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16.Abstract

The goal of this study was to improve the understanding of the relationship between experience with adaptive cruise control (ACC) and driving performance. The three study objectives were: (1) Determine whether drivers who are experienced with ACC respond appropriately to the feedback provided by a familiar ACC system under crash-likely scenarios; (2) Determine if there are usage and error patterns that emerge across a sample of drivers who currently use ACC; (3) Identify countermeasures if drivers make safety-critical errors or engage in problematic usage patterns when driving with familiar ACC systems.

Twenty-four participants completed the study protocol. There were two study scenarios and both had three driving environments: rural, interstate, and residential. As permitted within the constraints of the database, the order of events was balanced between the two scenarios to reduce order effects. The events were a mixture of critical and non-critical events.

Overall, early adopters had few critical errors, and only one driver failed to respond to alerts from the ACC system when the limits of the system were exceeded in critical events. The most frequent errors made by drivers were during the curve events and were not safety critical. Only two participants understood that their personal vehicle’s ACC system did not detect stopped vehicles, indicating a critical gap in ACC knowledge. Drivers did not appear to become more complacent with experience, although their trust in the system did increase. Suggested countermeasures for future analysis include reducing the acceleration of the system, which some report as too aggressive, and relocating the system icon to a more visible location.

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LIST OF ACRONYMS

ACC	adaptive cruise control
AG	age group
AMTTC	adjusted minimum time-to-collision
ANOVA	analysis of variance
CCC	conventional cruise control
DAQ	data acquisition
EG	experience group
IDOT	Iowa Department of Transportation
IFC	informed consent
IRB	Institutional Review Board
LCD	liquid crystal display
MTH	minimum time headway
MTTC	minimum time-to-collision
NADS	National Advanced Driving Simulator
NHTSA	National Highway Traffic Safety Administration
NSF	National Science Foundation
PI	principal investigator
RECAS	rear-end collision avoidance systems
SD	standard deviation
TTC	time-to-collision

EXECUTIVE SUMMARY

New advanced driver support systems are being introduced into passenger vehicles with little understanding of how driving performance and behavior adapts over long-term use. Early adopters of new technologies provide a unique population from which early assessments of new technologies' safety impact can be made. Examinations of early adopters of new in-vehicle technologies can offer insight into driver acceptance of these systems, providing valuable design and performance feedback as well as an early indication of the system's success among a broader population of consumers.

Of interest in this project are the potential safety implications engendered through long-term use of adaptive cruise control. An enhanced version of conventional cruise control, ACC automates the operational control of longitudinal headway and speed such that the vehicle speed can be regulated when a slower lead vehicle is present. ACC has been available since 2001 in select, high-end vehicle models. In the United States, as of 2010, there are approximately 60 vehicle models with ACC as a standard or optional feature. The ACC system used for this study was based on the Toyota Dynamic Laser Cruise Control System.

The goal of this study is to understand the relationship between experience with ACC and driving performance. This goal was achieved through three study objectives: (1) to determine whether drivers who are experienced with ACC (as part of their personal vehicle use) respond appropriately to the feedback provided by a familiar ACC system under crash-likely scenarios; (2) to determine if usage and error patterns emerge across a sample of drivers who currently use ACC, how critical any errors are, and what impact they may have on safety; and (3) to identify countermeasures if drivers make safety-critical errors or engage in problematic usage patterns when driving with familiar ACC systems.

A database of potential participants was made available through a questionnaire study funded by the National Science Foundation, which solicited information from drivers who currently own a registered vehicle with ACC. This database, approved by the Institutional Review Board, was acquired from the Iowa Department of Transportation and included a list of Iowa-registered vehicles by make, model, and year that could have ACC as an option, as well as the names and addresses of the registered vehicle owners. Based on a review of system operations, interface characteristics, and system prevalence in Iowa, only vehicle owners of Toyota Sienna XLE model years 2004 or newer, Toyota Avalon model years 2005 or newer, and Lexus RX model years 2005 or newer were considered for recruitment. Participant contact information came primarily from this source, but an e-mail was also sent to the University community and to the NADS recruitment database inviting ACC users to participate in the study.

Twenty-four participants completed the study protocol. There were two main study scenarios, and both had three distinct driving environments: rural, interstate, and residential. The database was the same for all three scenarios (two main and one practice). As permitted within the constraints of the database, the order of events was balanced between the two main study scenarios to reduce order effects. There was a mixture of critical and non-critical events.

A combination of performance measures and subjective measures was collected. Performance measures included various metrics for steering, accelerating, braking, speed, response time, collisions, ACC warnings, and several others. Subjective measures were also considered in order to document any potential ACC use patterns that may be engendered through sustained ACC use. The questionnaires elicited participants' understanding and expectations of the ACC system and its limitations. In addition, participants were asked to document problems or challenges with the ACC systems in their vehicles and potential countermeasures they would suggest based on their experience. Subjective measures included demographic information, level of exposure to ACC, and usage patterns.

A key result of this research was the relationship between the criticality of errors and driver experience. The essence of the question was whether, with increased experience, drivers would become more complacent with the automation and fail to respond appropriately to critical driving situations. The results show that this is not the case. In fact, the most critical errors were committed by drivers who had the least experience with their ACC-equipped vehicle. Overall, early adopters had few critical errors, and only one driver failed to respond to alerts from the ACC system when the limits of the system were exceeded in a crash-imminent situation. The most frequent errors made by drivers were not safety critical.

The results also indicate a critical gap in knowledge related to ACC. All but 4 participants were aware that the ACC system issued alerts when they were too close to a vehicle and needed to manually intervene. All but one of the participants who were aware that the ACC system issued warnings also knew that the ACC system did not issue warnings when it was turned off. However, only 2 participants understood that their ACC system did not detect stopped vehicles. In fact, 18 of the 24 (75%) participants thought that the ACC system would slow or stop their vehicle when they encountered a stopped vehicle in the road.

Participants identified issues with ACC based on their experience and then provided recommendations for countermeasures. One commonly reported problem was acceleration by the system that was perceived as being abrupt or aggressive. This situation can be safety critical if the driver or surrounding vehicles react to this acceleration in an unexpected or unsafe manner. Participants suggested a countermeasure to limit the acceleration to a more moderate level, either in all cases or when the vehicle is negotiating a curve. Another issue relates to poorly placed visual icons. Countermeasures for the redesign of the visual icons included better placement, illumination, contrast, and conspicuity. In addition, because so many drivers did not know that the system would not brake in response to a stopped vehicle, the researchers recommend an educational effort aimed at increasing understanding of system limitations.

ACC could be an effective tool for helping drivers maintain consistent headway gaps and preventing unnecessary lane changes when they are using cruise control. The system modeled in this study seems to be effective at engendering trust without causing complacency. Based on the experimental findings and self-reported data, suggested countermeasures for future investigation fall into two main categories: driver education and modifications to the driver-vehicle interface.

1 INTRODUCTION

1.1 Early Adopters of Adaptive Cruise Control

New advanced driver support systems are being introduced into passenger vehicles with little understanding of how driving performance and behavior adapts over long-term use. Early adopters of new technologies provide a unique population from which early assessments of safety impact can be made. Examinations of early adopters can offer insight into driver acceptance of these systems, providing valuable design and performance feedback as well as an early indication of the system's success among a broader population of consumers (Llaneras, 2006). Importantly, early adopters also shed light on short- and long-term driving performance and behavioral changes that users of new in-vehicle technologies can be expected to make with sustained system use. Behavioral adaptation in traffic safety research is defined as the often unexpected collective changes in driving behavior that occur after a change in the vehicle and/or driving environment that may jeopardize any anticipated safety benefits (Rudin-Brown & Noy, 2002; Saad, 2004). Although behavioral adaptation is acknowledged and accepted, little is clearly established about its underlying explanatory factors and processes (Rudin-Brown & Noy, 2002; Saad, 2004). Llaneras (2006), however, provides a basis for what behavioral adaptation encompasses: it extends beyond changes to driver performance to include drivers' attitudes and feelings, as well as their mental models of how the system operates, its capabilities and limitations, its utility and effectiveness, and its impact on driving style.

Of interest in this project are the potential safety implications engendered through long-term use of adaptive cruise control . An enhanced version of conventional cruise control, ACC automates the operational control of longitudinal headway and speed such that the vehicle speed can be regulated when a slower lead vehicle is present (Rudin-Brown & Parker, 2004; Stanton et al., 1997; Lee & Peng, 2002). ACC has been available since 2001 in select high-end vehicle models. As of 2010, there are approximately 60 vehicle models in the US that offer ACC as a standard or optional feature. ACC is typically viewed as a convenience system rather than a safety system because the driver can always override the system. However, ACC has also been incorporated into collision avoidance and brake assist systems as part of an integrated advanced safety system. Because it is an in-vehicle technology that partially automates the driving task and because of its potential application as an advanced safety system, the safety implications of ACC continue to be relevant and worthy of examination.

Studies have shown that benefits of ACC include an increased likelihood of maintaining safe headway distance (Vahidi & Eskandarian, 2003; Ward, 2000) with driver-selected gap distances typically ranging from 0.9 to 2.5 s (Kesting et al., 2007), fewer lane changes on the interstate (Llaneras, 2006), improved safety over conventional cruise control (CCC) (Llaneras, 2006), and reduced necessity to monitor the external surroundings or manually accelerate and brake (Stanton & Young, 2004; Stanton & Young, 2005). The reduction in mental and physical resources may help reduce overall driving effort, driver stress, and human error (Hoedemaeker & Brookhuis, 1998; Stanton & Marsden, 1996).

However, ACC has limitations that may actually reduce rather than enhance safety. For example, studies showed that driving with ACC increased secondary task performance (Stanton et al., 1997; Rudin-Brown et al., 2003) compared to driving with manual headway control. Driving performance measures, including standard deviation of lane position and mean headway distance, were shown to be affected by ACC use (Hoedemaeker & Brookhuis, 1998; Cho et al., 2006; Lee et al., 2007), although the effect of ACC varied depending on the situation and the type of ACC system used (Fancher et al., 2001; Stanton & Young, 2004; Lee et al., 2007). Minimum time headway in emergency situations has been shown to be shorter with ACC use (Stanton et al., 1997; Hoedemaeker & Brookhuis, 1998; Lee et al., 2007), resulting in more critical "near misses" or collisions. The decrease in minimum time headway has been attributed to both automation complacency and a lack of system understanding, especially in situations where limits are exceeded. Trust in ACC also has been found to increase with use (Rajaonah et al., 2006; Rajaonah et al., 2008), even with simulated system failures (Rudin-Brown et al., 2003). ACC use was found to be positively correlated with overall trust in the ACC, and trust was found to be negatively correlated with the minimum time headway in a cut-in event (Rajaonah et al., 2006).

Previous field operation tests and simulator studies have documented short-term performance and behavioral changes among first-time ACC users, and the effects of driving performance and behavioral changes associated with ACC on driving safety are well-documented (Hoedemaeker & Brookhuis, 1998; Hoedemaeker & Kopf, 2001; Sayer et al., 1995; Stanton et al., 1997).

This research project will address the potential long-term driving performance changes and behavioral adaptations among early adopters of ACC that may affect driving safety. Few studies have examined the safety impact of sustained ACC use. Kazi et al. (2007) showed through a longitudinal study that behavioral adaptation associated with ACC changes its form over a series of weeks, particularly in the context of trust and system (mis)understanding. Fancher et al. (2001) document changes in the strategies drivers develop to balance their roles of operator and supervisor.

Two NHSTA-sponsored survey studies (Llaneras, 2006; Jenness et al., 2008) of early adopters suggest that long-term adaptation, over the course of months or years, is also present through self-reported changes in performance and reliance on ACC. Both found that while ACC was well-received among early adopters, based primarily on its perceived convenience and improved safety, relatively few respondents fully understood how the system operated or, critically, the system's limitations. Respondents were unaware of their system's limitations or overestimated its effectiveness in situations where ACC is known to not work. In a series of questions specifically addressing stopped vehicles in the driver's lane, for example, only 1 percent of drivers correctly stated that the system would not be able to detect a stopped vehicle; most (63%) believed that the ACC system would react to a vehicle stopped in its path much like it reacts to a forward vehicle (e.g., the system would detect the stopped vehicle and begin to slow, but the driver would have to take over), and 29 percent of respondents did not know that the vehicle had an approach alert if the deceleration limit was exceeded and an intervention was required by the driver (Llaneras, 2006).

Respondents were not aware of manufacturer's warnings or limitations about ACC (Jenness et al., 2008), even though an overwhelming majority (90%) of owners reported reading all or some of the owner's manual. Hence, many respondents indicated that their ACC system would work well or perfectly to assist them in avoiding collisions with a lead vehicle in the following situations (Jenness et al., 2008):

- 24 percent responded that their ACC system would assist in avoiding a collision when following a vehicle in stop-and-go traffic;
- 43 percent responded that their ACC system would assist in avoiding a collision when the driver encountered a stopped vehicle in the lane ahead; and
- 27 percent responded that their ACC system would assist in avoiding a collision when following a vehicle on a curvy road.

Following a vehicle in stop-and-go traffic and encountering a stopped vehicle in the lane were dependent on experience; surprisingly, respondents at higher levels of experience were more likely to say that the system worked well or perfectly (Jenness et al., 2008).

Previous research indicates that while ACC has some positive effects on driving safety, automation of part of the driving task does challenge safe vehicle operation. Drivers' lack of knowledge about ACC's operation and incomprehension of the supervisory control requirements necessary when using ACC result in errors when users do not know when to take over from the automatic control. When users become less attentive to the driving task and more reliant on the automated system, they are less equipped to address time-sensitive critical driving situations that exceed the system's limits.

This study builds on the early adopter surveys of ACC use to better understand how ACC might change driver performance and behavior over time. An examination of early adopters with sustained ACC use addresses whether reported problems associated with ACC use, such as automation complacency and system misunderstanding, are isolated or systemic issues, and whether, if usage and error patterns are identified, empirically grounded countermeasures can be developed while exposure to the system is limited in order to address negative adaptations.

1.2 Research Objectives and Hypotheses

The goal of this study is to understand the relationship between ACC experience and driving performance. This goal was achieved through three study objectives:

1. Determine whether drivers who are experienced with ACC (as part of their personal vehicle use) respond appropriately to the feedback provided by a familiar ACC system under crash-likely scenarios.
2. Determine if there are usage and error patterns that emerge across a sample of drivers who currently use ACC, how critical the errors are, and what impact they may have on safety.
3. Identify countermeasures if drivers make safety-critical errors or engage in problematic usage patterns when driving with familiar ACC systems.

These study objectives were addressed in a driving simulator study of experienced ACC users. Driving performance measures were collected from critical and non-critical scenario events. Questionnaire responses completed prior to and after the simulator drive assessed participants' use of ACC, trust in ACC, and driving style.

From these study objectives, five research hypotheses were developed and are described in the next section.

1.2.1 Hypotheses

Hypothesis 1: Experienced ACC users will respond differently in critical and non-critical events (Objective 1).

This hypothesis compares the participants' performance on critical and non-critical events. It was expected that critical events would elicit crash-avoidance responses (such as manual braking and/or steering maneuvers) from the driver. Non-critical events included light lead vehicle braking and required no crash-avoidance responses.

This analysis used an analysis of variance (ANOVA) with the within-participant variables: event type (critical and non-critical), road geometry (straight and curve), and road type (rural and interstate). The response (dependent) variables are initial response time and minimum acceleration.

Significant results from testing this hypothesis serve as validation of the simulation in distinguishing between critical and non-critical events. This level of sensitivity is required in order to test subsequent hypotheses. Hypothesis 1 is discussed in Section 4.2.1.

Hypothesis 2: Drivers with higher levels of ACC experience, and/or in an older age group, will have slower response times to feedback provided by the ACC system when its operational limits are exceeded, and their responses will be inappropriate for the highly safety-critical events (Objective 1).

For this hypothesis, participants' responses to the ACC system when its operational limits were exceeded were compared. We expected that more experienced ACC users would react less quickly with steering or braking responses when the limits were exceeded, and that the response would be inappropriate for the safety-critical situation due to automation complacency. An appropriate response is defined as taking manual control and either decelerating at or above the ACC system's maximum deceleration authority of 0.3 g or steering to avoid an obstacle when the deceleration authority alert sounds. Because we expected that more experienced ACC users would wait longer to respond, we also expected that the time-frame for taking over manual control may compromise safety, resulting in a more safety-critical situation than if the driver responded immediately when the alert was issued.

An ANOVA of the within-participant variables event type (critical braking and cut-in), road geometry (straight and curve), road type (rural and interstate), experience group (see Section 4.1.1), and age group (see Section 4.1.2) was used to determine if there were differences between the dependent variables (response time from alert and initial response time). Hypothesis 2 is discussed in Section 4.2.4.

Hypothesis 3: Drivers with different levels of experience using ACC, and/or in different age groups, will exhibit distinct ACC use patterns (Objective 2).

For this hypothesis, participants' use of the ACC system over the duration of the study drive was categorized. We expected that more experienced users would use and rely more on ACC than less experienced users.

A cluster analysis was used to determine driving and use patterns, using key variables: percentage ACC engaged, disengage count, short gap setting percentage, medium gap setting percentage, long gap setting percentage, warnings issued, average set speed relative to speed limit, and percentage response to deceleration warnings. ANOVAs were then used, as appropriate, to examine the differences in experience level across these cluster groups. Hypothesis 3 is discussed in Section 4.2.3.

Hypothesis 4: Different types of errors will result in different levels of criticality (Objective 2).

For this hypothesis, different types of errors made by participants were compared to determine which were more severe in terms of driving safety. Five error types were determined a priori. The five error types are: (1) failure to respond to deceleration exceedance warning, (2) failure to disengage ACC around curves and exit ramps where the lead vehicle is lost (by the sensor) for at least 10 percent of the curve, (3) failure to decrease gap setting or disengage ACC when entering a small radius curve on the long gap setting, (4) failure to respond to the stopped vehicle, resulting in a collision or adjusted minimum time to collision (AMTTC) of less than 2.75 seconds before the end of the participant's first response, and (5) failure to decrease the vehicle's set speed or disengage ACC when approaching a decrease in speed limit.

A higher level of criticality was expected for errors on curves, exit ramps, and with stopped vehicles than for braking events because the ACC system is known not to work or to work poorly in these events. In other words, we anticipated that the ACC system would reduce the criticality in those situations for which it is designed to work.

ANOVAs were used to determine if there were differences in levels of criticality between error types utilizing key variables: minimum time headway and adjusted minimum time to collision. Hypothesis 4 is discussed in Section 4.2.2.

Hypothesis 5: Error types will vary with differences in ACC experience and/or age (Objective 2).

We expected that experience with ACC would influence the frequency, type, and severity of errors that a driver makes. Five pre-determined errors were examined in this study. Of these, three—failure to respond to deceleration exceedance warnings (error type 1), failure to disengage ACC on curves or exit ramps when the lead vehicle is lost (error type 2), and failure to respond to a stopped vehicle (error type 4))—are expected to generate fewer errors for the more experienced ACC users, while two—failure to adjust gap setting or disengage ACC on small radius curves (error type 3) and failure to adjust speed (error type 5)—are expected to generate more errors for this same experience group. Errors that were more frequent among experienced users were expected to be more critical as well.

These differences were examined using chi-square tests and Fisher's exact tests. Hypothesis 5 is discussed in Section 4.2.5.

2 METHODOLOGY

2.1 Apparati

2.1.1 NADS-1

The NADS-1 driving simulator, owned by the National Highway Traffic Safety Administration and located at The University of Iowa, comprises 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 is 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 1,600 x 1,200 pixels. The right and left projectors have a resolution of 1,280 x 1,024 pixels. The three projectors in the back have a resolution of 1,024 x 768 pixels. All scenery is updated and displayed 60 times per second. A complete statement of capabilities can be found in the *NADS Statement of Capabilities* (National Advanced Driving Simulator, 2007).

