand environment
		Time to Collision at Brake Response	longer in low-demand environment
		Time to Collision at Maximum Brake Response	longer in low-demand environment
Mitigation	Distraction Mitigation Event Driver Response	Maximum Brake Reaction Time	longer for adaptive condition

The majority of the statistically significant results occurred in the analysis of distraction mitigation for driver response variables; among them were mitigation and demand. Level of mitigation had a significant effect on maximum brake reaction time with the presence of mitigation showing a 0.07-second-longer reaction time, which is quite small and, given the variability of participant reaction time, unlikely to be consistent. The longer time-to-collision variables in the low-driving-demand portion of the drives range from 0.25 to 0.32 seconds. The headway and lead vehicle deceleration for the distraction mitigation events were the same for both driving demand levels, 1.7 sec and 0.2 g.

Distraction was significant more often than other variables; in fact, distraction was the only variable found statistically significant in the safety benefit analysis. However, the frequency of significance and differences in the means was not what was expected. One explanation could be that participants did not engage in the distraction task in the same manner as in other NADS studies where the task was successful in creating distraction. An examination of participant responses to the distraction tasks determined that participants did engage in the task. During 98 percent of the presentations of the distraction task, the participant saved or deleted at least one message (engaged); during 85% of the presentations, the participant saved or deleted a least 2 messages (very engaged); and during 56% of the presentations, participants saved or deleted 3 or more of the four messages (fully engaged). The mean number of messages saved or deleted per presentation of the distraction task was 2.65 messages, the median was 3 messages, and the mode was 3 messages. Participants commonly glanced back and forth between the in-vehicle distraction task and the roadway, chunking the task. In previous NADS studies where this task was used the task was auditory, simulating a telephone conversation. The visual nature of the text message task used in this study allowed the latitude for distributing interaction with the task over time in a manner that was not possible in the auditory task. Transitions back and forth between the task and the forward scene may not have been fully captured. Allowing this latitude for tasks is consistent with recommended practice for the design of in-vehicle tasks (Society of Automotive Engineers, 2000). The inability of the driver state monitoring to deal with this behavior may have affected the alert timing in such a way that no significant difference between the adaptive and non-adaptive conditions could be found.

The post-drive surveys and interview provided some insight into participants' interaction with the system; in the absence of statistically significant results in the quantitative data, these may be enlightening. The majority of participants did not perceive a difference between adaptive and non-adaptive alerts, and those who did provided a range of responses—often incorrect—accounting for the difference between the alerting systems. Despite this, participants' responses to the timing of the alert systems did vary. For the final event in Study Drive 2, which was a severe lead vehicle braking event, participants responded more favorably to the timing of the adaptive FCW than to the timing of the non-adaptive FCW, regardless of their distraction condition. For the final event in Study Drive 1, which was a strong wind gust, participants also responded more favorably to the adaptive LDW when distracted, although responses were more closely divided with a higher percentage disagreeing with the timing in comparison to the FCW responses. Perhaps most notable regarding the distraction mitigation alert is that of the participants without distraction mitigation, less than 40% indicated as such when asked to rate the distraction mitigation system. When asked to write suggestions to help improve the IVIS system, participant responses further supported the idea that many participants were unclear what constituted distraction mitigation despite training during the briefing session. Because participants overwhelmingly attributed the warnings' triggers to the driving environment, not to the driver's state or a combination of environment and driver, the FCW at the final event was rated more favorably, with more ambivalent responses for the seemingly benign driving environment or to the warning more participants found confusing.

While the majority of participants reported understanding the operation of the system, over half did not think that the safety system monitored the driving environment, and close to three-quarters did not think that it monitored the driver. Significant responses were found with participants' confidence increasing when veering from their lane, keeping an unsafe following distance, driving when tired, reading a map, using a navigation system, or using a cell phone with the system. This trend was not the case; however, for driving with children or adjusting radio settings, both of which participants felt less confident doing with the system. Participants did not transfer the potential safety benefits to other risky driving behaviors or driving environments.

Overall, for the tasks and situations presented, no significant safety benefit was found and no conclusions regarding the safety benefits of the SAVE-IT system can be drawn here. Additional research is needed. We recommend future research employing more focused experimental designs that look at each component of the SAVE-IT system andother kinds of tasks, such as cell phone calls, MP3 searches, lengthy text-message conversations, typing a text-message reply, which drivers would not be able to divide into small chunks may reveal benefits to the SAVE-IT system not seen here.

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Zhang, H., (Harry.Zhang@delphi.com), 23 January 2006. RE: Table for tomorrow. E-mail to T. Brown (tbrown@nads-sc.uiowa.edu)

6 APPENDICES

6.1 Demographic Questionnaire

Study: ___SAVE IT__
Date:__________
Participant: ___________

NADS Driving Survey

The following questions ask about you and your health, your personal vehicle, and your driving patterns. 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 if you choose.

Background Information

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

2) What is your gender?

- ☐ Male
- ☐ Female

3) What is your marital status? (Check only one)

- ☐ Single
- ☐ Married
- ☐ Domestic Partnership
- ☐ Separated or Divorced
- ☐ Widowed

4) What was your total household income last year? (Check only one)

- ☐ 0 - $4,999
- ☐ $5,000 - $9,999
- ☐ $10,000 - $14,999
- ☐ $15,000 - $19,999
- ☐ $20,000 - $29,999
- ☐ $30,000 - $39,999
- ☐ $40,000 - $49,999
- ☐ $50,000 or more

5) What is your present employment status? (Check only one)

- ☐ Unemployed
- ☐ Retired
- ☐ Work part-time
- ☐ Work full-time
- ☐ None of the above

6) What type of work do you do (e.g., teacher, law enforcement official, homemaker)?

____

7) 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

8) 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

9) How old were you when you started to drive? __________ years of age

10) For which of the following vehicles do you currently hold a valid driver's license <u>within</u> the United States? (Check all that apply)

	Vehicle Type	Year When FIRST Licensed (May be Approximate)
☐	Car	____ ____ ____ ____
☐	Truck	____ ____ ____ ____
☐	Motorcycle	____ ____ ____ ____
☐	Other: ________________________	____ ____ ____ ____
☐	Other: ________________________	____ ____ ____ ____

11) Approximately how many miles do you drive per year in each vehicle type? (Check only one for each vehicle)

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

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

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

13) In which environment do you most frequently drive? (Check only one)

- ☐ Rural highway (e.g., Route 1, Route 6, or Route 218)
- ☐ Small town (e.g., Solon, West Branch)
- ☐ Suburban (e.g., Iowa City, Cedar Rapids)
- ☐ City (e.g., Des Moines, Davenport)
- ☐ High density city (e.g., Chicago, Los Angeles)
- ☐ Highway/freeway (e.g., Interstate 80)

14) What speed do you typically drive on the highway when the speed limit is 55 miles per hour? __________mph

15) What speed do you typically drive on the highway when the speed limit is 65 miles per hour? __________mph

16) Have you ever participated in any special driving schools (e.g., Driver's education, AARP or insurance courses, racing school, or as part of law enforcement training)?

- ☐ 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)

	Very Hesitant	Slightly Hesitant	Moderately Confident	Very Confident	Not Applicable
Drive at night	☐	☐	☐	☐	☐
Drive in fog	☐	☐	☐	☐	☐
Drive in rain	☐	☐	☐	☐	☐
Drive in snow or sleet	☐	☐	☐	☐	☐
Drive in heavy traffic	☐	☐	☐	☐	☐
Drive on highways or interstates	☐	☐	☐	☐	☐
Change lanes on multiple-lane highways or interstates	☐	☐	☐	☐	☐
Change lanes in town	☐	☐	☐	☐	☐
Keep up with traffic on interstates	☐	☐	☐	☐	☐
Keep up with traffic on two-lane highways	☐	☐	☐	☐	☐
Keep up with traffic in town	☐	☐	☐	☐	☐
Pass other cars on interstates	☐	☐	☐	☐	☐
Pass other cars on two-lane highways	☐	☐	☐	☐	☐
Make left turns at	☐	☐	☐	☐	☐

	Very Hesitant	Slightly Hesitant	Moderately Confident	Very Confident	Not Applicable
uncontrolled intersections (intersections without traffic signs or lights)					
Exceed the speed limit	☐	☐	☐	☐	☐
Not read traffic signs	☐	☐	☐	☐	☐
Drive when tired	☐	☐	☐	☐	☐
Not wear a safety belt	☐	☐	☐	☐	☐
Veer from your lane	☐	☐	☐	☐	☐
Keep less than the suggested following distance between you and the car in front of you	☐	☐	☐	☐	☐
Drive while smoking	☐	☐	☐	☐	☐
Drive after drinking alcohol	☐	☐	☐	☐	☐
Drive with children	☐	☐	☐	☐	☐
Adjust your radio settings	☐	☐	☐	☐	☐
Read a map	☐	☐	☐	☐	☐
Use an in-vehicle navigation systems, such as TomTom®	☐	☐	☐	☐	☐
Use a wireless phone	☐	☐	☐	☐	☐

18) When driving, how confident do you feel when you perform each of the following tasks/maneuvers? (Check the most appropriate answer for each task/maneuver)

	Very Hesitant	Slightly Hesitant	Moderately Confident	Very Confident	Not Applicable
Drive at night	☐	☐	☐	☐	☐
Drive in fog	☐	☐	☐	☐	☐
Drive in rain	☐	☐	☐	☐	☐
Drive in snow or sleet	☐	☐	☐	☐	☐
Drive in heavy traffic	☐	☐	☐	☐	☐
Drive on highways or interstates	☐	☐	☐	☐	☐
Change lanes on multiple-lane highways or interstates	☐	☐	☐	☐	☐
Change lanes in town	☐	☐	☐	☐	☐
Keep up with traffic on interstates	☐	☐	☐	☐	☐
Keep up with traffic on two-lane highways	☐	☐	☐	☐	☐
Keep up with traffic in town	☐	☐	☐	☐	☐
Pass other cars on interstates	☐	☐	☐	☐	☐
Pass other cars on two-lane highways	☐	☐	☐	☐	☐
Make left turns at uncontrolled intersections (intersections without traffic signs or lights)	☐	☐	☐	☐	☐
Exceed the speed limit	☐	☐	☐	☐	☐
Not read traffic signs	☐	☐	☐	☐	☐

	Very Hesitant	Slightly Hesitant	Moderately Confident	Very Confident	Not Applicable
Drive when tired	☐	☐	☐	☐	☐
Not wear a safety belt	☐	☐	☐	☐	☐
Veer from your lane	☐	☐	☐	☐	☐
Keep less than the suggested following distance between you and the car in front of you	☐	☐	☐	☐	☐
Drive while smoking	☐	☐	☐	☐	☐
Drive after drinking alcohol	☐	☐	☐	☐	☐
Drive with children	☐	☐	☐	☐	☐
Adjust your radio settings	☐	☐	☐	☐	☐
Read a map	☐	☐	☐	☐	☐
Use an in-vehicle navigation systems, such as TomTom®	☐	☐	☐	☐	☐
Use a wireless phone	☐	☐	☐	☐	☐

Personal Vehicle

19) How many vehicles does your household own? (Check only one)

☐ 1
☐ 2
☐ 3
☐ 4
☐ 5 or more

20)
a. How many vehicles do you own personally? (Check only one)

☐ 0
☐ 1
☐ 2
☐ 3
☐ 4
☐ 5 or more

b. Of the vehicles that you personally own, how many of which are you the primary driver?

☐ 1
☐ 2
☐ 3
☐ 4
☐ 5 or more

c. For all of the vehicles you own, but are not the primary driver, what is the age, gender, and your relationship to the primary driver (mark all that apply)?

Age	Gender		Relationship
☐ 14-15	☐ Male	☐ Female	______________________
☐ 16-18	☐ Male	☐ Female	______________________
☐ 19-25	☐ Male	☐ Female	______________________
☐ 25-35	☐ Male	☐ Female	______________________
☐ 36-54	☐ Male	☐ Female	______________________
☐ 55-64	☐ Male	☐ Female	______________________
☐ 65-more	☐ Male	☐ Female	______________________

21) What type of automobile do you drive most often?