2.1.2 NADS-Adaptive Cruise Control System

An ACC system operates in two basic modes: maintaining the speed set by the driver and maintaining the desired headway set by the driver. When the ACC system detects a slower-moving vehicle ahead, the system decelerates the car using throttle control, transmission downshift, or braking. Which of these responses is initiated depends on the design of the system and the severity of the situation. ACC systems have limited longitudinal deceleration capacity, and if it is exceeded, the driver must intervene to avoid colliding with the car ahead. The driver must decide whether or not it is necessary to intervene, decide what the response should be, and then respond. The system is capable of adapting the direction of the sensor on curves to a certain extent; however, it is still common for the sensor to lose the lead vehicle on tight curves.

The ACC system used for this study was based on the Toyota Dynamic Laser Cruise Control system. The key parameters used in this system are shown in Table 1. Figure 1 shows the controls of this system, as integrated in the NADS-1. Figure 2 shows the displays of this system, as integrated in the NADS-1.

Table 1: Key Parameters of the NADS ACC Model.

Parameter	Values
Maximum Detection Range	400 ft
Engage Speed Range	25 – 88 mph
Minimum Speed for Vehicle Detection	7 mph
Gap Settings	1.24 s, 2.04 s, 3.04 s
Field of View	16 degrees horizontally
Deceleration Authority	0.05 - 0.3 g
Jerk Authority	0.14 - 0.66 g/s

Figure 1: ACC Controls in NADS-1.

Figure 2: ACC Display in NADS-1.

Real-world testing on a 2010 Toyota Avalon was conducted in a variety of roadway and traffic environments to validate the realism and performance of the ACC model used in this study (Appendix

1). The model includes built-in lag for detecting vehicles, adaptive limits on deceleration and jerk, and adaptive sensor object detection on curves (Appendix 2). The model provides very good face validity and compares quite well to the 2010 Avalon that was tested.

2.2 Experimental Procedure

2.2.1 Participants

Twenty-eight participants were enrolled in the study. Four were dropped from the study due to a high number of system aborts, incomplete data, or simulator sickness, so 24 participants completed the study protocol. The mean age was 56.7 (standard deviation (SD) 13.6 years), with a minimum age of 31.2 years and a maximum age of 77.8 years. There were 15 males, with a mean age of 61.2 years (SD13.8 years), and nine females, with a mean age of 49.3 years (SD 10.0 years).

2.2.2 Recruitment

Dr. Linda Boyle provided an IRB-approved database of potential participants through an NSF-funded questionnaire study. The database was acquired from the IDOT and included a list of Iowa-registered vehicles by make, model, and year that could have ACC, as well as the names and addresses of the registered vehicle owners. Based on an initial survey conducted by Dickie and Boyle (2009) and a review of system operations, interface characteristics, and system prevalence in Iowa, only vehicle owners of Toyota Sienna XLE model years 2004 or newer, Toyota Avalon model years 2005 or newer, and Lexus RX model years 2005 or newer were considered for recruitment. A recruitment e-mail was also sent to the University community and to members of the NADS recruitment database (Appendix 3).

Participants in the NSF-funded study who responded that they would be interested in participating in future ACC research, and who drove one of the three vehicle makes identified for this study, were contacted by phone or by mail and invited to participate (Appendix 4). If initial contact was made by phone, the Screening Procedure script (Appendix 5) was used to introduce the study and to determine if the contact was interested in participating in this study and met inclusion criteria. For those receiving the letter first, an introduction to the study was included in the letter, and interested parties were invited to contact a staff member by phone or e-mail. A sample of the remaining names (those not used in the NSF-funded study) in the Toyota/Lexus subset of the database were sent a postcard (Appendix 6) that introduced the study, provided information about its timeline, and requested that recipients provide contact information to indicate that they were willing to participate in this study. An e-mail script (Appendix 7) and a webpage (Appendix 8) were used to provide more information about the study for those who contacted NADS via e-mail or who viewed our website.

2.2.3 Screening Procedures

Potential participants were screened by phone (Appendix 5) on the following inclusion and exclusion criteria up to one month prior to the appointed visit.

Inclusion criteria:

- Age 25 to 80
- Valid U.S. driver's license
- Drive either a Toyota Sienna XLE model year 2004 or later, Toyota Avalon model year 2005 or later, or Lexus RX model year 2005 or later
- Have ACC in their vehicle and use it, on average, at least once per month
- Drive at least 3,000 miles per year

Exclusion criteria:

- Have participated in Rear-End Collision Avoidance Systems driving simulator study conducted at NADS
- Have participated in a driving simulator study in the past six months
- Any possibility of pregnancy
- Diagnosed with epilepsy or seizures
- Diagnosis of narcolepsy
- Have Meniere's Disease or any inner ear, dizziness, vertigo, or balance problems
- Currently suffer from any heart conditions, i.e., symptomatic congestive heart failure, unstable angina pectoris, cardiac arrhythmia
- Need for driving aids, such as booster seats, pedal extensions, etc.

If study inclusion criteria were met and no excluding factors existed, study staff sent the Informed Consent Document (Appendix 9) and cover letter (Appendices 10 and 11) through the mail or by e-mail to those who were scheduled to participate. Sending the IFC before the visit minimized the number of participants who declined to be enrolled after traveling to the NADS at the University of Iowa Research Park.

2.2.4 Study Visit

2.2.4.1 Briefing

Upon arrival at the NADS, study staff verbally reviewed the IFC with participants, answered any questions, provided time to read the IFC document, and then obtained their written consent. All participants received a copy of the signed IFC document at the end of their visit. All participants also read and signed a Video Release document (Appendix 12) or Video Release Altered document (Appendix 13).

Next, participants were asked to show their driver's licenses to confirm that they were valid and then fill out a payment form (Appendix 14). Participants were then asked to complete a questionnaire (Appendix 15) that covered some general questions about their driving, demographic, and health history. Driving history questions included the type of vehicles driven, license history, driving violations and accidents, and driving habits. Demographic questions asked for birth date, gender, ethnicity, highest level of education completed, and participation in other driving studies. The general health history questions were about vision correction, hearing aid use, medication use, and history of motion sickness.

Participants were asked to fill out one questionnaire about their previous experience with ACC (Appendix 16), including questions about situations in which they do or do not use ACC, how they feel about the ACC system and its features, and how useful they find ACC. Participants were then asked to complete questionnaires about their driving style (Appendix 17) and trust (Appendix 18).

Participants were also asked to view a PowerPoint presentation (Appendix 19) with an overview of the simulator cab, the simulator drive, and the ACC system they would be interacting with while driving. Immediately afterward, they were escorted into the simulator and asked to complete a five-minute practice drive to become familiar with the simulator and the ACC system. After the practice drive, participants were asked to complete a questionnaire about how they felt (Appendix 20).

Once the briefing was complete, participants then completed the main drive, which took approximately 30 minutes. The experimental procedure is described in the next section. However, participants were told that the drive was a 60-minute drive so as to curtail anticipation of the end of the drive. After the drive, participants were again asked to complete the questionnaire about how they felt (Appendix 20).

2.2.4.2 Debriefing

After completing the main simulated drive, participants were escorted back to the waiting room and asked to complete another questionnaire to assess the realism of the simulator (Appendix 21). Each participant was then asked to report what they were thinking about and paying attention to while watching three video clips from their study drive (Appendix 22). They then answered questions about the drive based on their review of the video (Appendix 23). Video clips reflected key events in the drive (e.g., critical driving event, small radius curve, stopped vehicle). Participants were then asked to complete an additional questionnaire (Appendix 24) seeking feedback about the participant's ACC system and about problems or challenges they have encountered while using ACC in their personal vehicles. After all questionnaires were complete, a debriefing statement (Appendix 25) explained the purpose of the ruse. A member of the research team completed the participants' payment forms, and then they were free to go.

3 EXPERIMENTAL DESIGN

The experimental design is separated into two parts, the simulator experiment to assess objective measures and the survey instruments for assessing subjective measures. The simulator experiment contains within-subject factors that control for the encountered event and event order. The outcomes or dependent variables were collected on both continuous and discrete scales. Twenty-four participants completed the study protocol.

Several questionnaires and a video review were used before and after the simulator portion of the study. They were designed to gather information about the participants and their experience with ACC.

- Demographic, general driving, and general health questionnaire (Appendix 15)
- ACC Questionnaire, modified and expanded version of Dickie and Boyle (2009) (Appendix 16)
- Driving Style Questionnaire, modified from West et al. (1992) (Appendix 17)
- Trust in Automation Questionnaire, modified from Muir and Moray (1996) (Appendix 18)
- Review of video clips from study drive (Appendix 22)
- ACC Post-Drive Questionnaire, following each video clip review (Appendix 23, Video Clip 1 version only; Video Clip 2 and 3 versions are the same)
- ACC Countermeasure Questionnaire (Appendix 24)

3.1 Independent Variables

The simulator experimental design contains the following within-participant factors: event type (critical and non-critical), road geometry (straight and curve), and road type (rural and interstate), and between-participant factor event order (main study scenario 1, main study scenario 2). Critical events elicit crash-avoidance maneuvers from the driver (e.g., braking or steering). Non-critical events do not require crash-avoidance maneuvers to safely respond to the event. The order of events in the two main study scenarios is not completely balanced due to database constraints. See Section 3.2.3 and Appendices 26 through 40 for detailed information about the scenario events and event order.

The between-subject factors gathered from the questionnaires were ACC experience, age, driving style, system operation understanding, and use pattern.

3.2 Event Locations

The road network for this study is depicted in Figure 3.

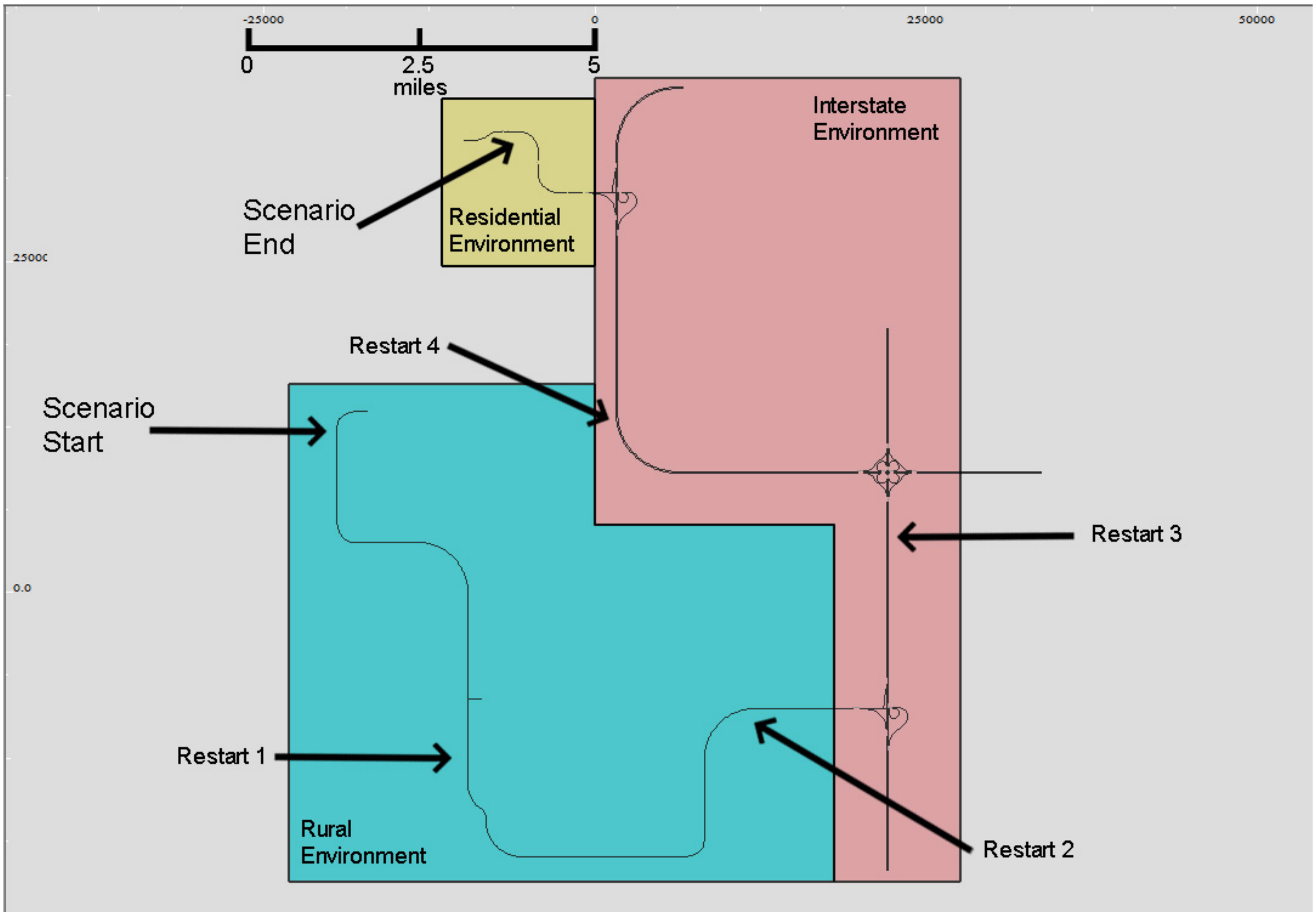

Figure 3: Database for This Study.

3.2.1 Study Scenarios

There were two main study scenarios and both had three distinct driving environments in the following order: rural, interstate, and residential. The start and end points are the same for both scenarios.

The database was the same for all three scenarios (two main and one practice). As permitted within the constraints of the database, the order of events was balanced between the two main study scenarios to reduce order effects. The order of the rural and interstate events was designed so that all the curve or straight events were not displayed consecutively. The order of the final two events was the same for both scenarios. The events with a lead vehicle decelerating had critical and non-critical levels and occurred in identically paired straight and curve segments in the rural environment and in identical straight segments in the interstate environment. The order of the matched critical and non-critical levels and the location of the curve-entering detection events were balanced between the main study scenarios. The event order for both main study scenarios is shown below in Table 2.

Table 2: Main Study Scenario Event Orders.

Event	Main Study Scenario 1	Main Study Scenario 2
1	Rural Event 411: Curve-Entering Detection Range	Rural Event 417: Curve Non-Critical Deceleration Authority Exceedance
2	Rural Event 412: Curve Critical Deceleration Authority Exceedance	Rural Event 416: Straight Critical Deceleration Authority Exceedance
3	Rural Event 413: Straight Non-Critical Deceleration Authority Exceedance	Rural Event 414: Encountering a Slow-Moving Vehicle
4	Rural Event 414: Encountering a Slow-Moving Vehicle	Rural Event 415: Combined Hill and Curve
5	Rural Event 415: Combined Hill and Curve	Rural Event 413: Straight Non-Critical Deceleration Authority Exceedance
6	Rural Event 416: Straight Critical Deceleration Authority Exceedance	Rural Event 411: Curve Entering Detection Range
7	Rural Event 417: Curve Non-Critical Deceleration Authority Exceedance	Rural Event 412: Curve Critical Deceleration Authority Exceedance
8	Interstate Event 421: Entering an Interstate with a Lead Vehicle	Interstate Event 421: Entering an Interstate with a Lead Vehicle
9	Interstate Event 422: Straight Critical Deceleration Authority Exceedance	Interstate Event 425: Straight Non-Critical Deceleration Authority Exceedance
10	Interstate Event 423: Vehicle Cut-in	Interstate Event 423: Vehicle Cut-in
11	Interstate Event 424: Exiting on an Exit Ramp with Lead Vehicle	Interstate Event 424: Exiting on an Exit Ramp with Lead Vehicle
12	Interstate Event 425: Straight Non-Critical Deceleration Authority Exceedance	Interstate Event 422: Straight Critical Deceleration Authority Exceedance
13	Interstate Event 426: Exiting on an Exit Ramp without Lead Vehicle	Interstate Event 426: Exiting on an Exit Ramp without Lead Vehicle
14	Residential Event 431: Encountering a Stopped Vehicle	Residential Event 431: Encountering a Stopped Vehicle

3.2.2 Practice Drive

This scenario took place in the interstate environment. Participants started from a stopped position, accelerated to the speed limit, and engaged the ACC system. They drove for approximately five minutes and were able to freely interact with traffic while utilizing the ACC system. Several lead vehicles and oncoming traffic were present in this scenario. The practice scenario layout can be seen below in Figure 4.

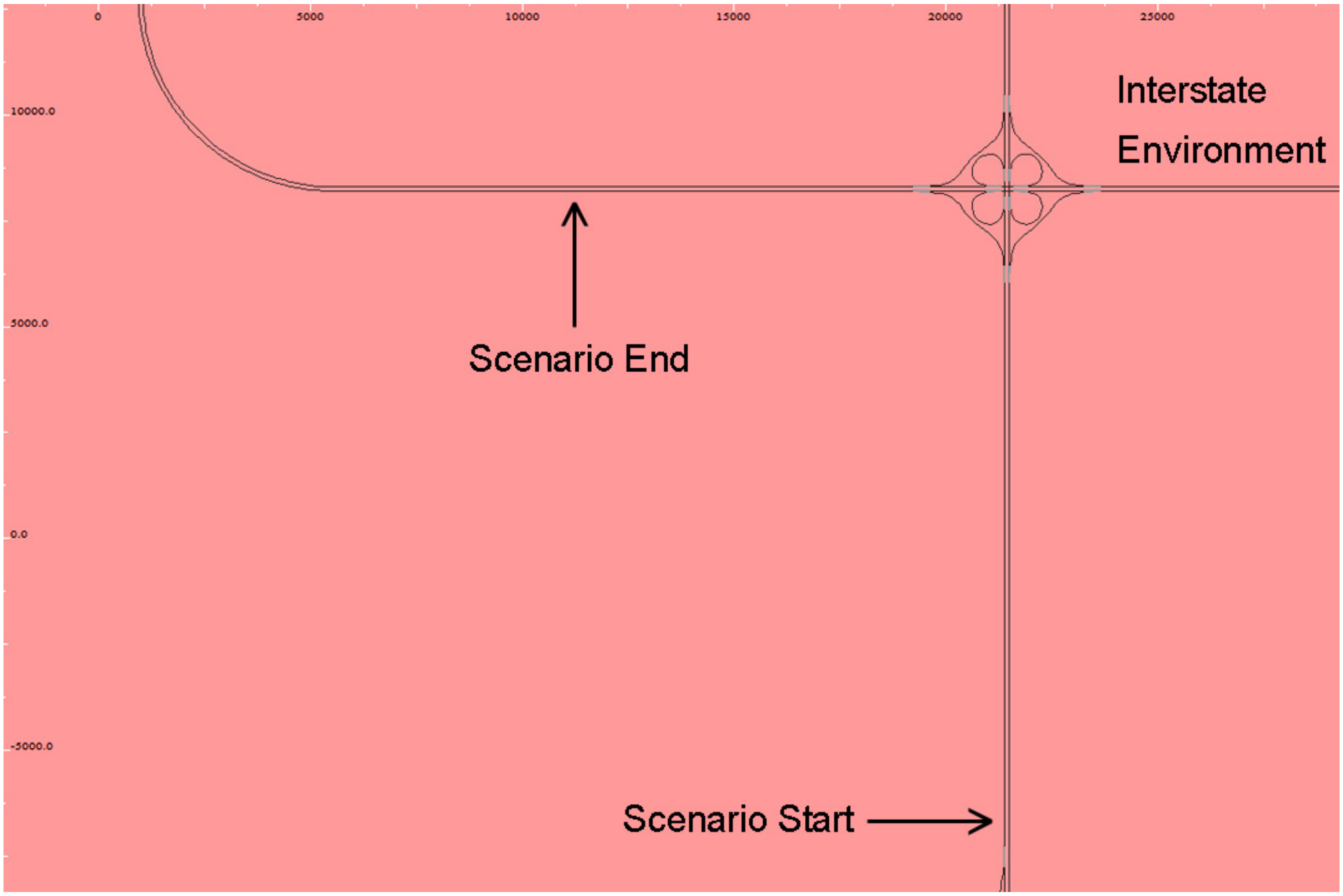

Figure 4: Practice Scenario Layout.