Year	Make (e.g., Ford, Toyota)	Model (e.g., Escort, Celica)
___ ___ ___ ___	______________________	______________________

22)

a. Which of the following features does this automobile have? (Check all that apply)

_____ None of these
_____ Air Bag
_____ Anti-Lock Brakes
_____ Automatic Transmission
_____ CB Radio
_____ CD/Cassette Player
_____ Cruise Control
_____ Power Brakes
_____ Power Steering
_____ Radar Detector
_____ Sun/Moon Roof
_____ Other technologies (e.g., trip computer, vehicle information center)
Please list other technologies: ________________________________

b. Of the features you marked above, please rank these features from those that most influenced your decision to purchase the vehicle to those that least influenced your decision to purchase the vehicle. Leave blank features that your vehicle does not have. (1 = **most** influenced)

_____ None of these
_____ Air Bag
_____ Anti-Lock Brakes
_____ Automatic Transmission
_____ CB Radio
_____ CD/Cassette Player
_____ Cruise Control
_____ Power Brakes
_____ Power Steering
_____ Radar Detector
_____ Sun/Moon Roof
_____ Other technologies (e.g., trip computer, vehicle information center)
Please list other technologies: ____

c. After having driven the vehicle, please rank your features from most to least important to you today. Leave blank features that your vehicle does not have. (1 = **most** important)

_____ None of these
_____ Air Bag
_____ Anti-Lock Brakes
_____ Automatic Transmission
_____ CB Radio
_____ CD/Cassette Player
_____ Cruise Control
_____ Power Brakes
_____ Power Steering
_____ Radar Detector
_____ Sun/Moon Roof
_____ Other technologies (e.g., trip computer, vehicle information center)
Please list other technologies: ____

Violations

23) Within the past five years, how many moving violations have you received?

☐ 0
☐ 1 - 2
☐ 3 - 4
☐ 5 or more
☐ Not sure

24) Within the past five years, have you received a ticket for any of the following? (Please check No or Yes for each and write how many tickets you have received in the last column)

	No	Yes	How many?
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	☐	☐	
Driving while intoxicated	☐	☐	
Other (please specify) ______________________			

Accidents

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

☐ 0 (Go to question # 26)
☐ 1
☐ 2
☐ 3
☐ 4 or more

Please provide the following information for each accident.

Accident 1

	No	Yes
Was another vehicle involved?	☐	☐
Was a pedestrian involved?	☐	☐
Were you largely responsible for this accident?	☐	☐
Did you go to driver's rehabilitation?	☐	☐

Weather Condition: ____________________

Month/Year: ____________________

Brief Description: ____________________

____

Accident 2

	No	Yes
Was another vehicle involved?	☐	☐
Was a pedestrian involved?	☐	☐
Were you largely responsible for this accident?	☐	☐
Did you go to driver's rehabilitation?	☐	☐

Weather Condition: ______________________________

Month/Year: ______________________________

Brief Description: ______________________________

____

Accident 3

	No	Yes
Was another vehicle involved?	☐	☐
Was a pedestrian involved?	☐	☐
Were you largely responsible for this accident?	☐	☐
Did you go to driver's rehabilitation?	☐	☐

Weather Condition: ______________________________

Month/Year: ______________________________

Brief Description: ______________________________

____

Brief Description: ______________________________

Health Status

26)

a) What type of prescription glasses or contact lenses are you wearing as you drive in today's study? (Check only one)

- ❒ None (Go to question # 27)
- ❒ Single Lens Glasses
- ❒ Bifocals
- ❒ Trifocals
- ❒ Contact Lenses

b) How many years ago did you obtain your current pair of glasses/contact lenses? (Check only one)

- ❒ 0 - 3
- ❒ More than 3

c) What type of visual problem do you have? (Check only one)

- ❒ Distance - can only see items that are near without glasses
- ❒ Near - can only see items that are far away without glasses
- ❒ Distance and Near - cannot see items that are near or far without glasses

27) Do you currently use a hearing aid? (Check only one)

❒ No
❒ Yes

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

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

29) 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

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

□ No
□ Yes (Please list all)

____

31) Have you consumed any alcohol or other drugs in the past 24 hours? (Check only one)

□ No
□ Yes (Please list all)

____

____

Other Studies

32) Have you participated in other driving studies?

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

Study 1

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

- ☐ Actual car - only
- ☐ Another simulator - only
- ☐ The National Advanced Driving Simulator only
- ☐ Both - actual car and another simulator
- ☐ Both - actual car and the National Advanced Driving Simulator

Brief Description:

____

____

Study 2

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

- ☐ Actual car - only
- ☐ Another simulator - only
- ☐ The National Advanced Driving Simulator only
- ☐ Both - actual car and another simulator
- ☐ Both - actual car and the National Advanced Driving Simulator

Brief Description:

____

____

Study 3

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

- ☐ Actual car - only
- ☐ Another simulator - only
- ☐ The National Advanced Driving Simulator only
- ☐ Both - actual car and another simulator
- ☐ Both - actual car and the National Advanced Driving Simulator

Brief Description:

____

____

6.2 Interpersonal Trust Questionnaire

Interpersonal Trust Survey

Please circle the number on the scale above the statement that best describes how you feel about that statement.

1. Hypocrisy is on the increase in our society.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

2. In dealing with strangers one is better off to be cautious until they have provided evidence that they are trustworthy.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

3. This country has a dark future unless we can attract better people into politics.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

4. Fear and social disgrace or punishment rather than conscience prevents most people from breaking the law.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

5. Using the honor system of *not* having a teacher present during exams would probably result in increased cheating.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

6. Parents usually can be relied on to keep their promises.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

7. The United Nations will never be an effective force in keeping world peace.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

8. The judiciary is a place where we can all get unbiased treatment.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

9. Most people would be horrified if they knew how much news that the public hears and sees is distorted.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

10. It is safe to believe that in spite of what people say most people are primarily interested in their own welfare.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

11. Even though we have reports in newspaper, radio, and T.V., it is hard to get objective accounts of public events.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

12. The future seems very promising.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

13. If we really knew what was going on in international politics, the public would have reason to be more frightened than they now seem to be.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

14. Most elected officials are really sincere in their campaign promises.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

15. Many major national sports contests are fixed in one way or another.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

16. Most experts can be relied upon to tell the truth about the limits of their knowledge.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

17. Most parents can be relied upon to carry out their threats of punishment.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

18. Most people can be counted on to do what they say they will do.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

19. In these competitive times one has to be alert or someone is likely to take advantage of you.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

20. Most idealists are sincere and usually practice what they preach.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

21. Most salesmen are honest in describing their products.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

22. Most students in school *would not* cheat even if they were sure of getting away with it.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

23. Most repairmen will not overcharge even if they think you are ignorant of their specialty.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

24. A large share of accident claims filed against insurance companies are phony.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

25. Most people answer public opinion polls honestly.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

6.3 Training Materials

6.3.1 IVIS Training

Slide 1

IVIS Training

Delphi-SAVE-IT Study

Slide 2

In this slide show, you will be introduced to IVIS and to the IVIS functions you will use during your drives today.

When you feel comfortable with the system's display and controls, you will receive additional training on the specific tasks you'll complete using IVIS.

Slide 3

The first set of slides provide basic information about how to use IVIS. They also provide instruction on how to operate the navigation and the text message systems, which you will use during your drives today.

After reviewing these slides, you should know how to turn on the system, open different functions, and use specific features on the navigation and text message screens.

The researcher can answer questions you may have about the system, as well as the functions you will use today.

Slide 4

What is IVIS?

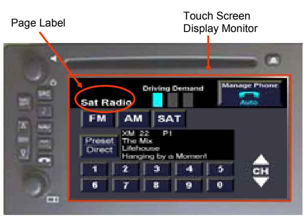
- A single interface used to manage a variety of technologies that drivers use while driving.
  - Navigation system
  - Text messaging
  - Phone, Radio, CD/MP3, etc.
- A system that gauges driving safety and provides feedback to the driver.
  - Provides alerts in order to warn the driver when their safety is threatened
  - Also provides alerts when the driver is distracted

Slide 5

IVIS Display & Controls System Off

Slide 6

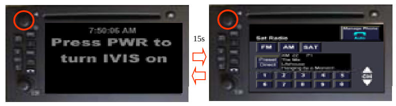
IVIS Display & Controls System On



Slide 7

Turning On IVIS

- Press Power Button to turn on IVIS
- One of the system's pages will appear on screen

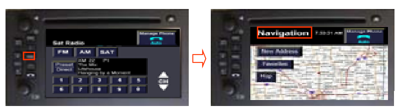


In this example, the default screen is the SAT Radio page.

Slide 8

Using the Navigation System

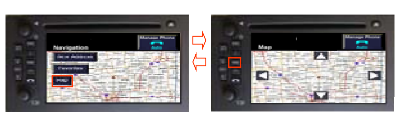
- Press the NAV button to enter the Navigation page



Slide 9

Using the Navigation System

- Touch the "Map" button on the touch-screen to go to the Map page



- Press the NAV button to return to the Navigation page

Slide 10

Using the Text Message System

- Press the Text Message button to enter the Text Message page
- Text Message Inbox Folder will appear on screen

Slide 11

Using the Text Message System

- Touch the folder buttons at the bottom of the screen to move between different folders

Slide 12

Using the Text Message System

- Touch the “Save” button on the screen to move a message to the Saved folder

Slide 13

Using the Text Message System

- Touch the “Delete” button on the screen to delete the current message

Slide 14

You have finished reviewing the first set of slides. You should know how to:

- ✓ Turn on the system
- ✓ Identify what page you are viewing
- ✓ Open the navigation system
- ✓ Open the “map” feature of the navigation system
- ✓ Return to the navigation page from the map page
- ✓ Open the text messaging system
- ✓ Save and delete messages in the text message system
- ✓ Move between the text message Inbox and Saved folders

You may take this time to review slides before you proceed with additional training on IVIS. The researcher can answer questions you have about the system or its functions.

Slide 15

IVIS is also a system that gauges driving safety, and provides feedback to the driver, in the form of alerts, when necessary. The following slides provide basic information about the alerts you may experience during your drives.

In some instances the system will issue alerts based solely on the driving environment. In other instances, it may issue alerts taking into account your driving behavior. One of the ways it evaluates your behavior is through information collected from a camera that watches your head and eye movement.

Alerts of this type are called adaptive warnings because they adapt to your behavior under various driving and road conditions.

Slide 16

After reviewing these slides, you should be familiar with each of the alerts, know what the alerts indicate, and have a basic understanding of the trip report.

The researcher can answer questions you may have about the system, as well as the functions you will use today.

Slide 17

Alerts to Reduce Distraction

An amber circle of light ( ) may flash on the windshield just under the horizon.

Click on the road to play a video clip of the flashing light

Slide 18

Alerts to Reduce Distraction

Buttons or features on the IVIS display may change color.

- Advisory message will notify you if using an IVIS function is advised against
- Certain functions of IVIS lock-out
- Changes to the display color of buttons (from white to amber to gray if function is not available)

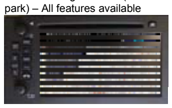
Advisory Message

Buttons change color from white to amber, or are grayed out to indicate advisory against some or many IVIS tasks.

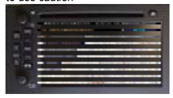
Slide 19

Alerts to Reduce Distraction: Navigation Screen Example

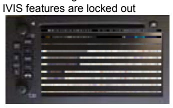
Lowest Driving Demand (car in park) – All features available



Low Driving Demand – Advised to use caution



Medium Driving Demand – Some IVIS features are locked out



High Driving Demand – All IVIS features are locked out

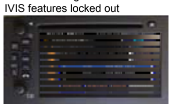
Slide 20

Alerts to Reduce Distraction: Text Message Screen Example

Lowest Driving Demand (car in park) – All features available

Low Driving Demand – Advised to use caution

Medium Driving Demand – Some IVIS features locked out



High Driving Demand – All IVIS features are locked out

Slide 21

Lane Departure Warning

If you cross the lane without using your turn signal:

- A series of beeps may sound click to hear beeping
- The driver's seat may vibrate
- A red circle of light may flash on the windshield just under the horizon

Slide 22

Forward Collision Warning

If the distance between your car and the car in front of you is too short:

- A series of beeps may sound click to hear beeping
- The throttle (gas peddle) may release automatically, slowing down the vehicle
- A red circle of light may flash on the windshield just under the horizon
- An amber circle of constant (not flashing) light may appear on the windshield just under the horizon

Slide 23

The Trip Report

IVIS may provide a report between your drives that gives you feedback on your driving performance.