3.2.3 Main Study Scenario 1

Participants began the scenario on the shoulder of a rural, two-lane highway, with no lead vehicle present. They experienced seven events in the rural environment (descriptions in Appendices 27-33). A map of the rural environment with event locations for main study scenario 1 is shown in Figure 5.

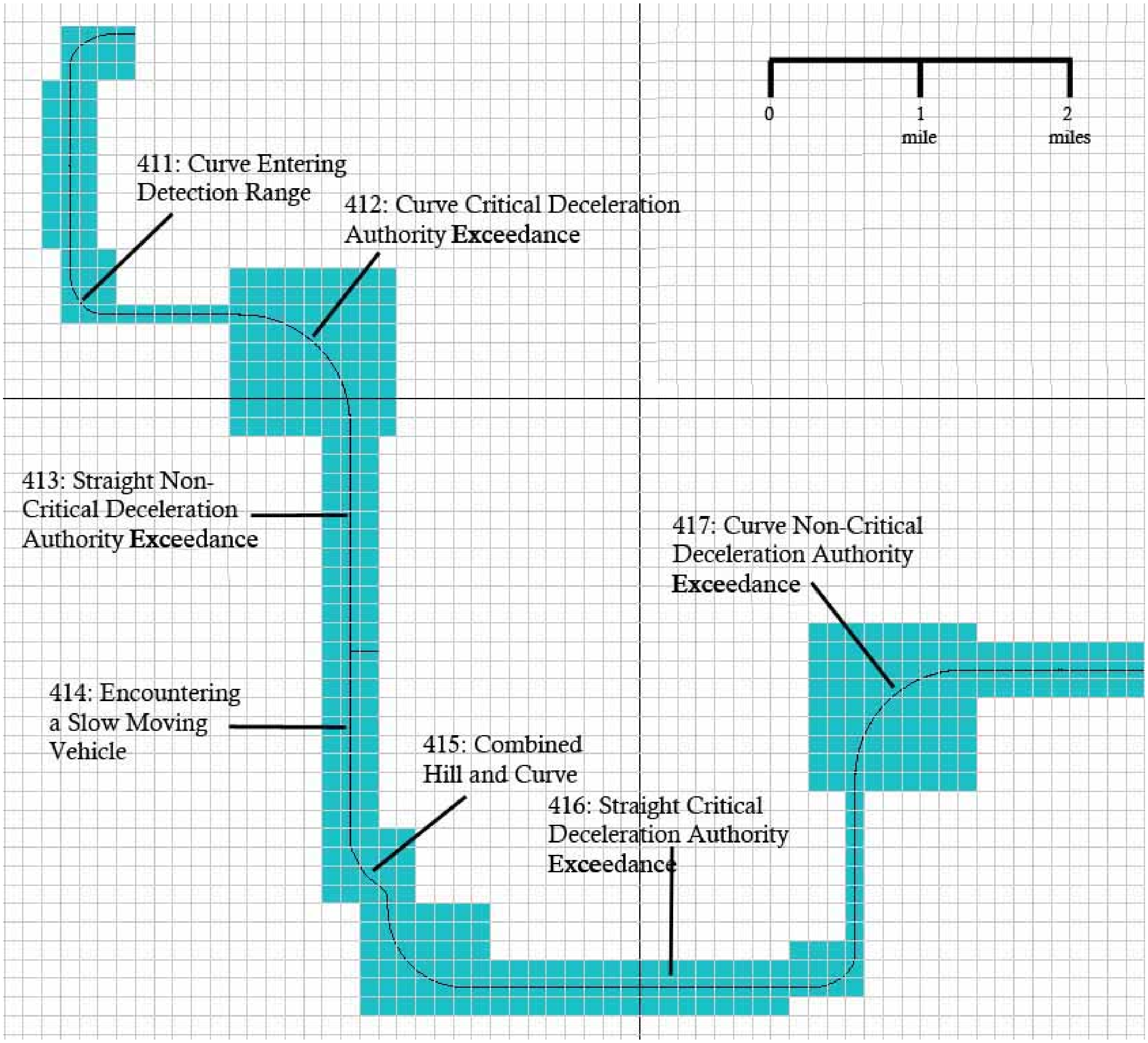

Figure 5: Map of the Rural Environment for Main Study Scenario 1.

Participants then merged onto the interstate, where six more events occurred (descriptions in Appendices 34-39). A map of the interstate environment with event locations for main study scenario 1 is shown in Figure 6.

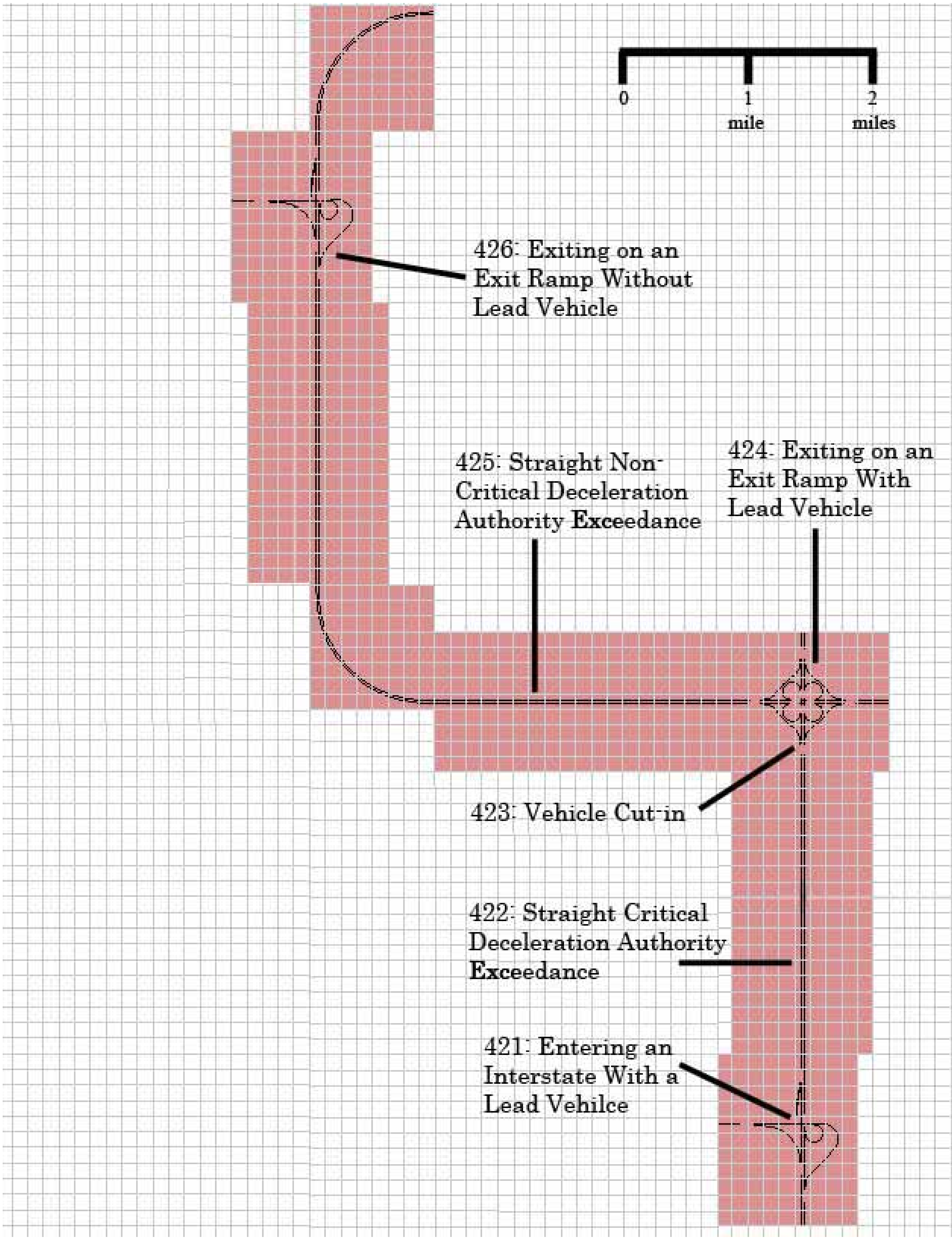

Figure 6: Map of the Interstate Environment for Main Study Scenario 1.

Participants ended the drive in a residential environment, where one event occurred (description in Appendix 40). A map of the residential environment with the event location for main study scenario 1 is shown in Figure 7.

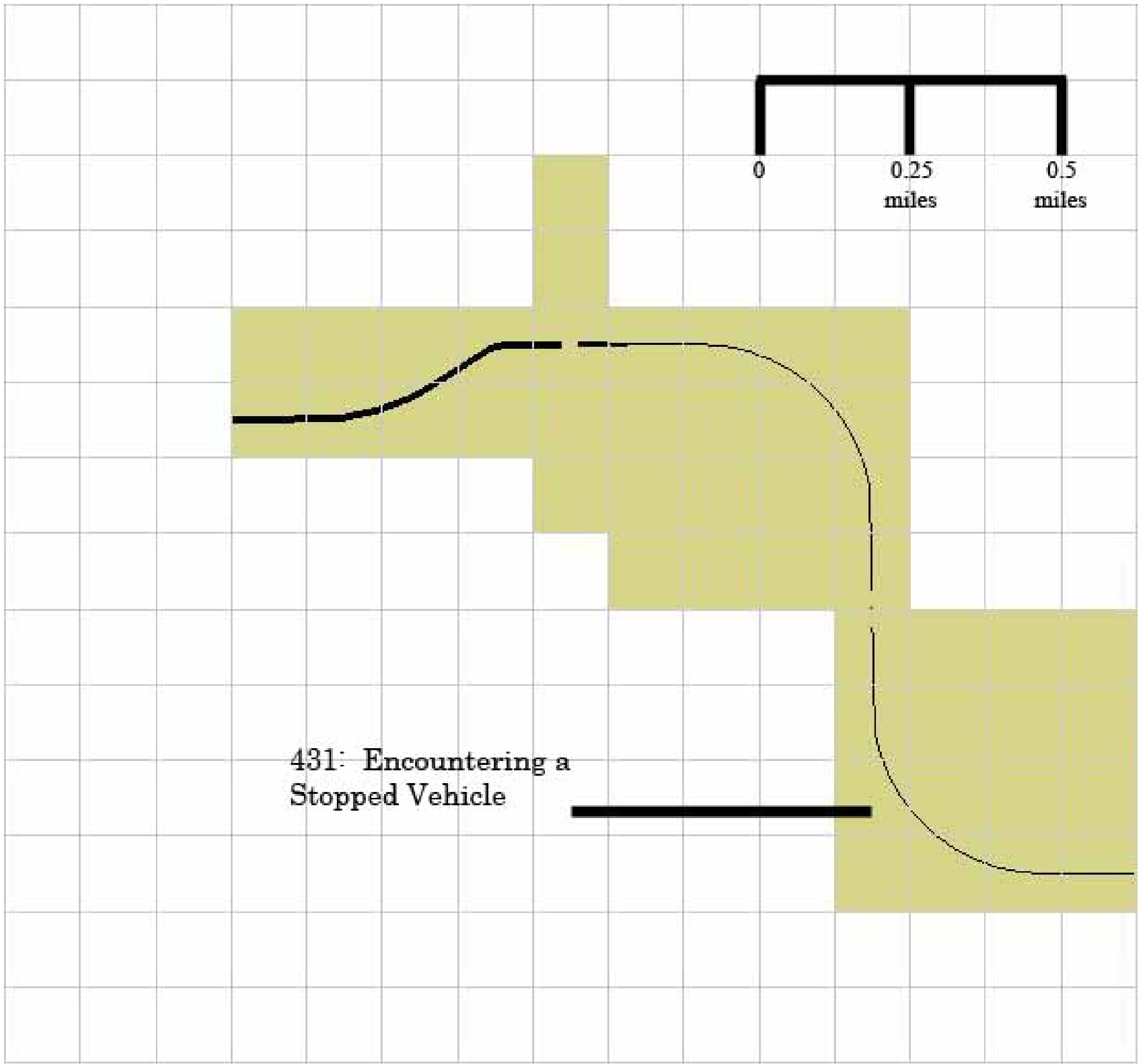

Figure 7: Map of the Residential Environment for Main Study Scenario 1.

3.2.4 Main Study Scenario 2

This scenario has three environments, which occurred in the following order: rural, interstate, residential. Participants began the scenario on the shoulder of a rural, two-lane highway. They experienced seven events in the rural environment (descriptions in Appendices 27-33). The event locations were different than in main study scenario 1 (see Section 3.2.3). A map of the rural environment with event locations for main study scenario 2 is shown in Figure 8.

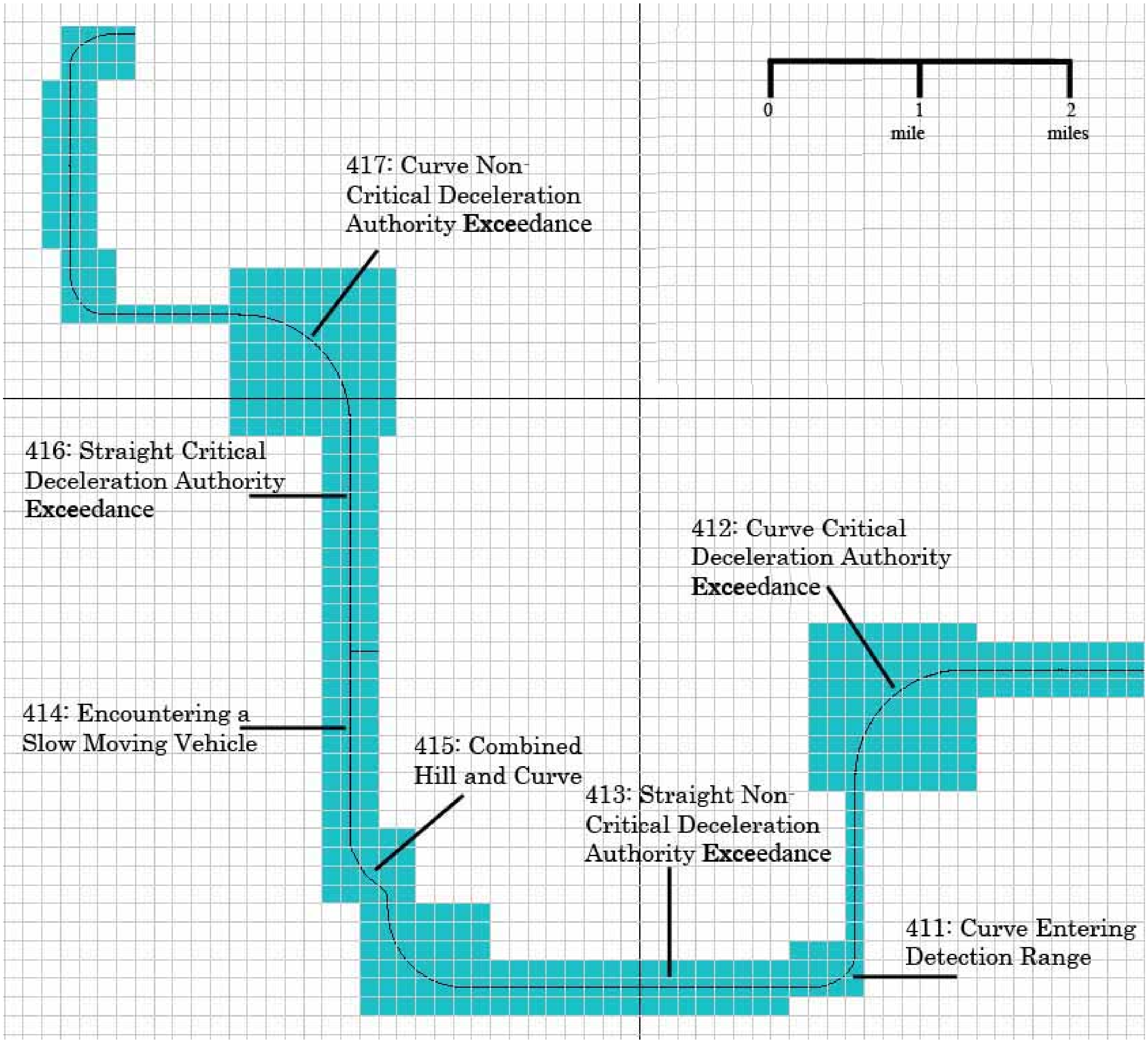

Figure 8: Map of the Rural Environment for Main Study Scenario 2.

Participants then merged onto the interstate, where six more events occurred (descriptions in Appendices 34-39). A map of the interstate environment with event locations for main study scenario 2 is shown in Figure 9.

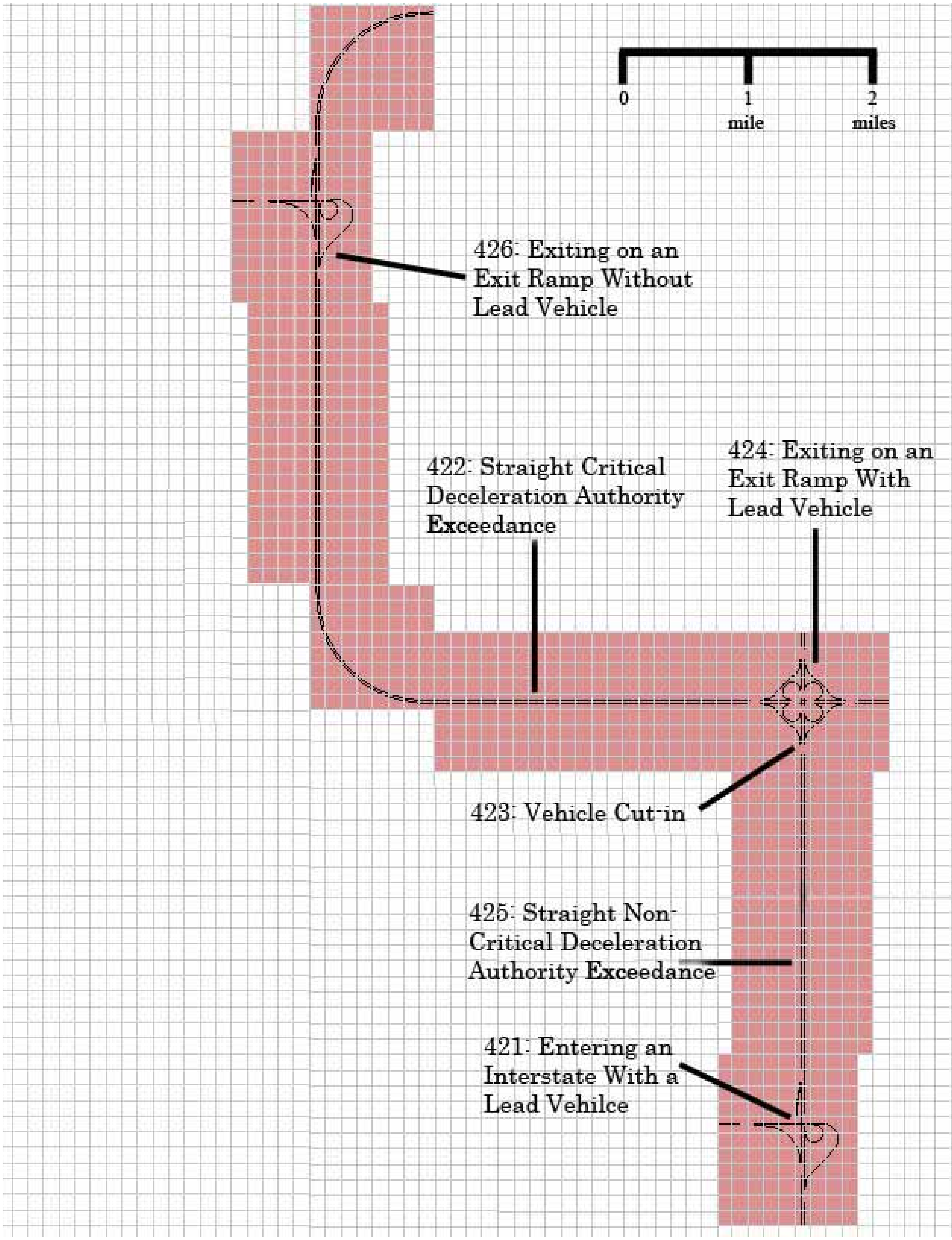

Figure 9: Map of the Interstate Environment for Main Study Scenario 2.