Feedback may include information such as:

- Number of severe braking events
- Number of unintentional lane changes
- Amount of time attention was diverted from the roadway

Slide 24

You have finished reviewing the second set of slides. You should be familiar with the different alerts and what they indicate:

- ✓ Distraction Reduction alerts
  - ✓ Visual alert on windshield
  - ✓ Changes to the IVIS display
- ✓ Lane Departure Warning
  - ✓ Audio alert
  - ✓ Vibrating seat
  - ✓ Visual alert on windshield
- ✓ Forward Collision Warning
  - ✓ Audio alert
  - ✓ Throttle release
  - ✓ Visual alert on windshield

You also should have a basic understanding of the trip report.

Slide 25

You may take this time to review slides before we end the IVIS training.

The researcher can answer questions you have about the system or its functions.

6.3.2 Navigation Task Training

NAVIGATION TASK TRAINING

SAVE-IT

This task involves you obtaining route information and identifying landmarks and street intersections using the IVIS system.

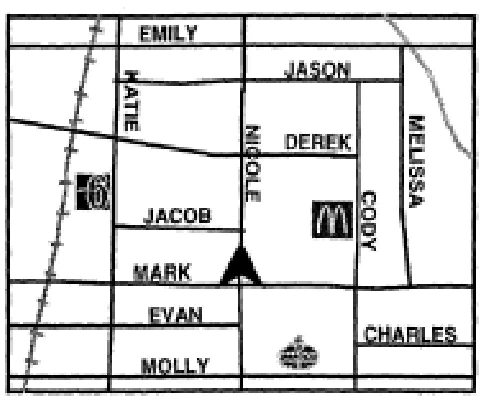
During each drive, an auditory message from IVIS will refer you to the navigation system for driving directions.

- You will hear *"Turn ahead. Please check the navigation system."*
- Press the NAV button on the IVIS display to call up the navigation system.
- Touch the "Map" button on the screen to bring up the navigation instructions on the display.
- After viewing the navigation information, press the NAV button to confirm the information presented.
- Complete the turn when appropriate.

Additionally, during one of your drives, you will receive an auditory message from IVIS requesting that you identify landmarks and street intersections on a map presented on the IVIS navigation system.

- You will hear *"Please activate the map and identify the following information…"*
- The question will ask you to find a landmark or street. For example:

  "What street is the Motel 6 on?"
- Press the NAV button on the IVIS display to call up the navigation system.
- Touch the "Map" button on the screen.
- Review the map and provide a verbal response to the question.



What would your answer be?

- After answering the question, press the NAV button to end the task.

Using the Navigation System

- Press the NAV button to enter the Navigation page

Using the Navigation System

- Touch the “Map” button on the touch-screen to go to the Map page

- Press the NAV button to return to the Navigation page

6.3.3 Text Message Task Training

WORKING MEMORY TASK TRAINING

Delphi SAVE-IT Study

This task will simulate receiving and responding to a text message. You will perform this task using the IVIS system while driving the simulator. For this task, you will read a number of sentences on the IVIS display and answer specific questions about the sentences. Each sentence will have three parts, including: a subject, a verb, and, an object. For example, if you hear the sentence:

The boy hit the ball.

“boy” is the subject, “hit” is the verb, and “ ball” is the object.

In the following sentence please identify the subject, the verb, and the object:

The frog ate the fly.

Your task will have two parts. First, you will be asked to determine whether or not the sentence makes sense. In this context, “makes sense” means the action expressed in the sentence could happen. The examples presented previously make sense because a boy could hit a ball, and, a frog could eat a fly. An example of a nonsensical sentence or one that does not make sense, is:

The dog ate the noise.

This sentence is nonsensical because it cannot happen.

Immediately after you read a sentence, you should try to decide if it makes sense and respond as quickly as possible. If the sentence makes sense, you will press the “SAVE” button on the IVIS display. The message will be moved to the “Saved” folder on the text message screen. Press the “Inbox” tab at the bottom of the screen to retrieve your next message from the text message inbox. If the sentence does not make sense, you will press the “DELETE” button on the IVIS display. After you press “DELETE,” the next message in the Inbox will appear in the message window.

Sentences will be presented in groups of 4. The second part of your task is to remember a specified word in each sentence, so that you can say these words aloud when prompted by the experimenter at the end of a group of sentences. The specified word always will be the subject of the sentence. The IVIS system will begin the task by presenting an audio message, stating “Incoming Message. Determine the subjects.” You should remember the specified word even if the sentence does not make sense. When all sentences in the group have been completed, the experimenter will say “Now” to indicate that you should say the specified words aloud as quickly as possible. You do not need to say them in the order presented. You should just try to recall as many of the subjects as possible.

Please do not ask questions or say anything other than the answers to the questions during this time, unless it is urgent.

To summarize, one text message will consist of 4 sentences, presented one sentence at a time on the display. The task begins when you hear “Incoming Message. Determine the subjects.” You will then read each of the 4 sentences, one at a time. As soon as possible after each sentence, you will press “SAVE” or “DELETE” to indicate whether or not the sentence makes sense. After you respond to the last sentence, you will be prompted with “NOW,” which is the signal for you to say aloud the subjects in each of the sentences. Following the completion of the task, the IVIS system will return to its standby state without driver intervention.

Here is an example of the types of sentences to which you will read and respond. You can see the correct responses in capital letters next to the sentences.

Example

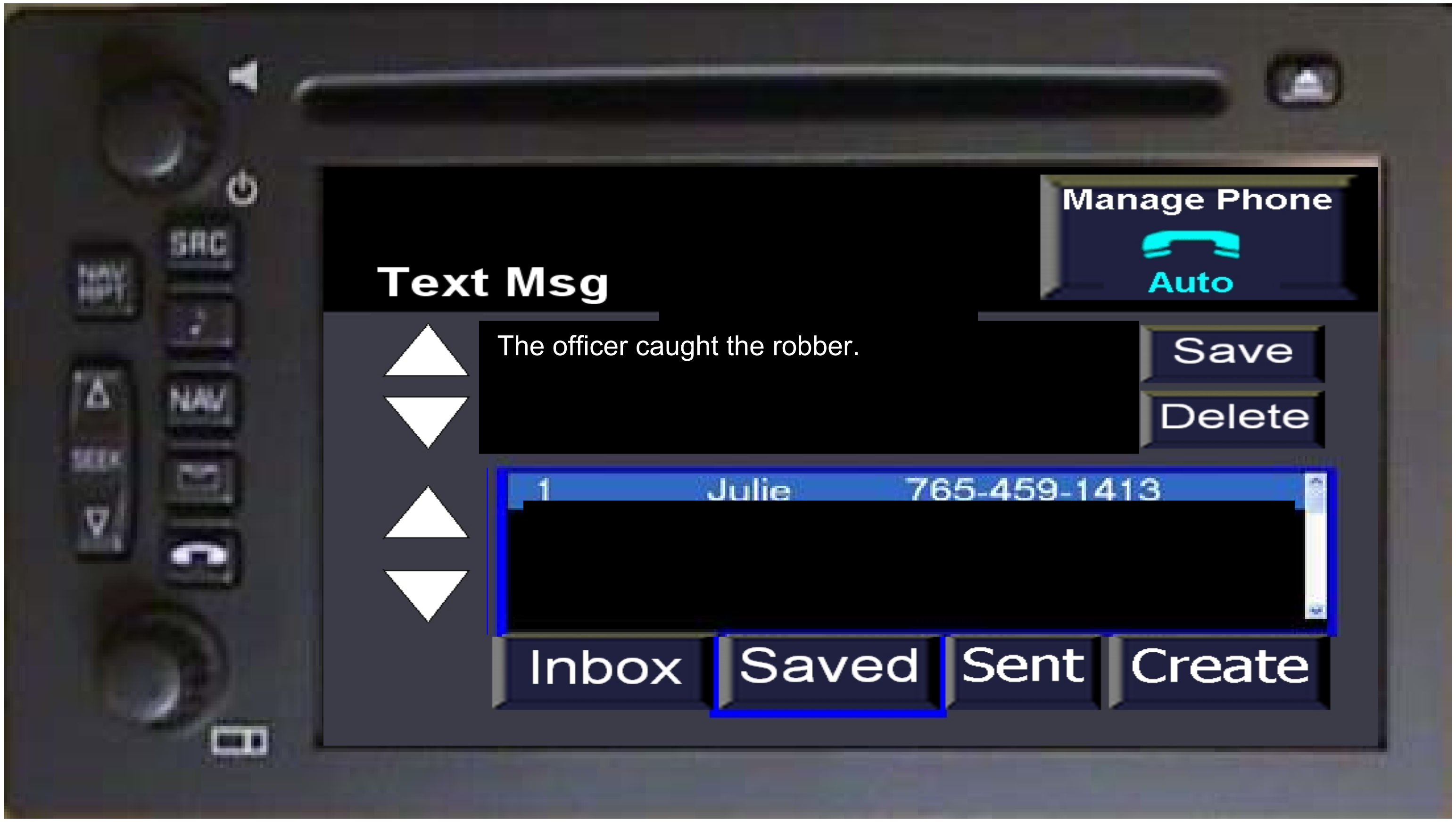
“Incoming Message. Determine the subjects.”

The boy drank the water.	SAVE.
The girl swallowed the dream.	DELETE.
The fish ate the ceiling.	DELETE.
The shortstop caught the ball.	SAVE.

Now.

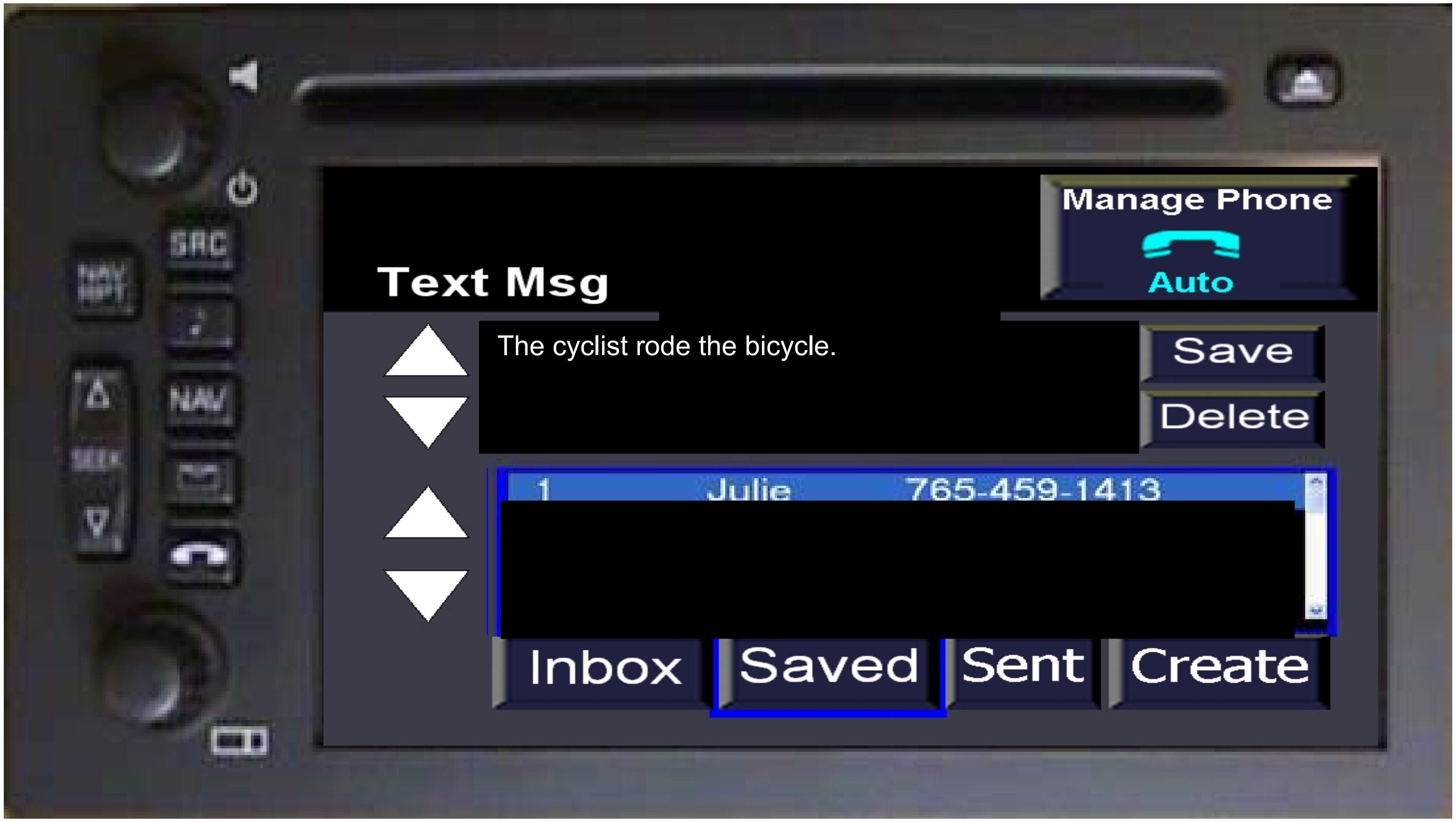
BOY, GIRL, FISH, SHORTSTOP.