Participants ended the drive in a residential environment, where one event occurred (description in Appendix 40). A map of the residential environment with the event location for main study scenario 2 is shown in Figure 10.

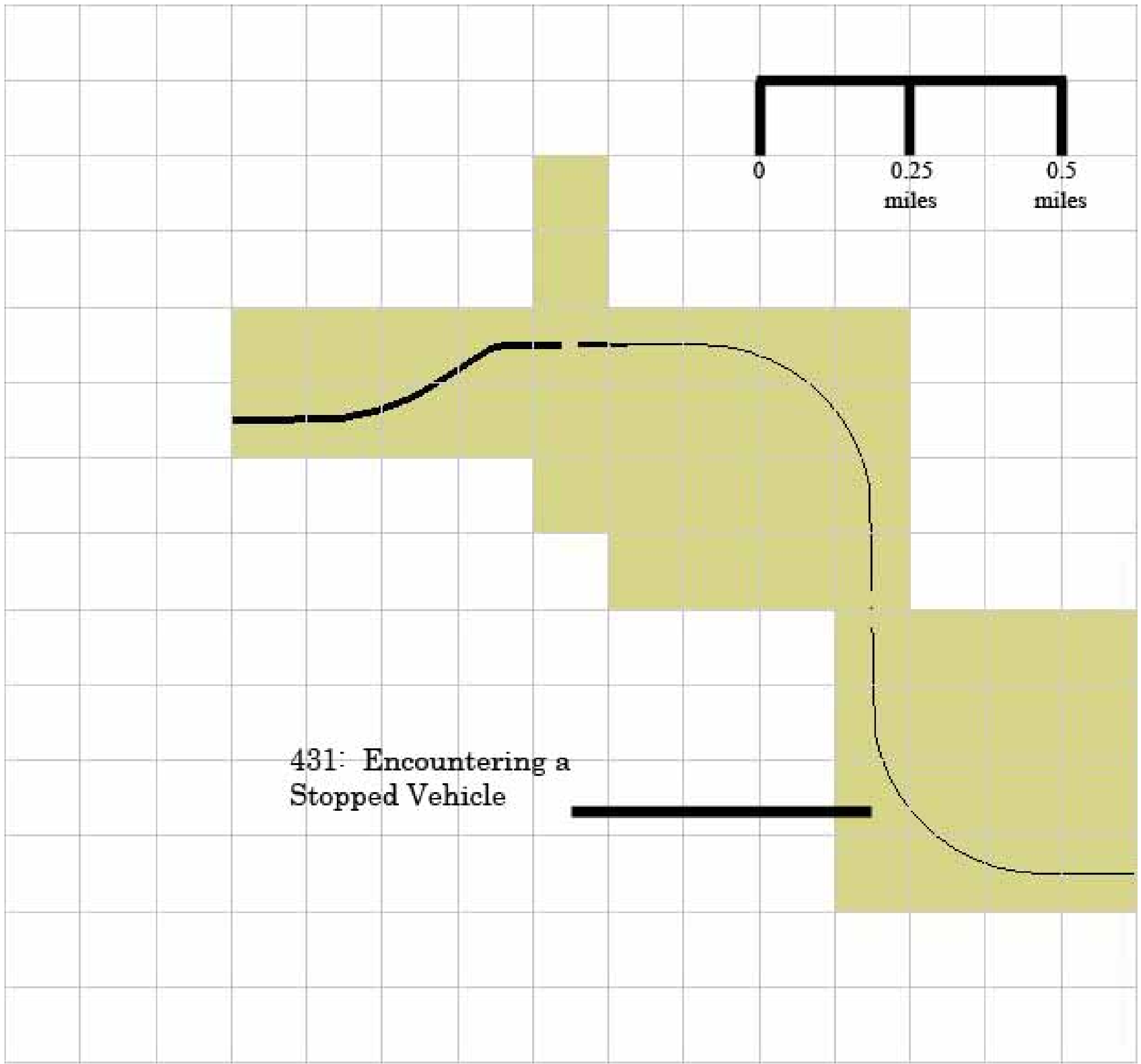

Figure 10: Map of the Residential Environment for Main Study Scenario 2.

3.3 Measurements

3.3.1 Performance Measures

Table 3 contains all of the dependent measures that are reduced in the simulator portion of this study. Several global dependent measures are also reduced that gather cumulative data over the duration of the main study drive. Not all measures are reduced for all events. Table 4 shows the dependent measures that are reduced for each event. For details about the events, see Appendices 26-40.

Table 3: Comprehensive List of Dependent Variables.

Category	Dependent Measure	Description	Units
Event Measures			
	Steering Response	0 for steering response less than or equal to 5 degrees; 1 for steering response greater than 5 degrees	binary
	Initial Response Time	The time elapsed from event condition to when a steering response has been initiated or the ACC system has been disengaged	seconds
	Response Time from Alert	The time elapsed from the onset of the deceleration exceedance alert to when the ACC system has been disengaged	seconds
	Minimum Acceleration	The minimum acceleration (maximum deceleration) during the event	meters/second^2
	Maximum Brake Pedal Force	The maximum force exerted on the brake pedal during the event	Newtons
	Adjusted Minimum Time-To-Collision (AMTTC)	The amount of spare time the driver had based on the avoidance response chosen. In the case of a collision, returns a negative number indicating the time a driver had to avoid the collision.	seconds
	Relative Velocity at Collision	The difference between the participant and lead vehicle velocities at the time of collision	meters/second
	Minimum Time Headway	The minimum time it would take the participant's vehicle to travel the distance between the participant and lead vehicles given the participant vehicle's current velocity	seconds
	Response to Stopped Vehicle	0 for AMTTC to the stopped vehicle greater than 2.75 seconds before the end of the first response; 1 for AMTTC to the stopped vehicle less than 2.75 seconds before the end of the first response	binary
Global Measures			
	Percentage ACC	The percentage of the entire drive that	percentage

Category	Dependent Measure	Description	Units
	Engaged	ACC is engaged	
	Disengage Count	The total number of times that ACC was disengaged during the drive	count
	Short Gap Setting Percentage	The percentage of time that the short gap setting was selected out of the total time ACC was engaged	percentage
	Medium Gap Setting Percentage	The percentage of time that the medium gap setting was selected out of the total time ACC was engaged	percentage
	Long Gap Setting Percentage	The percentage of time that the long gap setting was selected out of the total time ACC was engaged	percentage
	Warnings Issued	The total number of times that the ACC system issued an auditory alert due to limitation exceedances	count
	Percentage Response to Deceleration Warnings	The percentage of deceleration exceedance warnings that the participant responded to, of all deceleration exceedance warnings that occurred over the drive	percentage
	Average Set Speed Relative to Speed Limit	The weighted average set speed throughout the entire drive relative to the speed limit, e.g., set speed of 31.3 m/s (70 mph) in a 29.1 m/s (65 mph) zone would yield a value of 2.2 m/s (5 mph).	m/s
	ACC Status During Curves	Percentage of curves where ACC sensor lost lead vehicle for 10 percent or more of the curve and ACC was not disengaged during the curve	percentage
	ACC Gap Setting During Small Radius Curves	Percentage of small radius curves driven where the gap setting was decreased from the longest setting or disengaged	percentage
	Set Speed Change Prior to Speed Limit Change	Number of instances where the set speed is not decreased or ACC is not disengaged in the 30 seconds prior to a decrease in speed limit.	count

Table 4: Dependent Measures That Are Reduced for Each Event.

Dependent Measure	Events													
	Rural (41)							Interstate (42)						Residential (43)
	1	2	3	4	5	6	7	1	2	3	4	5	6	1
Steering Response		X	X	X		X	X		X	X		X		X
Brake Response		X	X	X		X	X		X	X		X		X
Initial Response Time		X	X	X		X	X		X	X		X		X
Response Time from Alert		X				X			X	X				
Minimum Acceleration	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Maximum Brake Pedal Force	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Adjusted Minimum Time-To-Collision (AMTTC)	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Relative Velocity at Collision	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Minimum Time Headway	X	X	X		X	X	X	X	X	X	X	X	X	
Response to Stopped Vehicle														X

3.3.2 Subjective Measures

The subjective measures were considered along with the driving performance measures collected during the drive in order to document any use and error patterns that emerge through sustained ACC use. Simulator data were used to classify the frequency, criticality, and type of driver errors over the duration of the simulated drive.

The questionnaires elicited participants' understanding and expectations of the ACC system and its limitations. Participants were also asked to document problems or challenges they had with the ACC system in their personal vehicles and to provide any thoughts on potential countermeasures, based on their experience (Appendix 24). Information from the simulator (i.e., driver errors), countermeasures identified in the literature, and countermeasures identified by participants were used to prioritize countermeasures for future research and implementation.

Several subjective measures were to assess driving behavior and participants' engagement with ACC. These included demographic information, level of exposure to ACC, how the participant learned to use ACC, when and how participants typically engage ACC in varying traffic conditions and road infrastructures, perceived driving style, and how drivers share control of the driving task with ACC. The information was recorded from four questionnaires administered after the simulator drive.

- Age and gender: from the demographic questionnaire (Appendix 15)
- Experience with ACC: Questions included the estimated number of miles traveled with their ACC-equipped vehicle since it was purchased (new or used), the percentage of the miles the subject drove, and what percentage of the time they used ACC while driving. Knowledge of the

system with regard to its limitations, specifically emergency braking and warnings, slowing or stopped vehicles, and following vehicles through curves, was also surveyed. (Appendix 16).

- Driving style (Appendix 17)
- Trust in ACC (Appendix 18)

4 RESULTS

4.1 Descriptive Statistics

4.1.1 Experience Groups

Previous survey studies on early adopters of ACC have used the number of miles driven as a surrogate measure of experience driving the vehicle and concomitant experience with ACC (Llaneras, 2006; Jenness et al., 2008). In this study, several methods of categorizing experience were explored. First, experience was categorized by the number of total miles driven by the participant with the ACC-equipped vehicle. Next, experience was categorized by the percentage of time drivers used ACC. Finally, ACC was categorized by multiplying the first two methods. Only the first method, categorizing experience by the number of miles driven with the ACC vehicle, was found to be a significant predictor in hypotheses 2, 4 and 5.

Experience was divided into three groups by total miles driven with the ACC vehicle. The groups are defined as follows: Experience Group 1 (EG1) with 0-20,000 miles; Experience Group 2 (EG2) with 20,001-40,000 miles; and Experience Group 3 (EG3) with more than 40,000 miles. There were 8 participants in EG1, 4 males and 4 females with a mean age of 55.4 years (SD 12.4 years). There were 0 participants in EG2, 6 males and 3 females with a mean age of 53.2 years (SD 13.1 years). There were 7 participants in EG3, 5 males and 2 females with a mean age of 62.6 years (SD 15.4 years).

4.1.2 Age Groups

Participants were also divided into two age groups: Age Group 1 (AG1) included participants 60 and younger, and Age Group 2 (AG2) included participants over 60. There were 13 participants in AG1, 5 male and 8 females with a mean age of 46.4 years (SD 9.1 years). There were 11 participants in AG2, 10 males and 1 female with a mean age of 68.9 years (SD 4.8 years).

4.1.3 System Knowledge

There were three questions on the ACC questionnaire (Appendix 16) that test specific knowledge about the ACC system:

1. Does the ACC system warn or alert you if you get too close to the vehicle ahead and need to intervene by applying the brakes? (deceleration alert)
2. Is the warning only active when the ACC is in use, or is the warning active even when the system is off? (general ACC use)
3. If you encountered a stopped car ahead in your lane with the ACC system engaged, how do you think the system would react? (stopped vehicle)

The percent of participants that answered each question correctly by experience group and age group are shown in Figure 11 and Figure 12. No respondents in groups EG2 or EG3 gave the correct answer to the stopped vehicle question.

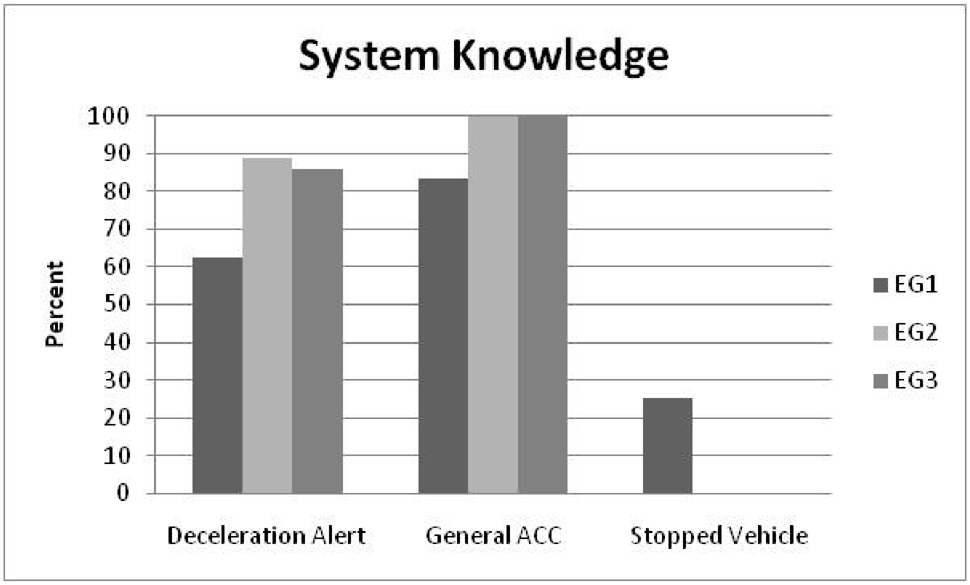

Figure 11: Effect of Experience on Correct Understanding of System Response.

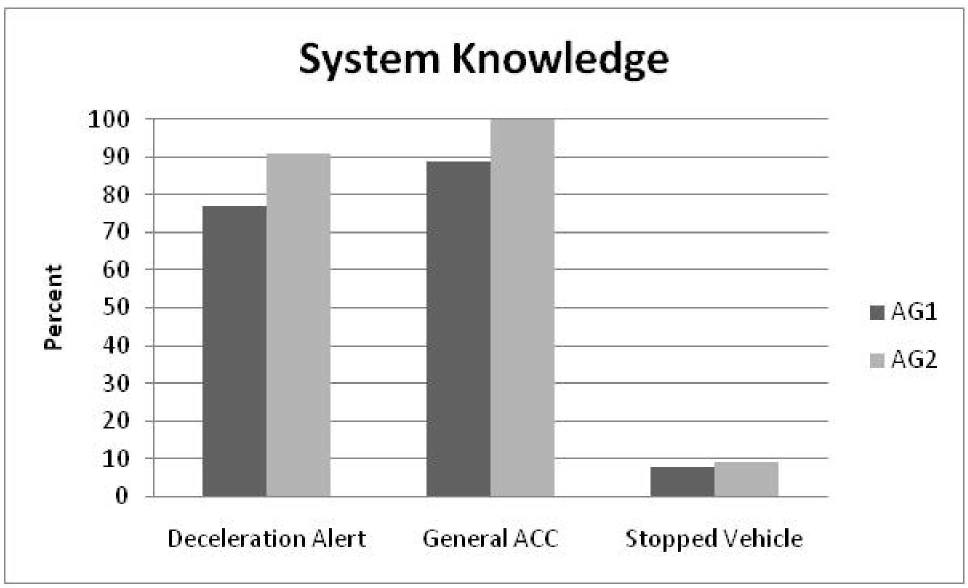

Figure 12: Effect of Age on Correct Understanding of System Response.

As the figures illustrate, more experienced drivers were more likely to understand when deceleration alerts would be given and how system engagement affects alerts but less likely to understand that the system does not respond to stopped vehicles. The older age group appears to understand the system better than the younger age group.

There were additional survey questions (Appendix 16) that tested participants' knowledge of the ACC system on a 5-point Likert scale with anchors "Not at all" (1) to "Very much" (5), with an additional option of "Don't Know." The question read as follows:

> For each of the following situations, please rate how much you think that ACC would help you in avoiding a crash with the vehicle in front of you if…

- You are following a vehicle in stop-and-go traffic,

- The vehicle stopped in your lane,
- You are following a vehicle that slows to a stop,
- You are following the vehicle on a curvy road, and
- You are following a vehicle that brakes suddenly, as if in an emergency situation.

Participants rated the utility of the systems neutral to negative across all situations with the exception of the emergency braking situation, which they rated as slightly positive (Figure 13). The majority of drivers in the moderate experience group ranked the system as more helpful in all situations except during stop-and-go traffic. The younger age group found the system more helpful than did the older age group for all situations except for emergency braking, where it was found equally helpful (Figure 14).

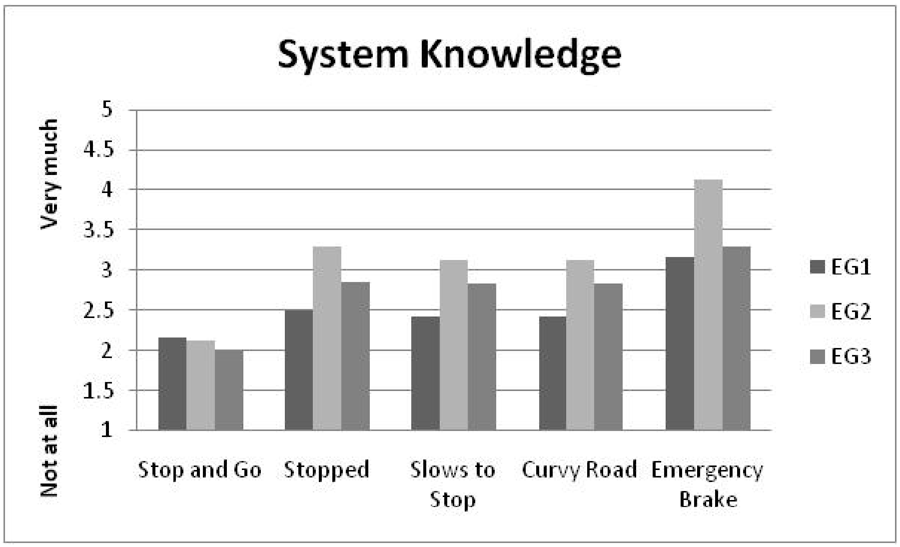

Figure 13: Effect of Experience on Perceived System Utility.

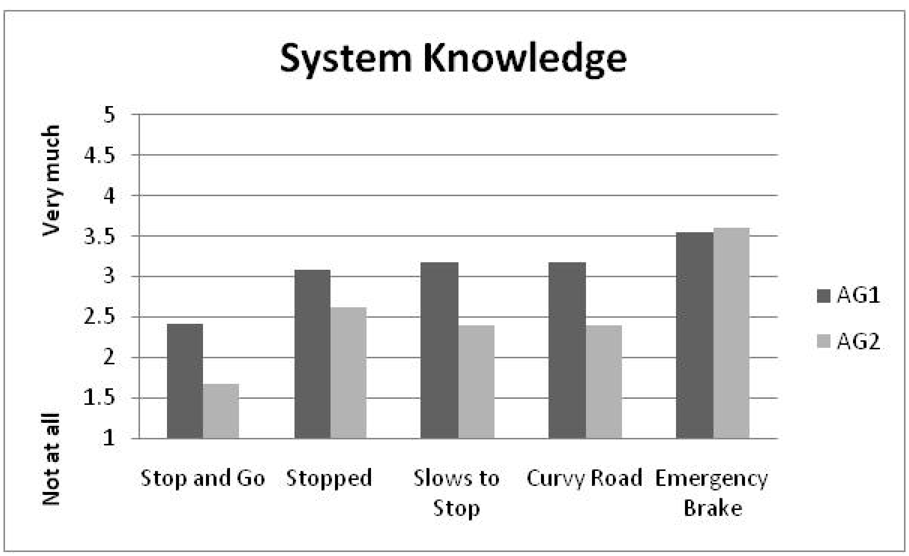

Figure 14: Effect of Age on Perceived System Utility.