Auditory request: *"Incoming message. Determine the subjects."*


Manage Phone
Auto
Text Msg
The officer caught the robber.
Save
Delete
1 Julie 765-459-1413
Inbox
Saved
Sent
Create
SRC
NAV
SEEK


Manage Phone
Auto
Text Msg
The goat ate the ocean.
Save
Delete
1 Julie 765-459-1413
2 Unknown 219-944-2598
3 Dad 765-854-0097
4
Inbox
Saved
Sent
Create
SRC
NAV
SEEK


Text Msg
Manage Phone
Auto
The cyclist rode the bicycle.
Save
Delete
1 Julie 765-459-1413
2 Unknown 219-944-2598
3 Dad 765-854-0097
4
Inbox
Saved
Sent
Create
SRC
NAV
SEEK


Manage Phone
Auto
Text Msg
The cyclist rode the bicycle.
Save
Delete
1 Julie 765-459-1413
Inbox
Saved
Sent
Create
SRC
NAV
SEEK


Manage Phone
Auto
Text Msg
The maid boiled the rock.
Save
Delete
1 Julie 765-459-1413
2 Unknown 219-944-2598
3 Dad 765-854-0097
4
Inbox
Saved
Sent
Create
SRC
NAV

Now.

6.4 Warning Response Questionnaire

Study: SAVE IT
Date:__________
Participant: ____________

Warning Response Questionnaire

Please read each question carefully. If you did not experience alerts during this drive, write "Not applicable" in the space provided. If something is unclear, ask the research assistant for help.

1) List the alerts you experienced during this drive:____
____
____
____
____

For the following questions, circle the number that best represents your answer.

2) The **forward collision warning** came too late for me to safely respond to my driving environment.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

3) The **lane departure warning** came too late for me to safely respond to my driving environment.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

4) The **distraction mitigation alert** came too late for me to safely respond to my driving environment.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

6.5 Post-Drive Questionnaires

6.5.1 Wellness Survey

Study: SAVE IT

Date: ____________________

Participant #:______________

WELLNESS SURVEY

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

* 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.

6.6 Debriefing Materials

6.6.1 Mental Model Exercise

Study: SAVE-IT

Date:_______________

Participant:___________

Mental Model Exercise

A mental model is a model "people have of themselves, others, the environment, and the things with which they interact" (Norman 1988). As a user of a device or form of technology, your model is what you, the user, develop to explain the operation of the gadget or system.

Please draw your mental model of how IVIS works.

6.6.2 Mental Model Interview Script

Study:__SAVE-IT______

Date:________________

Participant:___________

Mental Model Interview Script

Document for research staff only. Interview will include, but is not limited to, these questions in order to accommodate follow-up questions regarding the system and the driver's experience using it while driving.

Questions about user's perceived understanding of the system:

1. Using your mental model, explain to me the relationship between (a) the driver and the vehicle.

2. Now explain the relationship between (b) the driver and the system.

3. Now explain the relationship between © the vehicle and the system.

Comparative questions establishing the distinctions the participant makes between a 'baseline' driving experience (driving his/her own vehicle) and a driving experience using the warning system:

4. How was your experience driving with the system similar to your experience driving your personal vehicle?

5. How was your experience driving with the system different than your experience driving your personal vehicle?

And between the adaptive and non-adaptive system:

6. How was your experience driving with the adaptive system similar to your experience driving without the adaptive system.

7. How was your experience driving with the adaptive system different than your experience driving without the adaptive system.

6.6.3 Critical Event & Trip Report

Study: SAVE-IT

Date:_______________

Participant:__________

Critical Event & Trip Report Interview Script

Document for research staff only. Interview will include, but is not limited to, these questions in order to accommodate follow-up questions regarding the system and the driver's experience using it while driving.

After reviewing the critical event (lane departure, forward collision, intersection incursion) for each drive, the researcher will ask the participant the following questions (slight variations in the questions may occur based on the actual driving experience):

1. Describe what happened during this event. [user reliance]
2. Did you receive a warning during this event?
    a. What do you think triggered the warning? [user reliance, user understanding]
    b. When you were alerted to the fact that you were departing your lane, and the vehicle was in the oncoming lane, what went through your mind as you reacted? [reaction to the system]

    OR

    c. When you were alerted to the fact that you were about to collide with the vehicle in front of you, what went through your mind as you reacted? [reaction to the system]

    OR

    d. At the intersection in the final drive, what went through your mind as you reacted? [reaction to the system]

    e. How did the warning affect your ability to handle this event? [user reliance, user understanding]

3. What was your level of confidence as you experienced the critical event? [user reliance]

Very Unconfident	Slightly Unconfident	Slightly Confident	Very Confident	Not Applicable

4. How confident would you feel about your ability to handle this event if you hadn't received a warning? [user reliance]

Very Unconfident	Slightly Unconfident	Slightly Confident	Very Confident	No Change	Not Applicable

5. What effect do you think the trip report had on your response to the intersection event in the final drive? [user reliance]

a. Did you consciously change your driving behavior because of the report's feedback?

b. If so, provide an example of a change you made in your driving behavior in the final drive.

c. If not, why?

After you finish discussing the critical events, ask the following questions:

6. Were you presented with a false warning? [user reliance, perceived utility]

    a. If so, what was your reaction to the false warning?

    b. Using an example from your drive, how did the false warning affect your response to future warnings from the Driver Safety Management System?

7. Were there instances where you *relied* on the system to alert you of an impending critical event, instead of using it as a 'backup' system? [user reliance]

    a. If so, provide an example.

    b. If not, why?

8. Were there instances where you disregarded the system's warnings? [user reliance, perceived utility]

    a. If so, provide an example.

    b. If not, why?

6.6.4 Distraction and Demand Evaluation

Study: SAVE-IT______

Date:________________

Participant:___________

Distraction & Demand Evaluation

Distraction: something that diverts the attention and prevents concentration on the driving task

Demand: driving task workload

After reviewing anchor video clips of distraction and demand while driving, please rate your examples shown from your drives using the anchors to guide your evaluation.

Please make a slash across the line to indicate the level of distraction and the level of demand for each of your examples.

Drive Number________

Level of Distraction

Low ______________________________ Middle ______________________________ High

Level of Demand

Low ______________________________ Middle ______________________________ High

Drive Number________

Level of Distraction

Low ______________________________ Middle ______________________________ High

Level of Demand

Low ______________________________ Middle ______________________________ High

Drive Number________

Level of Distraction

Low ______________________________ Middle ______________________________ High

Level of Demand

Low ______________________________ Middle ______________________________ High

Drive Number________

Level of Distraction

Low ______________________ Middle ______________________ High

Level of Demand

Low ______________________ Middle ______________________ High

Drive Number________

Level of Distraction

Low ______________________ Middle ______________________ High

Level of Demand

Low ______________________ Middle ______________________ High

Drive Number________

Level of Distraction

Low ______________________ Middle ______________________ High

Level of Demand

Low ______________________ Middle ______________________ High

Drive Number________

Level of Distraction

Low ______________________ Middle ______________________ High

Level of Demand

Low ______________________ Middle ______________________ High

Drive Number_________

Level of Distraction

Low Middle High

Level of Demand

Low Middle High

6.6.5 System Utility Questionnaire

Study: SAVE IT
Date: __________
Participant: __________

System Utility Questionnaire

The following questions ask about your use of and opinions related to IVIS. Please read each question carefully, circling the number that best represents your answer, unless otherwise directed. 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) IVIS would help me drive more carefully than I normally would in typical daily driving.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

2) The lane departure warning was annoying.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

3) The forward collision warning was annoying.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

4) The warning alerting me when I was distracted for too long was annoying.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

5) The forward collision warning came too late for me to safely respond to my driving environment.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

6) The lane departure warning came too late for me to safely respond to my driving environment.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

7) The distraction mitigation warning came too late for me to safely respond to my driving environment.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

8) How confident would you feel driving in the following conditions or performing the following maneuvers **if your vehicle had IVIS**? (Check the most appropriate answer for each condition)

	Very Hesitant	Slightly Hesitant	Moderately Confident	Very Confident	Not Applicable
Drive at night	☐	☐	☐	☐	☐
Drive in fog	☐	☐	☐	☐	☐
Drive in rain	☐	☐	☐	☐	☐
Drive in snow or sleet	☐	☐	☐	☐	☐
Drive in heavy traffic	☐	☐	☐	☐	☐
Drive on highways or interstates	☐	☐	☐	☐	☐
Change lanes on multiple-lane highways or interstates	☐	☐	☐	☐	☐
Change lanes in town	☐	☐	☐	☐	☐
Keep up with traffic on interstates	☐	☐	☐	☐	☐
Keep up with traffic on two-lane highways	☐	☐	☐	☐	☐
Keep up with traffic in town	☐	☐	☐	☐	☐
Pass other cars on interstates	☐	☐	☐	☐	☐
Pass other cars on two-lane highways	☐	☐	☐	☐	☐
Make left turns at uncontrolled intersections (intersections without traffic signs or lights)	☐	☐	☐	☐	☐
Exceed the speed limit	☐	☐	☐	☐	☐
Not read traffic signs	☐	☐	☐	☐	☐
Drive when tired	☐	☐	☐	☐	☐
Not wear a safety belt	☐	☐	☐	☐	☐
Veer from your lane	☐	☐	☐	☐	☐
Keep less than the suggested	☐	☐	☐	☐	☐

	Very Hesitant	Slightly Hesitant	Moderately Confident	Very Confident	Not Applicable
following distance between you and the car in front of you					
Drive while smoking	☐	☐	☐	☐	☐
Drive after drinking alcohol	☐	☐	☐	☐	☐
Drive with children	☐	☐	☐	☐	☐
Adjust your radio settings	☐	☐	☐	☐	☐
Read a map	☐	☐	☐	☐	☐
Use an in-vehicle navigation systems, such as TomTom®	☐	☐	☐	☐	☐
Use a wireless phone	☐	☐	☐	☐	☐

9)IVIS helped me avoid a potential crash.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

10) IVIS helped me avoid potential collisions faster than I would have without the system.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

11) I won't use the system, but other drivers in my household would benefit from its use.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

12) The next car I purchase will have IVIS.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

13) What is the most you would pay for IVIS?

☐ I would not purchase an IVIS system
☐ $0 - $500
☐ $500 - $1000
☐ $1000 - $1500
☐ $1500 - $2000
☐ $2000 or more

14) Overall, what suggestions would you give to help improve the IVIS system?

6.6.6 Trust Questionnaire

Study: SAVE IT
Date: ___________
Participant : _____

Trust Questionnaire

Please **circle the number** on the scale above the statement that best describes how you feel about that statement.

1) I understand the operation of the system.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

2) I trust the system.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

3) The system is reliable.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree

4) I am confident with my ability to drive the car safely without the system.

1	2	3	4	5
Strongly Agree	Mildly Agree	Agree and Disagree Equally	Mildly Disagree	Strongly Disagree