4.1.4 Driving Styles (DS)

There were 15 questions in the driving style questionnaire (Appendix 17). Each question is on a 6-point Likert scale ranging from (0) "Never or very infrequently" to (5) "Very Frequently or Always." The mean scores of participants who answered each question segmented by experience, age, and gender groups are shown in Table 5 through Table 7. Inferential statistics were not examined for these questions, but some of the differences (0.3 and greater) may be of interest for future analysis and are noted.

Mean responses for the driving style questions based on experience level are shown in Table 5. Less experienced drivers (EG1) had a higher mean response of 2.3 for Q3 (Do you dislike people giving you advice about your driving?) than EG2 (mean=1.9) and EG3 (mean=1.3). EG1 also responded more frequently (mean=1.8) for Q8 (Do you become flustered when faced with sudden dangers while driving?) than EG2 (mean=1.0) and EG3 (mean=1.1). Moderately experienced drivers (EG2) had a slightly higher mean response (mean=2.6) for Q10 (Are you happy to receive advice from people about your driving?) than EG1 (mean=1.9) and EG3 (mean=2.3). More experienced drivers (EG3) had a higher mean response (mean=4.0) for Q1 (Sometimes when driving things happen very quickly. Do you remain calm in such situations?) than EG1 (mean=3.5) and EG2 (mean=3.3). They also had a higher mean response (mean=1.9) for Q9 (How often do you set out on an unfamiliar trip without first looking at a map?) than EG1 (mean=1.0) and EG2 (mean=1.1).

Table 5: Effect of Experience on Driving Style.

Experience Group	Driving Style Questions														
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15
EG1	3.5	2.9	2.3	2.8	0.0	0.8	2.0	1.8	1.0	1.9	4.0	3.3	1.8	3.8	1.1
EG2	3.3	3.2	1.9	2.6	0.3	1.1	1.8	1.0	1.1	2.6	4.1	3.1	2.2	3.8	1.2
EG3	4.0	2.3	1.3	2.3	0.1	0.9	1.7	1.1	1.9	2.3	4.0	2.9	2.1	2.7	0.6

Note: The highest mean responses with a difference (Δ) greater than 0.3 from another value in the same column are highlighted.

The mean responses for the driving style questions based on age are shown in Table 6. The mean responses of Q6 (Do you exceed the speed limit in business areas?) (mean=1.3) and Q4 (Do you exceed the 70 mph limit on Iowa intestates?) (mean=3.0) for drivers in the younger age group (AG1) are higher than those of AG2 (mean=0.5 and 2.0, respectively). They appeared more likely to dislike people giving advice about their driving (Q3) and to not be happy to receive advice from people about their driving (Q10). Overall their driving style is much less cautious than that of drivers in AG2.

Table 6: Effect of Age on Driving Style.

Age Group	Driving Style Questions														
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15
AG1	3.6	2.6	2.4	3.0	0.2	1.3	2.2	1.4	1.6	1.9	3.9	3.3	2.3	3.8	1.2
AG2	3.5	3.1	1.2	2.0	0.1	0.5	1.5	1.2	0.9	2.9	4.3	2.8	1.7	3.1	0.8

Note: The highest mean responses with a difference (Δ) greater than 0.3 from another value in the same column are highlighted.

The mean responses for the driving style questions based on gender are shown in Table 7. Male drivers reported higher mean values for Q1 (Sometimes when driving, things happen very quickly. Do you remain calm in such situations?) and lower mean values for question Q8 (Do you become flustered when faced with sudden dangers while driving?) than female drivers.

When asked about planning trips in advance (Q2 and Q9), male drivers plan more than female drivers. However, female drivers have higher mean values for Q3 (Do you dislike people giving you advice about your driving?) and Q7 (Do you ignore passengers urging you to change your speed?). In terms of driving speed, female drivers reported higher mean values for Q4 (Do you exceed the speed limit 70 mph limit on Iowa interstates?) (mean=2.8), Q6 (Do you exceed speed limit in business areas?) (mean=1.1), and Q14 (Do you pass vehicles on a four-lane roadway if you have the opportunity?) (mean=3.7) than male drivers (mean=2.4, 0.8, and 3.3, respectively). Females reported that they seldom drive fast (Q13) and can frequently (mean=3.6) ignore distractions while driving (Q12).

Table 7: Effect of Gender on Driving Style.

Gender Group	**Driving Style Questions**														
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q11**	**Q12**	**Q13**	**Q14**	**Q15**
Male	3.7	3.0	1.7	2.4	0.1	0.8	1.7	1.0	0.9	2.4	4.1	2.8	2.2	3.3	1.0
Female	3.3	2.6	2.1	2.8	0.3	1.1	2.1	1.8	1.9	2.1	4.0	3.6	1.8	3.7	1.0

Note: The highest mean responses with a difference (Δ) greater than 0.3 from another value in the same column are highlighted.

4.1.5 Trust in Automation

There were 12 questions related to trust in automation (Appendix 18). Participants were asked to give the percentage (out of 100) that they trusted ACC. The means for participants' responses by experience, age, and gender are shown in Table 8, Table 9, and Table 10, respectively.

Drivers with less experience (EG1) reported less trust in ACC than the other two groups. For example, the mean values of Q6 (ACC will be able to cope with future driving situations) (mean=60), Q7 (ACC system to respond accurately) (mean=58), Q9 (Overall trust of ACC) (mean=57), and Q10

(“Cooperation with ACC”) (mean=59) were much less than those of EG2 (mean=76, 83, 87, and 85, respectively) and EG3 (mean=84, 84, 84, and 84, respectively).

Table 8: Effect of Experience on Trust in Automation.

Experience Group	**Trust in Automation Questions**											
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q11**	**Q12**
EG1	68	67	63	71	76	60	58	66	57	59	75	87
EG2	82	82	84	83	85	76	83	84	87	85	86	92
EG3	81	79	78	84	85	84	84	85	84	84	87	90

Note: The highest mean responses with a difference (Δ) greater than 5 units from another value in the same column are highlighted.

All mean trust scores for older drivers were higher than those of younger drivers. The greatest difference appears to be with questions Q4 (the ACC system to perform the task it was designed to do), Q6 (the ACC system will be able to cope with future driving situations), Q7 (ACC system to respond accurately), and Q8 (trust in the ACC system’s display).

Table 9: Effect of Age on Trust in Automation.

Age Group	Trust in Automation Questions											
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
AG1	74	76	72	74	79	69	71	75	73	73	82	89
AG2	80	77	79	84	86	78	80	83	80	79	83	91

Note: The highest mean responses with a difference (Δ) greater than 5 units from another value in the same column are highlighted.

Females appear to have less trust in ACC than males. The lowest responses corresponded to questions Q6 (the ACC system will be able to cope with future driving situations) (mean=63), and Q7 (ACC system to respond accurately) (mean=62).

Table 10: Effect of Gender on Trust in Automation.

Gender Group	Trust in Automation Questions											
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Male	80	79	80	83	85	79	83	83	83	82	85	92
Female	72	72	67	72	78	63	62	71	64	65	78	86

Note: The highest mean responses with a difference (Δ) greater than 5 units from another value in the same column are highlighted.

4.2 Data Analysis

4.2.1 Critical Versus Non-Critical Events

This chi-square analysis demonstrates, as expected, that the critical and non-critical events did indeed elicit different responses. Table 11 shows the number of responses and non-responses for the critical and non-critical events for all participants. Participants were observed to respond more often to critical events than non-critical events ($\chi^2(1) = 79.02$, $p<0.001$)(significance was determined at $p<0.05$ for all analyses). For critical events, participants responded 94 percent of the time; however, for the non-critical events, participants responded 21 percent of the time. The most surprising aspect of this comparison was that in the non-critical situations where no response was needed, one-fifth of drivers still responded.

Table 11: Response Data for Critical and Non-critical Events.

	Critical	Non-Critical
Response	67	15
No Response	4	57
Total	71	72

Beyond initiation of response, two parametric measures were used to further evaluate driver response: initial response time and minimum acceleration. These measures were analyzed as an ANOVA using the SAS general linear models procedure with the inclusion of event type (critical or non-critical), road geometry (straight or curve) and road type (rural or interstate). There was not a statistically significant difference for the initial response time between the critical and non-critical events ($F(1,10)=2.37$, $p=0.1546$); however, there was a statistically significant difference for the minimum acceleration ($F(1,23)=668.32$, $p<0.001$) with greater negative accelerations (higher decelerations) present in the critical events (see Figure 16).

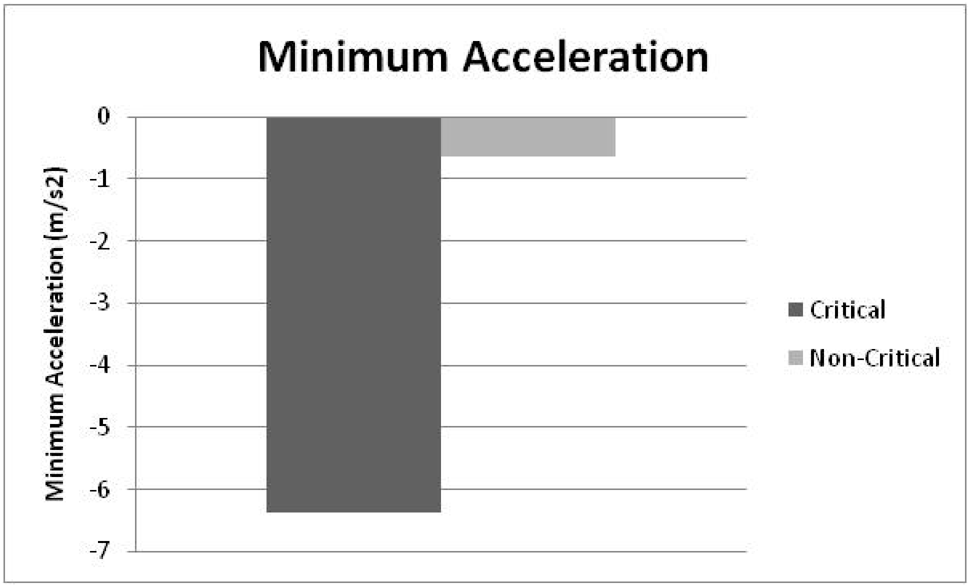

Figure 15: Minimum Acceleration for Critical and Non-critical Events.

4.2.2 Error Criticality

This analysis examined the relative criticality of different types of errors (Hypothesis 4). Thirty errors were committed across all drives by all participants. The frequencies of the five defined error types are provided in Table 12. As shown, the most frequent error types were associated with the use of ACC in curves, and no participants failed to adjust the ACC in response to changes in speed limit.

Table 12: Frequency of Errors with the ACC System.

Error Type	Error Description	Count
1	Failure to respond to the deceleration exceedance warning	2
2	Failure to disengage ACC around curves and exit ramps where the lead vehicle is lost for at least 10 percent of the curve	21
3	Failure to decrease gap setting or disengage ACC when entering a small radius curve on the long gap setting	4
4	Failure to respond to the stopped vehicle, resulting in a TTC of less than 2.75 seconds by the end of the first response	3
5	Failure to decrease the vehicle's set speed or disengage ACC when approaching a decrease in speed limit	0

To examine the criticality of the errors, ANOVAs were used to determine if there were differences in levels of criticality between adjusted minimum time to collision and minimum time headway (see Appendix 42).

No statistical difference was found for either AMTTC or MTH between error types. However, the standard deviation (8,166 seconds) for AMTTC for Error Type 2 (curves) far exceeds its mean (2,067 seconds). Many instances of Error Type 2 (curves) occur in situations where the lead vehicle is traveling at the same speed as the participant, resulting in very large AMTTC values. To adjust for the instances where AMTTC is very large, errors with AMTTC values above the median value (42 seconds) were excluded from the analysis, leaving only the more critical errors of Error Types 2 and 3. After this adjustment, a significant difference was found between error types ($F(3,11)=7.92$, $p=0.0043$), which is shown in Figure 16. Error Types 2 (curves) and 3 (small radius curves) pertaining to following vehicles around curves were found to be less critical than Error Types 1 (deceleration authority) and 4 (stopped vehicle).

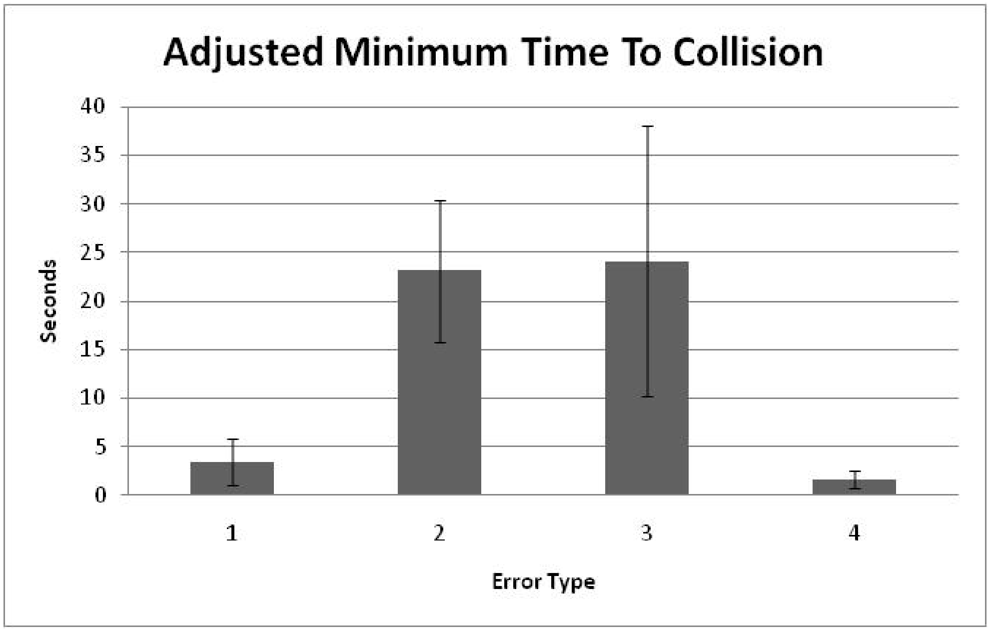

Figure 16: Adjusted Minimum Time to Collision between Error Types.

4.2.3 Use Patterns

This analysis examined the relationship between drivers with different levels of experience using ACC, and/or in different age groups, and their ACC use patterns (Hypothesis 3).

A cluster analysis using a hierarchical method (Ward's minimum variance) was conducted using the statistical package, R. This analysis grouped drivers based on percentage ACC engaged, disengage count, short gap setting percentage, medium gap setting percentage, long gap setting percentage, warnings issued, and average set speed relative to speed limit. All data were normalized prior to the analysis. The "percentage response to deceleration warnings" was recommended in the experimental plan but was not included in the analysis due to missing values. The cluster analysis revealed three groups of drivers (as shown in Figure 17).

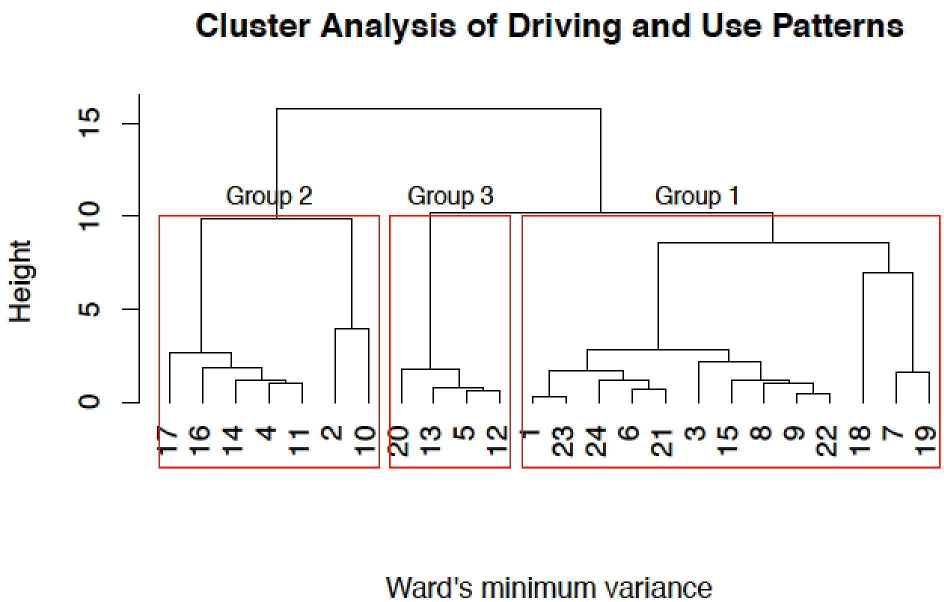

Figure 17: Cluster Analysis of Drivers using Ward's Minimum Variance in R.

Group 2 had highest higher number of short (mean=32.5%) and medium (mean=54.14%) gap settings than Group 1 (mean=1.4% for short gap setting and 4.49% for medium gap setting) and Group 3 (mean= 0% for short gap setting and 2.87% for medium gap setting). Group 2 also had a higher number of disengaged events (mean =15.66). These two findings may be highly related since the ACC will automatically disengage when you manually brake.

When these three groups were examined based on trust, the largest cluster (Group 1, n=13) trusted the system the most with scores ranging from 78 to 91 (out of 100) across the 12 trust questions. Group 2 (n=7) trusted ACC the least with scores from 60 to 85. Group 3 was the smallest group with n=4, and they had a more diverse range of trust (from 69.75 to 90). Specifically, Group 3 had less trust that the ACC system's behavior can be predicted from moment to moment (mean response of 69.75) but more trust in their self-confidence to manually intervene with the ACC system (mean response = 90.25).

The three groups reported very different driving styles. Group 1 was more likely to be influenced by passengers telling them to change their speed (Driving Style Q 7). Group 2 appears to be very confident in their own driving skills, as exemplified by the short gap settings used and their responses to the driving style questions. This group never ran a red light (mean=0.00), could frequently ignore distractions while driving (mean=3.57), and tended to drive faster (mean=3.00) than Group 1 (mean=1.7) and Group 3 (mean=1.5). Group 3 reported using ACC the most (with 70% or mean driving miles of 23,301 miles), and Group 2 reported the least exposure to ACC (with 51% or mean driving miles of 13,645).

The mean ages across the three groups were similar (mean age=57 for Group 1, 57 for Group 2, and 54 for Group 3. The proportion of males and females were relatively similar for Group 2 (57% males, 43% females) and Group 3 (50% males, 50% females), but there was a higher proportion of males in Group 1 (69% males, 31% females). The proportions of EG1 across the three groups were similar (37.5% for Group 1, 37.5% for Group 2, and 25% for Group 3). But there was a higher proportion of EG2 in Group 1 (55.6% for Group 1, 33.3% for Group2, and 11.1% for Group 3). The proportion of EG3 is even higher in Group 1 (71.4% for Group 1, 14.3% for Group 2, and 14.3% for Group 3).

4.2.4 Response to Critical Events

This analysis examined drivers with different levels of ACC experience, and/or in an older age group, and their response times to feedback provided by the ACC system when its operational limits were exceeded (Hypothesis 2). When the ACC system's operational limits are exceeded, it issues an auditory alert to indicate that the driver should brake. Seventeen alerts were issued during the 96 events (four per participant) that were expected to elicit the deceleration alert. These events include three critical braking events and a lead vehicle cut-in event. Of the 17 alerts, 9 were issued when participants were in the process of responding to the critical event. The majority of participants disengaged ACC before it issued an alert but after the lead vehicle had begun to decelerate or cut in.

An ANOVA was used to determine if there were differences between response time from alert and initial response time. There was no significant difference by experience group for response time from alert ($F(2,4)=0.19$, $p=0.8366$). Because most participants disengaged ACC prior to an alert, the initial response time from the point where the lead vehicle began to brake or change lanes was examined.

The response times for the three critical braking events were averaged. Again, no statistical difference was found by experience group ($F(2,18)=0.11$, $p=0.8951$). However, a significant difference was found by age group ($F(1,18)=6.51$, $p=0.0201$), event type (critical braking vs. cut-in) ($F(1,13)=7.70$, $p=0.0158$), and the interaction between age and event type ($F(1,13)=8.55$, $p=0.0119$). This interaction is shown in Figure 18. There was a difference between age groups in the response to cut-in events, with the older participants (AG2) responding faster. There were no significant differences for initial response time by cluster groups ($F(2,18)=0.72$, $p=0.5021$).

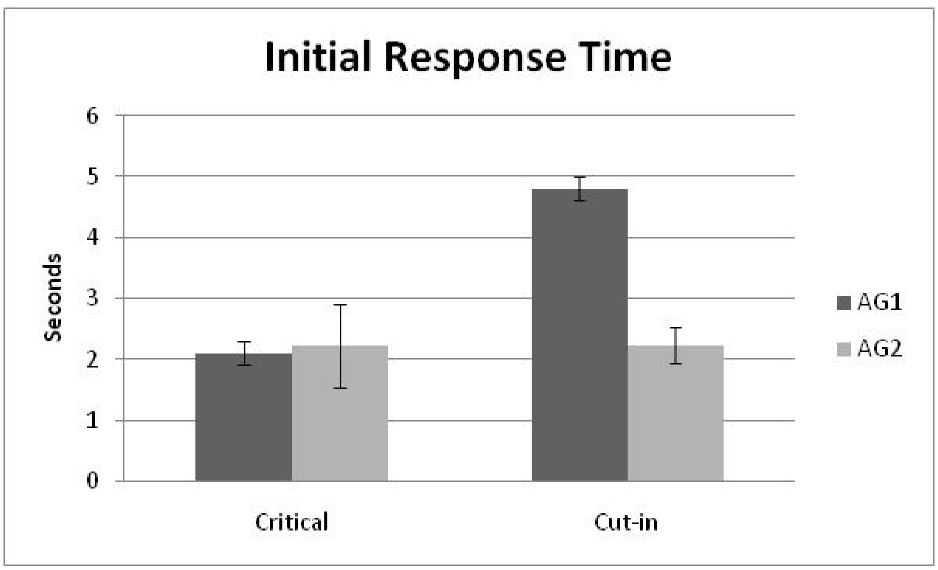

Figure 18: Mean Initial Response Time for Age Group and Event Type.

4.2.5 Errors Committed

This analysis examined the relationship between error types, ACC experience, and age groups (Hypothesis 5). For this analysis, Error Type 5 (speed limit) was excluded since there were no errors of this type. There is a significant difference between the count of errors types between experience groups (Fisher's exact test, $p=0.0459$), which is presented in Table 13. Only participants with the least experience (EG1) committed Error Types 1 and 4, which were found to be the more critical errors (see

4.2.4). Error Types 2 and 3 were committed by both the inexperienced and more experienced participants.

Table 13: Error Types by Experience Group.

Error Type and Description	**Experience Group**			**Total**
	1	**2**	**3**	
1. Failure to respond to the deceleration exceedance warning	2	0	0	2
2. Failure to disengage ACC around curves and exit ramps where the lead vehicle is lost for at least 10 percent of the curve	5	9	7	21
3. Failure to decrease gap setting or disengage ACC when entering a small radius curve on the long gap setting	1	3	0	4
4. Failure to respond to the stopped vehicle, resulting in a TTC of less than 2.75 seconds by the end of the first response	3	0	0	3
5.Failure to decrease the vehicle set speed or disengage ACC when approaching a decreasing speed limit	0	0	0	0
Total	11	12	7	30

In the survey on knowledge of ACC (Appendix 16), participants were asked how the ACC system would react to a stopped vehicle in the lane. The selections were: (1) Detect the vehicle and slow to a stop; (2) Detect the vehicle, start to slow, but require the driver to stop; (3) Not detect the stopped vehicle; and (4) Don't know. Analysis of this question revealed that there was a significant difference between participants in each experience group as to what they thought the system would do (Fisher's exact test, $p=0.0373$) (Table 14). The least experienced group (EG1) contained the only participants that knew that the ACC system would not detect the stopped vehicle. One of the participants who indicated that ACC would not detect the stopped vehicle committed Error Type 4. Additionally, the single participant who committed Error Type 1 (two times) indicated that ACC would not warn or alert the driver if they get too close to the vehicle ahead.

Table 14: Stopped Vehicle Question by Experience Group.

Response	**Experience Group**			**Total**
	1	**2**	**3**	
1 – Stop	0	0	1	1
2 – Slow	3	8	6	17
3 – Not Detect	2	0	0	2
4 – Don't Know	3	1	0	4
Total	8	9	7	24

4.2.6 Potential Countermeasures

Survey responses were examined to identify countermeasures that could be employed to abate the safety-critical errors drivers make with familiar ACC systems. Participants were administered a survey on perceived problems and countermeasures. They were asked: "Please list problems or challenges you have experienced with your ACC system where it worked differently than you thought it should. Suggest any recommendations you would make to change the system's functionality or design." (Appendix 24). The results of that survey are tabulated in Table 46 (Appendix 41). The results of the survey responses were grouped into four categories: system limitations, annoyances, safety concerns, and driver misconceptions.

4.2.6.1 System Limitations

Several of the problems noted by drivers related to actual limitations of the system. Rain, fog, and bright sun can interfere with the system's ability to accurately sense lead vehicles. Snow can accumulate on the sensor locations, blocking the laser. Rock chips can strike the sensor locations, causing damage to the system. In most cases, these limitations are merely annoyances. However, they become a potential safety concern if the driver isn't aware of the limitation and depends too much on the system to supply braking. The only suggested countermeasure for these situations was to redesign the systems to move the sensors to locations on the car that are less prone to interference.

4.2.6.2 Annoyances

Some problems noted by drivers were annoying to them. Four drivers perceived the gap as an opportunity for other vehicles to pass and pull in front of them. Suggested countermeasures included switching to conventional cruise control (CCC) and decreasing the following distance. Three drivers were annoyed that there was no warning if the lead vehicle gradually slowed down over time. The suggested countermeasure was for the system to provide notification in such a situation. Two drivers felt that the set speed resolution of 5 mph was too coarse and would prefer if the system allowed 1 mph increments and decrements. Finally, one driver felt that the system braked too rapidly, and another thought that the following distance setting resolution was too coarse. The suggested countermeasures were to react earlier to prevent over-braking and to allow more choices for gap setting.

4.2.6.3 Safety Concerns

Some problems noted by drivers can be interpreted as legitimate safety concerns. Four drivers felt that the system accelerated the car too rapidly, especially when there was a 10 mph or larger difference between the set speed and the current speed. This can happen on interchanges and curves and is a safety concern if the driver is not expecting it and reacts in an inappropriate manner. The suggested countermeasure is to better manage the system acceleration, making it less aggressive.

Three drivers felt that the system's icon was hard to see due to its placement or its brightness. This is of particular concern if it makes it difficult for the driver to know whether the system is on and active. The suggested countermeasures were to move the icon higher on the dashboard and to make it brighter.

One driver mentioned an adaptation issue, specifically, that it was easy to forget that ACC wasn't there in another car. No countermeasure was suggested. Another driver stated that white lines on the road can cause false positive warnings and braking. False warnings, whether positive or negative, can be safety concerns if the driver is otherwise distracted and responds based only on the false warning. Also, a driver of a following vehicle could be startled by a braking initiated by a false warning. The suggested countermeasure was to redirect the laser, a suggestion that could be based on a misconception of how the technology works. Driver misconceptions are covered in the next section.

4.2.6.4 Driver Misconceptions

Some of the drivers' comments revealed possible misconceptions about the operation of the ACC system. One driver suggested redirecting the laser as a countermeasure to three separate problems. Another suggested moving the sensors as a countermeasure to heavy rain, a solution that wouldn't solve the problem of sensing a lead vehicle in rain. Some comments from drivers implied that they may be relying on the system to provide sufficient braking in a wide variety of situations or treating the system like a safety system rather than a convenience system.

5 DISCUSSION

5.1 Response to Events

Objective 1 and Hypothesis 1 compare the participants' performance on critical and non-critical events. We expected that critical events would elicit crash-avoidance responses (such as manual braking and/or steering maneuvers) from the driver. Non-critical events included light lead vehicle braking and required no crash-avoidance responses. Driver age was also examined with respect to reliance on ACC, specifically whether drivers became more reliant with increased use and therefore attended less to the driving environment and responded more slowly to emerging events.

In this study, drivers 60 and younger and drivers over 60 both responded to a series of events. The older group responded to the critical braking and cut-in events equally quickly. The younger group's response to the critical braking events was equivalent to the older group; however, their response to the cut-in event was about three seconds longer.

Without additional studies, there is no clear reason for this outcome. Driving history does not provide insight to critical event response: only two participants (one in each age group) reported crashes in the past 5 years, and neither had errors during their study drives. It is speculated that older drivers may be more attentive to (rather than more complacent about) oncoming traffic and therefore respond more promptly to unexpected events such as the cut-ins. Alternatively, the younger driver group may have developed a complacency that has led to narrower visual scanning of the environment. This may, therefore, lead to missed cues from the peripheral that could have provided important information on cut-ins from vehicles in the adjacent lane, resulting in a slower response. Further analysis, including a review of the eye tracking, would be critical to understanding this issue.

5.2 Driving Style and Trust in Automation

One of the goals (Objective 1) of this project is to examine driver performance changes and behavioral adaptations among ACC users over long-term use. Previous studies show that driving style and trust in ACC can influence driver's behavioral adaptation (Kazi et al., 2007).

The less experienced group appeared to have less trust in ACC than the other two groups, younger drivers showed less trust than older drivers, and females had less trust than males. The less-experienced, younger, and female drivers showed similar driving styles in the following areas: reported higher frequency of exceeding the posted speeds (Q4) and passing vehicles on four-lane roadways (Q14). They also indicated with greater frequency that they disliked people giving advice about their driving (Q3), could ignore passengers urging them to change speed (Q7), and could ignore distractions while driving (Q12). However, these drivers also reported that they received advice from people about their driving (Q10) less frequently than their counterpart groups reported.

5.3 Error Criticality

For Objective 2, experience with ACC was examined with respect to the frequency, type, and severity of errors that a driver makes. Based on Hypothesis 4, we expected that three of the five error types—failure to respond to deceleration exceedance warnings (Error Type 1), failure to disengage ACC on curves or exit ramps when the lead vehicle is lost (Error Type 2), and failure to respond to the stopped vehicle (Error Type 4)—would generate fewer errors for the more experienced ACC users, while two—failure to adjust gap setting or disengage ACC on small radius curves (Error Type 3) and failure to adjust speed (Error Type 5)—were expected to generate more errors for this same experience group.

The results show that more experienced drivers did not have any errors associated with Error Types 1 and 4. As expected, less experienced drivers did encounter these two error types. There were, however, no errors associated with Error Type 5 (speeding) among any groups even though this error type was expected for experienced users.

A key result of this research was the relationship between the criticality of errors and driver experience. Errors that are more frequent among experienced users were expected to also be more critical. However, the most critical errors were actually committed by drivers who had the least experience with their ACC-equipped vehicles.

When considering the less critical errors, there did not appear to be a difference between the experience groups. Drivers in each group were equally likely to commit errors of low criticality, such as failure to adjust to a lead vehicle that has left the sensor cone of the ACC system while negotiating a curve. It should be noted that the criticality of the curve events was limited by the experimental setup. Specifically, with a lead vehicle traveling at a speed close to that set by the driver, there was little opportunity for this to result in a critical event. In situations where the subject vehicle is traveling significantly below the set speed of the ACC, the loss of the lead vehicle could result in a sudden acceleration while negotiating the curve. This could result in a lane or roadway departure. Although this error did not result in critical events for this study, the frequency of these errors is cause for concern.

Overall, it appears that drivers with more experience made fewer and less critical errors than did drivers with less experience with the system. This was counter to what we expected, and it appears that automation complacency did not have a significant impact within the range of experiences studied. However, it should be noted that this does not include a comparison with drivers who had very little experience with the system (i.e., novice users).

5.4 Understanding of System Limitations

All but four participants were aware that the ACC system issued alerts when they were too close to a vehicle and needed to manually intervene. All but one of the participants who were aware that the ACC system issued warnings also knew that the ACC system did not issue warnings when it was turned off. However, only two participants understood that their ACC system did not detect stopped vehicles. In fact, 18 of the 24 (75%) participants thought that the ACC system would slow or stop their vehicle when they encountered a stopped vehicle in the road. Even though the majority of the participants thought that the ACC system would respond to the stopped vehicle, they still disengaged ACC and slowed down when encountering one in the roadway. Interestingly, one of the two participants who indicated that they knew that ACC would not detect the stopped vehicle chose to decelerate using the ACC system upon detecting the stopped vehicle, and when unable to reduce speed in time, failed to regain manual control early enough to avoid a near collision with the stopped vehicle during the drive. The post-drive video review revealed that the participant attributed a high degree of comfort and self-confidence in his ability to regain manual control of the vehicle in this event, and that he did not recognize his error.

These results indicate a critical gap in knowledge related to ACC. It is clear that although drivers may understand the ACC system in general and how it will respond in typical situations, there are critical situations in which their perceptions of vehicle response are inaccurate. It was also evident that reported driver knowledge did not necessarily correspond to how drivers reacted in those situations. This may be related to the relative rarity of experiencing some of the limitations of the ACC system. The poor calibration between drivers' level of confidence and ability to safely manage the interplay between manual and supervisory control suggests that the gap in knowledge extends beyond understanding system capabilities and limitations to include a broader misconception of the role the driver plays and the new set of requirements necessary to adequately perform that role.

Another possible explanation relates to the nature of early adopters, many of whom are prone to adopt the technology due to their interest in it, and whose knowledge base might include other brands of ACC systems with differing specifications. Five participants reported that they were aware of ACC systems prior to purchase and wanted to purchase their vehicle because it had ACC. For these types of drivers, there may be confounding between the knowledge of their own system and other systems that they may have already been familiar with, especially with respect to these rare, critical limitations. Because ACC is becoming more prevalent, this may become an increasing problem in the future. To further examine this issue, a study that looks at drivers across a range of system approaches in these rare critical events has the potential to provide more critical answers about the impact of how different systems react to these critical events.

5.5 Safety Critical Countermeasures

The subject-identified countermeasures are presented in Table 46 in Appendix 41. Those classified as safety-critical problems were identified as high-priority items and are summarized in Table 15. Additionally, researcher-identified countermeasures have been suggested, and the problems are linked to the error types listed in Hypothesis 4 (Section 1.2.1).

We note that some problems that are classified as system limitations or annoyances can become safety critical if: (a) the driver relies on the system too much, and (b) the visual/auditory indicators are difficult to see or hear. A clearly observable status indicator with auditory cues helps the driver realize whether or not the system is engaged and is therefore a very important consideration of the ACC system. However, Stanton and Young (2005) reported that providing a heads-up display (HUD) actually decreased participants' situational awareness and that an auditory warning along with an LCD message display was an optimal feedback system with higher workloads. Therefore, the recommended countermeasure to a poorly placed visual icon, noted in the table, is to investigate a better location on the dash, one that is more convenient for the driver's regular glance patterns.

Another commonly reported problem was acceleration that was perceived as being abrupt or aggressive. For example, if the driver has chosen a set speed on the highway, and the ACC system slows the speed significantly in response to a lead vehicle that is slowing for an exit ramp, there is danger of the system causing a sudden acceleration if it loses tracking of the lead vehicle. Drivers have reported aggressive accelerations, especially if the speed is more than 10 mph lower than the set speed. This situation can be safety critical if the driver or surrounding vehicles react to this acceleration in an unexpected or unsafe manner. The suggested countermeasure is to limit the acceleration to a more moderate level, either in all cases or when the vehicle is negotiating a curve. Another possible countermeasure is for the system to have the ability to adjust the set speed intelligently if it detects that multiple system accelerations have taken place, or if the speed/set-speed difference is large. Aggressive acceleration is linked to Error Types 2 and 3 because the penalty for losing the lead vehicle in these situations with the ACC engaged is a potential sudden acceleration. Thus, eliminating the sudden acceleration in these situations would effectively remove the penalty from those errors.

An identified problem of braking too slowly by the system is an indication of over-reliance on the system or a misunderstanding of its purpose as a convenience system. The proper countermeasure would be an effort to educate the driver as to the system's purpose. It should even be possible for the car to monitor system-activated braking and detect whether the driver is relying on the system in too many situations.

Table 15: Safety Critical Countermeasures.

Problem	Subject-identified countermeasure	Researcher-identified countermeasure	Error type	Notes
Accelerates too rapidly	More gradual acceleration	More gradual acceleration. Self-adaptive set speed after repeated accelerations	2,3	Rapid auto-acceleration is the penalty for losing the LV and failing to disengage ACC
Display is hard to see, poorly placed	Make brighter, move higher on dash	Make larger, place higher, use contrasting colors	1	
Picks up cars in next lane	Narrow the beam of the laser			
Brakes too slowly	Manually apply brakes	Driver education on the purpose and limitations of ACC		Drivers may over-rely on ACC, treating it like a safety, rather than a convenience, system
White lines can cause false positive warnings	Redirect laser?			White lines and other reflective surfaces, if they are sensed, should appear as a 'stopped' hazard
Forget that it's not there when change cars		Strongly differentiate system active and inactive status		
Short gap setting not safe	Only use longest gap setting		3	
Poor front detection, does not alert	Make more sensitive, redirect laser?	Detect and indicate perceived sensor failures caused by dirty or snow-covered sensors		Could be linked to misunderstanding of system limitations (rain, snow) and dirty sensors

5.6 Conclusions

Twenty-four participants completed scenarios through rural, interstate, and residential environments. Data were collected using surveys and simulator variables, and the results were grouped and analyzed by experience, age, and gender. All participants were experienced with ACC to some degree; thus, there was no novice component to this study. There were three main objectives of this research study related to how early adopters of ACC technology perform and behave with the system.

1. Objective 1: Determine whether drivers who are experienced with ACC (as part of their personal vehicle use) respond appropriately to the feedback provided by a familiar ACC system under crash-likely scenarios.

   Finding: Overall, these early adopters had few critical errors, and only one driver failed to respond to alerts from the ACC system when the limits of the system were exceeded in critical events where crashes were possible when the driver did not intervene. More concern exists when a vehicle is stopped on the roadway in front of the driver. There seemed to be general confusion about how the system would respond in this situation, which poses a significant safety concern.

2. Objective 2: Determine if there are usage and error patterns that emerge across a sample of drivers who currently use ACC, how critical the errors are, and what impact they may have on safety.

   Finding: The most frequent errors were curve-related and were not safety critical and resulted in little immediate risk to the driver. The critical errors were related to not responding to system limitations. These errors did not result in any collisions in this study, but did result in average minimum TTCs of less than four seconds. It should also be noted that these most critical errors were also associated with the least experienced drivers, providing some indication that increased exposure to the ACC system results in better system understanding and a reduction in the most safety-critical types of errors.

3. Objective 3: Identify countermeasures, if drivers make safety-critical errors or engage in problematic usage patterns when driving with familiar ACC systems.

   Finding: The most frequent errors, resulting from curve-related events, were not safety critical under the situations tested. Subjective data sheds additional light on these situations as evidenced by driver concern over rapid acceleration when the lead vehicle is lost by the system and the vehicle is traveling below the set speed. A promising countermeasure would be to augment the ACC system to avoid acceleration commands when the lead vehicle is lost by the system while the vehicle is approaching or negotiating a curve.

The results from the trust survey confirmed an expectation that more experienced ACC users would have greater trust in the technology. This highlights the contrast with the result that less experienced ACC users committed more safety-critical errors. It does not appear that greater trust correlates with more complacency in this study. While the number of observed safety-critical errors was small, further research into the impact of automation complacency on driver behavior adaptation with ACC may be warranted.

The less experienced ACC users showed more knowledge of system limitations regarding stopped vehicles than their more experienced counterparts. Further research is needed on how drivers were educated on ACC system limitations and why so few knew of the stopped vehicle limitation. In particular, were misunderstandings conveyed by dealers, or did drivers simply develop a mental model of ACC from their experience that was too simplistic?

This study focused on a particular implementation of ACC found on Toyota and Lexus vehicles. Driver knowledge of other systems and its potential influence on their understanding or behavior was not studied. Future work may consider whether advertisement of conflicting system specifications influences misunderstandings about system limitations.

ACC continues to be an effective tool for helping drivers maintain consistent headway gaps and prevent unnecessary lane changes. The system modeled in this study seems to be effective at engendering trust without causing complacency. Driver education and a clear driver-vehicle interface will help mitigate potential problems from encountering system limitations.

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APPENDIX 1: VALIDATION

Toyota Avalon Test Results

A new Toyota Avalon was rented from a dealership for the purpose of instrumentation and testing. We had the car for almost three days, in which time we were able to spend considerable time with it on various types of roads testing out the ACC system. Minimal instrumentation was installed to collect data during the tests. A portable accelerometer with onboard storage was installed in the car. The data from the accelerometer was collected at 10 Hz and included longitudinal acceleration (*Ax*), lateral acceleration (*Ay*), and engine RPM. Moreover, a laptop data acquisition system was connected to the car's OBD port. The data collected on the laptop included engine RPM, engine load, throttle input, and velocity. The OBD data was collected at a variable sampling period that averaged about 1.3 s, or about 10 times slower than the accelerometer. The longitudinal acceleration (*Ax*) was calculated as the derivative of velocity. Finally, a video camera and digital voice recorder were utilized to capture comments and record the icons and alerts generated by the car.

Some sample OBD and accelerometer data for five tests (ranging from 1.5-3.5 minutes each) are shown in the following four figures. The beginning and end of each tests is marked with a red dot (unless the beginning of the test was at zero, in which case the dot doesn't appear). Figure 19 and Figure 20 show the OBD Ax, Accelerometer Ax, OBD engine speed, and Accelerometer engine speed respectively. The difference in sampling rates is visibly noticeable between the accelerometer and OBD data in the jagged appearance of the traces. The accelerometer data, having a faster sampling rate, is a better signal to use for estimating jerk.

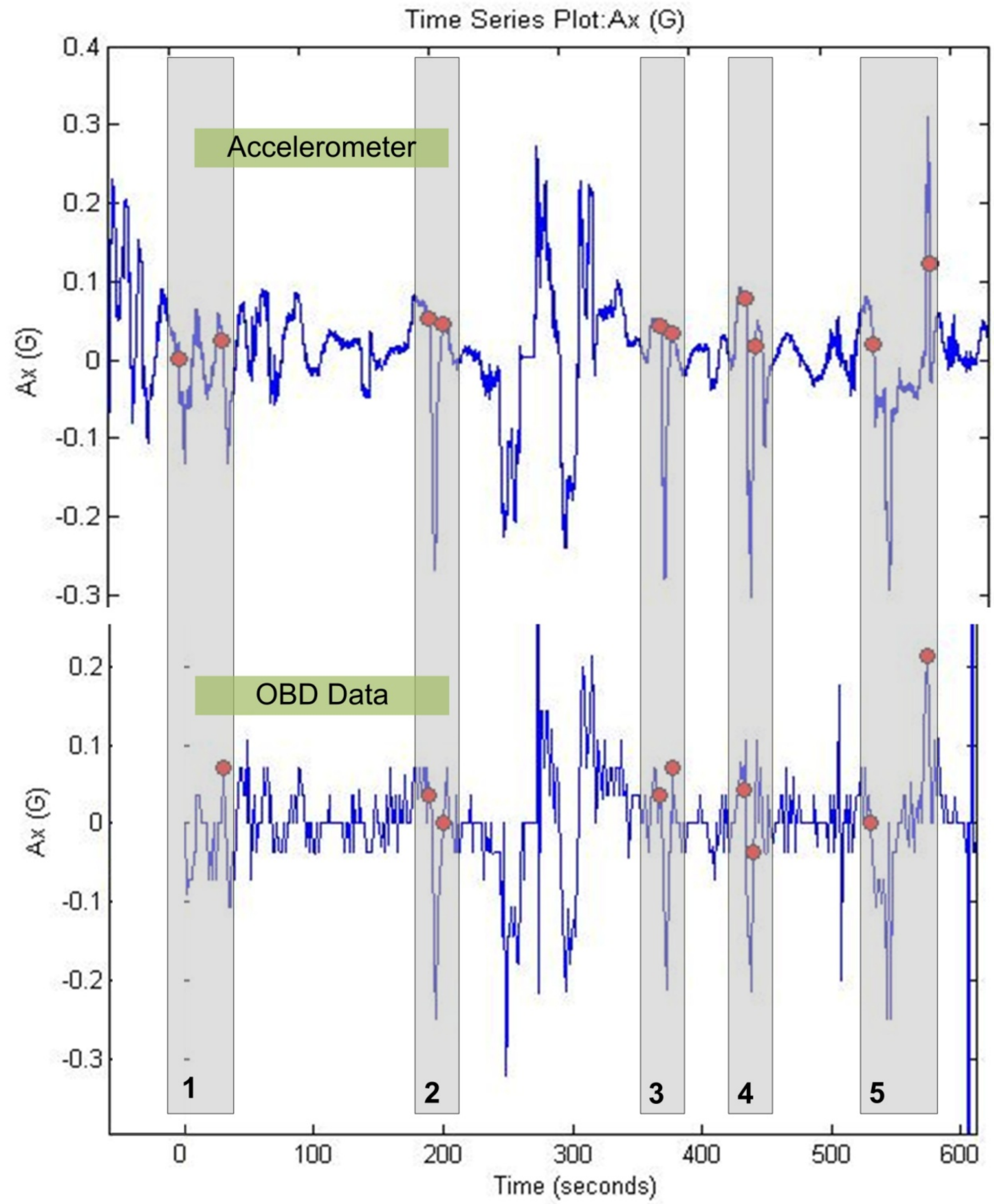

Figure 19: OBD and Accelerometer Data: Longitudinal Acceleration

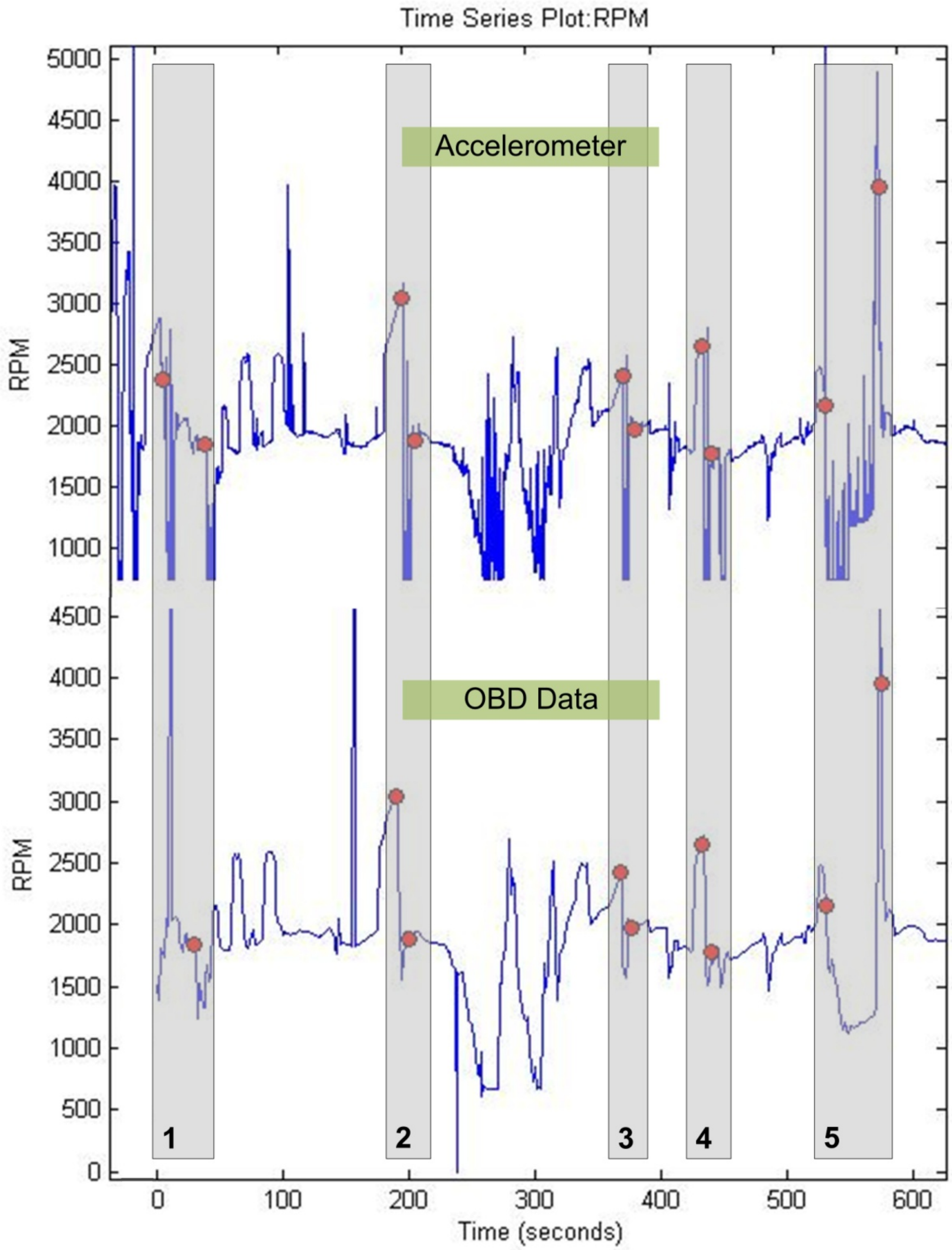

Figure 20: OBD and Accelerometer Data: Engine RPM

A list of specific tests that were conducted is compiled in Table 16: ACC Test Descriptions. Beyond this list, several hours of data are also available from on-road driving. That data was also used to glean information about the system's behavior during normal driving in traffic.

Table 16: ACC Test Descriptions

Test Description	Accelerometer	OBD
Lead Vehicle cut-in event at long gap setting. No manual intervention.	X	X
Lead Vehicle cut-in event at medium gap setting, closer to vehicle than long gap setting. No manual intervention.	X	X
Lead Vehicle cut-in at short gap setting. No manual intervention.	X	X
Lead Vehicle cut-in at short gap setting. No manual intervention.	X	X
Exit ramp at short gap setting. No manual braking was done, but manual acceleration was done at the end of the ramp.	X	X
Exit ramp at medium gap setting. No manual braking was done.	X	
Exit ramp at long gap setting. No manual braking was done, manual acceleration was done at the end of the ramp.	X	X
Accelerometer test 1	X	X
Accelerometer test 2	X	X

Validation Procedure

We were able to do some model validation using the data that was collected during the testing to deduce the values of model parameters with unknown values. The difficulty was that some parameters are adaptive in nature and could change values based on the situation. Finally, parameters do not tell the whole story of how the system logic works to transition between modes, etc.

A full-scale testing and validation regiment was beyond the scope of the project. Rather we aimed for a model that behaves like the Toyota system as far the drivers can tell. It will not be possible to perfectly match the system behavior in all its various regions of operation.

We had multiple sources of data against which to compare our model's performance, some quantitative, and some qualitative. Data collected from the accelerometer and OBD port were used to estimate some model parameters, while the remaining video data and observations were used to validate the general behavior of the system.

The main unknown parameter in the model was the limit on the jerk, or derivative of acceleration. Toyota has stated that this limit is variable, depending on the situation; but that it remains small most of the time (no additional information about jerk limits was provided). The jerk is easily computed from the acceleration. The accelerometer data is best suited for this purpose because it has a higher sampling rate and measures acceleration directly. We had tests from mild and severe situations, so jerk limit variations could be studied. Minimum and maximum jerk limits used in the model are 0.2 g/s and 6.5 g/s, respectively (all parameter values for the ACC model are shown in Appendix 2, Table 17. The enforced jerk limit is a function of several variables, as shown in Figure 23, discussed in the ACC model description in Appendix 2.

Another unknown parameter was the system latency. We estimated one part of the system latency from our tests in which the accelerometer was started when the vehicle icon appeared on the dash. The latency that occurred before the vehicle was acquired by the system was not measured, merely estimated from anecdotal experience while driving.

The final ACC model was tested, verified, and validated using on-road tests with a Toyota Avalon, and through extensive simulator testing on the MiniSim, as well as throughout the pilot. The ACC algorithm showed good face validity and its behavior was consistent with comments that drivers made about their own vehicles' ACC behavior.

APPENDIX 2: ACC SYSTEM IMPLEMENTATION

ACC Distributed Model Architecture

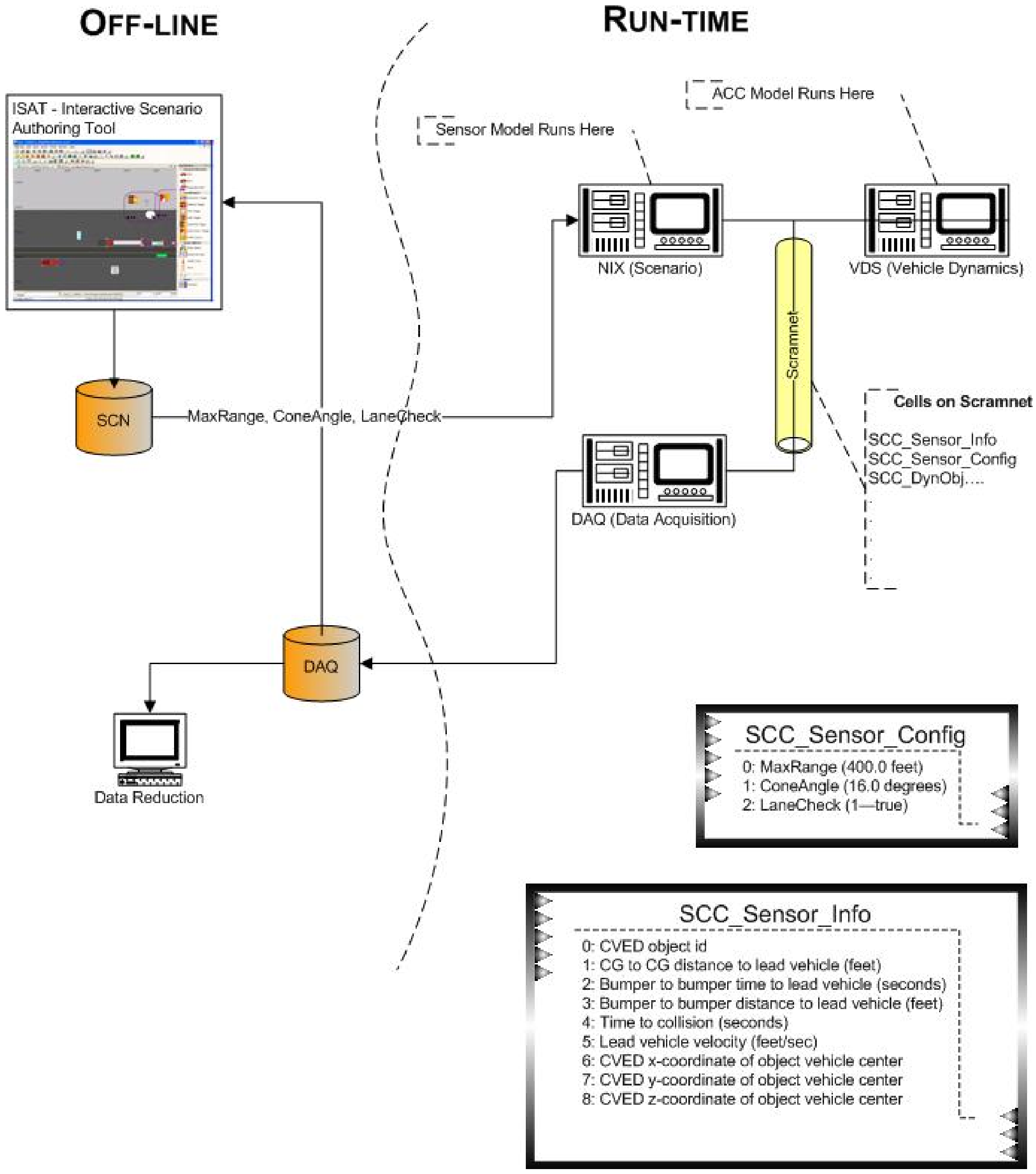

Figure 21: ACC Distributed Model Architecture.

Cruise Control Logic

The cruise control is operated by pressing a button on the steering column, which in turn sets the value of a variable that is passed over the network to NADSDyna. The set of values in the cruise control variable is mapped to the internal functions of the cruise control model. Those functions are: Off, On, Cancel, Resume, Set, Coast, Accel, and Ext. The last is not a standard cruise function, but is a useful way to have the car track a pre-recorded velocity profile.

The model incorporates the ACC algorithm and provides the desired functional modes of cruise control. There are four modeled cruise states: OFF, ON, SET, and WARN. The state transition diagram that summarizes the logic for the model is shown in Figure 22. The internal cruise functions control state transitions as well as setting the desired cruise speed. Other things that cause state transitions are shifting out of drive, depressing the brake pedal, the ACC system meeting its braking authority, or the vehicle speed dropping below a minimum cutoff speed.

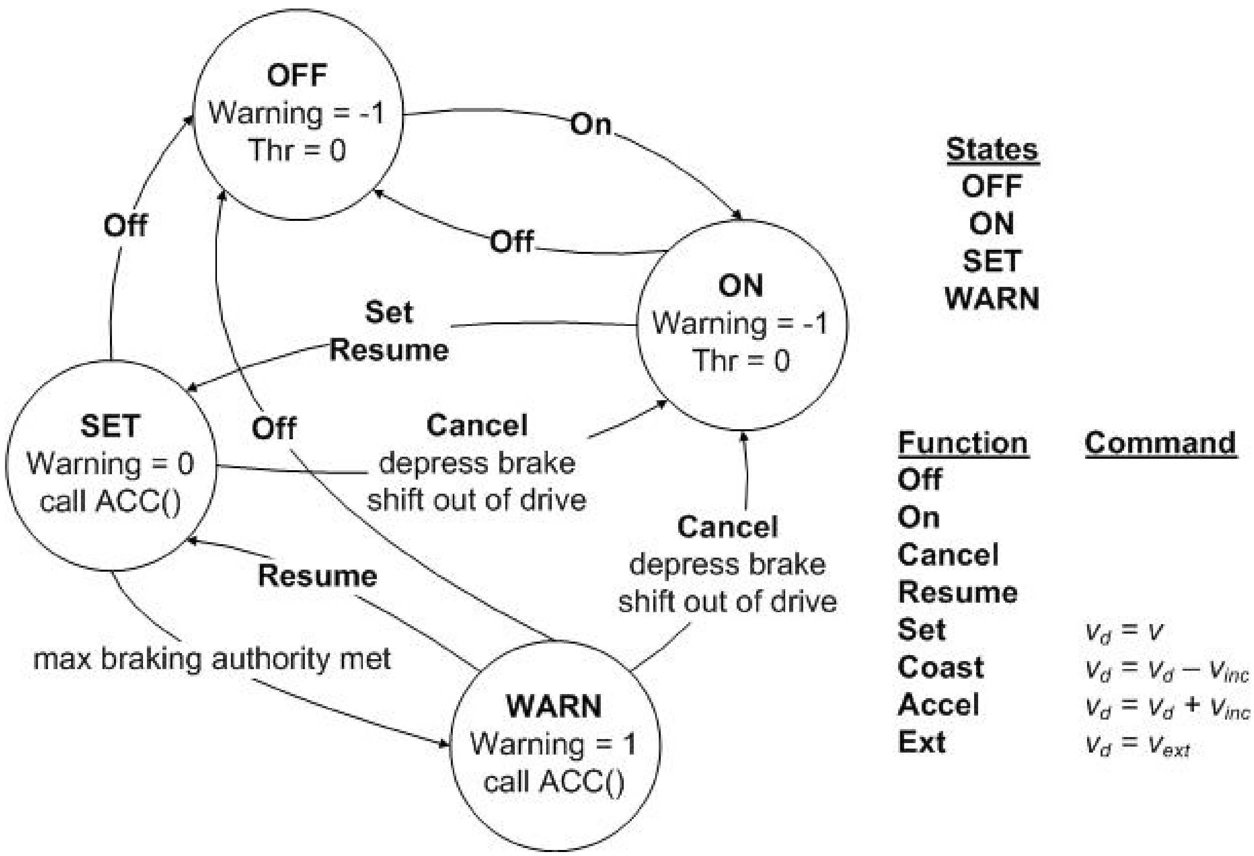

Figure 22: Cruise control state transition diagram

Sensor Model

The vehicle dynamics software, NADSDyna, doesn't know anything about other vehicles in the environment, so it cannot model the laser radar sensor. The subsystem that controls the traffic vehicles does know about those vehicles as well as the driver's car, so it is the logical place to model the ACC sensors. Previous studies have been conducted that modeled lane change warning systems and forward collision warning. Because of this work, some of the required code was already present, and the ACC sensor model was integrated into this code. The steps that the sensor model goes through 30 times per second are summarized in the following list. SV refers to subject vehicle, and LV to lead vehicle.

1. Estimate self-curvature from velocity and yaw rate. Buffer and filter curvature
2. Increment and limit lag counters
3. Begin loop through up to 20 nearest dynamic objects
   a. If vehicle ID is not valid, exit loop
   b. If range is greater than threshold, exit loop
   c. If algorithm selection is not set, exit loop
   d. Compute relative heading between LV and SV
   e. Compute closing velocity between LV and SV
   f. If object velocity is fast enough, then call sensor cone model
      i. Compute sensor point and target points
      ii. Compute cone boundaries and test each target point for inclusion
      iii. Compute angle of center target point from cone center line
      iv. Adjust object selection based on curvature and object position in cone (predict path bending around curves)
   g. If object found in sensor, data written to output cell
   h. Exit loop
4. Apply lag to object detection and object loss
   a. Exception: If ID of new object is stored in memory, don't apply lag
5. If in lag period, use data from memory as appropriate instead of sensor data

The sensor data is published to the network and picked up by vehicle dynamics, where the ACC model flow continues.

System Model

An ACC model was developed to meet the needs of the project. The portion of the model implemented in vehicle dynamics (NADSDyna) includes the system state changes, the controllers for free driving and vehicle following, and general system lag in responding to sensor data. After the notation is presented, the basic functionality of the model is described.

Notation

The symbols used in the model documentation are as follows:

$v = speed\ of\ the\ following\ vehicle$
$v_d = target\ speed\ set\ by\ cruise$
$v_l = speed\ of\ the\ lead\ vehicle$
$v_{inc} = cruise\ control\ speed\ increment$
$t_g = desired\ time\ gap$
$r = distance\ between\ vehicles, range$
$r_d = desired\ range$
$r_{min} = minimum\ allowed\ range$
$\dot{r} = range\ rate$
$\dot{r}_{th} = range\ rate\ threshold$
$a_d = desired\ acceleration$
$a_{max} = maximum\ allowed\ acceleration$
$d_{max} = maximum\ allowed\ deceleration$

j_{max} = maximum allowed jerk
A_{max} = global maximum acceleration
A_{min} = global minimum acceleration
D_{max} = global maximum deceleration
D_{min} = global minimum deceleration
J_{max} = global maximum jerk
J_{max} = global minimum jerk
ttc = time to collision
ttc_{th} = time to collision threshold
K_{Pfree} = free driving proportional gain
$K_{P\,follow}$ = following proportional gain
$K_{D\,follow}$ = following derivative gain
thr = throttle cruise command
brk = throttle brake command
$K_{P\,thr}$ = throttle control proportional gain
$K_{I\,thr}$ = throttle control integral gain
$K_{P\,brk}$ = brake control proportional gain
$K_{I\,brk}$ = brake control integral gain

ACC Model

The ACC system tests a condition to determine whether it should be operating in free-driving or vehicle-following mode, per

$$ACC\ Mode = \begin{cases} free\ driving, & r > r_{max}\ \ or\ \ v + \dot{r} > v_d \\ following, & otherwise \end{cases}$$

In each region of control, the acceleration (or deceleration) command is limited by max and min limits; and the rate at which the command changes is limited by max and min jerk limits. These limits adapt based on the situation, such that severe braking only occurs when there is a risk of collision. Given global limits on the maximum magnitudes of accel, decel, and jerk denoted by capital letters *Amax*, *Dmax*, and *Jmax* respectively, the variables' limits are calculated using several possible methods. First, the local accel limit is set differently for free driving and following modes.

$$a_{max} = \begin{cases} A_{max}, & free\ driving \\ A_{min}, & following \end{cases}$$

Three possible values for the local decel limit are calculated based on different conditions. First, the limit can be varied according to the instantaneous time-to-collision value.

$$d1_{max} = \begin{cases} D_{max}, & ttc < ttc_{th} \\ D_{max} - (ttc - ttc_{th})\dfrac{(D_{max} - D_{min})}{4\ ttc_{th}}, & ttc_{th} < ttc < 5\ ttc_{th} \\ D_{min}, & 5\ ttc_{th} < ttc \end{cases}$$

Alternatively, it can be calculated based on how close the SV is to the desired following range.

$$d2_{max} = \begin{cases} D_{max}, & \frac{r}{r_d} \leq 0.2 \\ D_{max} - \left(\frac{r}{r_d} - 0.2\right)\frac{(D_{max} - D_{min})}{0.3}, & 0.2 < \frac{r}{r_d} \leq 0.5 \\ D_{min}, & 0.5 < \frac{r}{r_d} \end{cases}$$

Finally, it can be calculated using a metric that combines range rate and time-to-collision, as an additional measure of severity. This metric works out to the range rate squared divided by the range. This local decel limit is also saturated by D_{max} and D_{min}, as in the previous two equations.

$$d3_{max} = -\frac{\dot{r}}{ttc}$$

Corresponding local jerk limits are also calculated using similar equations. A summary plot of the three possible curves for local limits on the deceleration is displayed in Figure 23. The black, piecewise linear line represents the first two limits, while the family of blue dashed curves shows three possible values for the last limit. The three curves are shown on the same figure, but have different horizontal axes with distinct ranges, shown on the figure. All three curves are limited at D_{max} and D_{min}, specified in Table 17.

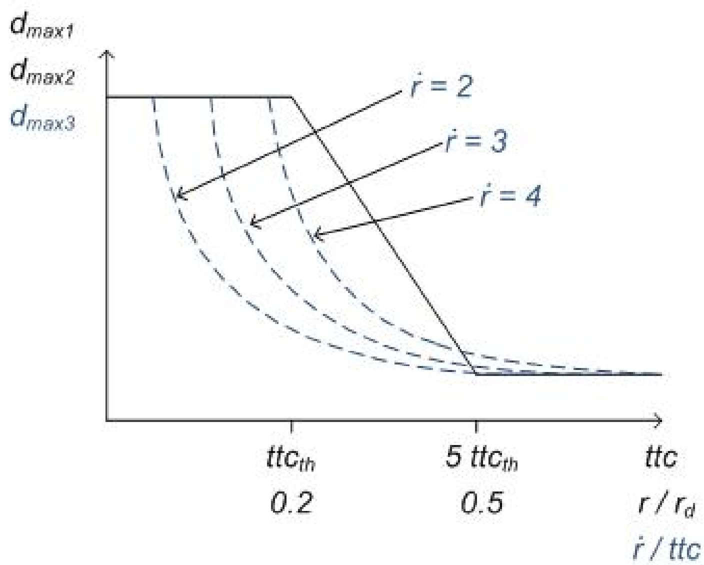

Figure 23 Different formulas for maximum deceleration

The final value of the local decel limit is chosen as the maximum of the three choices, and the corresponding local jerk limit, j_{max}, is also selected.

$$d_{max} = \max(d1_{max}, d2_{max}, d3_{max})$$

Free Driving

In free-driving mode, the desired vehicle acceleration is some multiple of the velocity error. The desired acceleration is saturated by the local accel limit value.

$$a_d = K_{p\,free}(v_d - v)$$

Vehicle Following

The desired range in vehicle-following mode is simply the desired time gap (or headway) multiplied by the velocity.

$$r_d = t_g v$$

The desired acceleration is set by one of three conditions. It can be saturated at its authority limit, it can be operated with some "boost" authority if the range error is large, or it can be generated by a PD controller operating on the range error and range rate. The desired acceleration is saturated by the local accel limit value.

$$a_d = \begin{cases} -d_{max}, & \dot{r} < r_{th} \text{ and } r < r_{min} \\ K_{D\ follow}\dot{r} + K_{P\ follow}(r - r_d), & otherwise \end{cases}$$

Limiting

The local accel limit is saturated using the global accel limit, shown here.

$$a_d = \begin{cases} A_{max}, & a_d > A_{max} \\ -A_{max}, & a_d < -A_{max} \end{cases}$$

If the severity of the situation calls for it, the desired accel (or decel) may be overridden by a more severe decel, given by the following condition and assignment.
if $(a_d > -d3_{max} \times g)$ & $(-d3_{max} < -0.1)$, $\quad a_d = -d3_{max} \times g$

It is first limited by the local jerk limit values only if the jerk and accel commands fall in the first or third quadrant of the accel-jerk phase plane. Then the desired jerk is saturated using the global jerk limit value.

$$j_d = \dot{a}_d$$

$$j_d = \begin{cases} j_{max}, & j_d > j_{max} \ \&\ a_d > 0 \\ -j_{max}, & j_d < -j_{max} \ \&\ a_d < 0 \end{cases}$$

$$j_d = \begin{cases} J_{max}, & j_d > J_{max} \\ -J_{max}, & j_d < -J_{max} \end{cases}$$

Actuation

Given a desired acceleration, the throttle or the brake can be actuated to track the command. A positive acceleration triggers the throttle, while a negative acceleration triggers the brakes. The conditions on activating throttle or brake may not seem intuitive; but they ensure that the transition from throttle to brake, or vice versa, takes place only after the integrator has fully unwound.

The actuation commands are generated by PI controllers, and both the throttle and brakes are saturated at some maximum value. The following two equations detail the ACC actuation. The integral terms are limited to prevent windup in the controller. The resulting values for throttle and brake are saturated so by global limits on their values as well.

$$thr = \begin{cases} K_{P\ thr}(a_d - a) + K_{I\ thr}\int (a_d - a), & brk \le 0 \\ 0, & otherwise \end{cases}$$

$$brk = \begin{cases} 0, & thr \le 0 \\ -K_{P\ brk}(a_d - a) - K_{I\ brk}\int (a_d - a), & otherwise \end{cases}$$

Parameters

The parameters that need to be set in the model are summarized in the table below.

Table 17: ACC Parameters

Parameter	**Value**	**Parameter**	**Value**
v_{inc}	5 mph	K_{Pfree}	0.4
ttc_{th}	3 s	$K_{P\ follow}$	0.1
$\dot{r}_{th}$	-1 m/s	$K_{D\ follow}$	0.3
A_{max}	0.2 g	$K_{P\ thr}$	0.2
A_{min}	0.1 g	$K_{I\ thr}$	2
D_{max}	0.3 g	$K_{P\ brk}$	50
D_{min}	0.05 g	$K_{I\ brk}$	70
J_{max}	6.5 g/s	r_{max}	121.9 m
J_{min}	0.2 g/s	r_{min}	5 m

APPENDIX 3: ACC E-MAIL ADVERTISEMENT

ACC Email Advertisement

The National Advanced Driving Simulator at The University of Iowa Oakdale Campus is inviting adults to participate in a driving simulation study to understand how Adaptive Cruise Control affects driving behavior among early users of the technology.

Who can be part of this study?

- Adults ages 25 to 80
- Have a valid U.S. driver's license
- Drive one of the following Toyota or Lexus vehicles:
    - Toyota Sienna XLE model year 2004 or later
    - Toyota Avalon model year 2005 or later
    - Lexus RX model year 2005 or later
- Have ACC in their vehicle and use it, on average, at least once per month per year
- Drive at least 3,000 miles per year
- Attend one study visit for approximately 2.5 hours in length

If you meet the above criteria and are interested in participating, please contact us:

Call: 319-335-4719
Email: recruit@nads-sc.uiowa.edu (please include a phone number so we can contact you)

If you participate in the study, you will be paid for your time and effort..

If you don't qualify to participate in this study, please forward this message to anyone you know who does!

APPENDIX 4: RECRUITMENT MATERIAL - LETTER

THE UNIVERSITY OF IOWA

COLLEGE OF ENGINEERING
Department of Mechanical & Industrial Engineering
3131 Seamans Center for the Engineering Arts and Sciences
Iowa City, Iowa 52242-1527
319-335-5668 *Fax* 319-335-5669
mech_eng@engineering.uiowa.edu
indeng@engineering.uiowa.edu

[Date]

Dear *insert name here*,

The Human Factors and Statistical Modeling Laboratory at The University of Iowa would like to give our thanks and appreciation to you for your participation in our Adaptive Cruise Control (ACC) research study. You are one of a select group of drivers that have cars equipped with ACC and your unique insights based upon your experience driving your *insert vehicle here* have helped us understand the impact these types of systems may have on driving safety.

In this study you indicated that you would be interested in being contacted for future ACC research studies. In Spring 2010 the National Advanced Driving Simulator will be conducting a study funded by the National Highway Traffic Safety Administration that examines the relationship between ACC use and driving safety among experienced ACC users. This study will utilize the world's most sophisticated driving research simulator, located at the University of Iowa in Iowa City. We would like to invite you to participate. Your experience with ACC will help us understand what impact ACC use has on safe driving, as well as identifying potential improvements to its design and use. We will compensate you for your time and effort.

If you would be willing to participate in this study, please contact us by phone at 319-335-4719 or email at recruit@nads-sc.uiowa.edu (please include a daytime phone number in your message). You also can view a brief study description and request more information through our recruitment webpage, www.drivingstudies.com.

Thank you again for your participation.

Sincerely,

Linda Ng Boyle
Associate Professor
College of Engineering

Jane Moeckli
Staff Researcher
National Advanced Driving Simulator

APPENDIX 5: SCREENING PROCEDURE SCRIPT

NADS ACC TELEPHONE SCREENING PROCEDURE

FOR THE SCREENER:

We are recruiting from three populations for this study:

-Past participants in Linda Boyle's study interested in future ACC studies

-General public contacted through UI, CoE, NADS Database mass emails, the webpage, press release/news coverage, other publicly available sources

-IDOT database of registered vehicle owners who may/may not have ACC

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

-Be able to participate when the study is scheduled

-Meet all driving and system criteria

-Pass the health screening

STUDY OVERIVEW

Introductions

May I speak with (name of interested contact)? Hello, I'm (state your name) with the National Advanced Driving Simulator at the University of Iowa.

We are currently recruiting for a study examining Adaptive Cruise Control, also known as ACC or Dynamic Laser Cruise Control. How did you hear about this study?

- *Previous participant in UI survey study, received a letter or phone message (GO TO A)*
- *Responding to email sent to NADS database, UI, or CoE, webpage, press release/news coverage, other publicly available source (GO TO B)*
- *Responding to post card sent to IDOT vehicle registration database (GO TO C)*

A. ***PAST PARTICIPANT IN LINDA BOYLE STUDY, INTERESTED IN FUTURE STUDIES:***

Last year you participated in a survey study examining how people use Adaptive Cruise Control, and you indicated then that you were willing to participate in additional studies evaluating ACC. We are beginning to schedule study visits for those who would like to participate in a driving study at our facility. Would you like to hear more about the study?

- *IF YES, continue with study purpose and general information.*
- *IF NO:* Would you like to be contacted for other ACC-related research studies? *[Note answer]* Thank you for your interest and time.

B. EMAIL, WEBPAGE, AND OTHER SOURCES WIDELY DISTRIBUTED AND AVAILABLE

We are beginning to schedule study visits for those who would like to participate in a driving study at our facility and who meet study eligibility requirements. Would you like to hear more about the study?

- *IF YES, continue with study purpose and general information.*
- *IF NO:* Would you like to be contacted for other ACC-related research studies? *[Note answer]* Thank you for your interest and time.

C. POST CARD

We are beginning to schedule study visits for those who would like to participate in a driving study at our facility and who meet study eligibility requirements. You received a post card because you have a registered vehicle in the state of Iowa that may qualify you to participate in this study. Would you like to hear more about the study?

- *IF YES, continue with study purpose and general information.*
- *IF NO:* Would you like to be contacted for other ACC-related research studies? *[Note answer]* Thank you for your interest and time.

Purpose of the Study:
The purpose of this research study is to evaluate how experience with ACC affects driving.

> *If asked: ACC is different than conventional cruise control. It extends conventional cruise control by "automatically" adjusting your vehicle speed to maintain a distance you select from your car to the car in front of you. ACC is available on several recent vehicle models. The purpose of this research is to examine how ACC affects driving among early adopters of the technology. Early adopters are those people who purchase and use new technologies before they become widespread. They provide important information about the safety benefits and challenges of technologies like ACC after sustained use.*

Study Details:
Participating in this study involves a time commitment of approximately 2.5 hours. To participate, you will be required to come to our facility at the University of Iowa's Research Park located in Coralville, Iowa (one mile north of the Coral Ridge Mall off I-80).

When you arrive, we'll ask you to read and sign a consent form. If time permits, we will send the consent form to you by email or by mail for your review prior to the visit.

Then you'll complete several questionnaires before you drive. You will receive instructions about the simulator cab, the ACC system, and the drives you'll complete as part of the study. Then you will drive the simulator, and after you drive you will asked to fill out several questionnaires.

You will be paid $200 for your time and effort for completing all study procedures. If you do not complete all study procedures you will be paid $50 for your time and effort.

Are you still interested in participating?
- *If YES, continue with General Driving Questions.*
- *IF NO:* Would you like to be contacted for other driving studies? If you aren't already entered into our participant database, I can take your information now, or you can go to our on-line registration site at www. drivingstudies.com. [*If NO, make a note to deactivate the participant, and provide the reason if given*.] Thank you for your interest and time.

Overview
I will need to ask you several questions to determine your eligibility to participate in this study. These include general driving and health questions, and questions about your ACC system.

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

General Driving Inclusion Questions

1) Do you possess a valid U.S. Drivers' License? *(Must answer YES)*

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

3) Do you use any special equipment to help you drive such as pedal extensions, hand brake or throttle, spinner wheel knobs, seat cushion or booster seat? *(Excluded if use hand brake or throttle, spinner wheel; need to provide own cushion or booster seat)*

4) Have you participated in a driving simulator study conducted at NADS? *(Excluded if in RECAS study looking at ACC and forward collision warnings or other NADS study in last 6 months)*

Age Inclusion Question

5) Are you between the ages of 25 - 80 years old? *(Must answer YES)*

ACC Inclusion Questions

The following are specific questions about your ACC system.

6) Do you drive a Toyota Sienna XLE model year 2004 or newer, Toyota Avalon model year 2005 or newer, or Lexus RX model year 2005 or newer? What model of vehicle do you drive? *(Must answer YES).*

7) Does your vehicle have ACC (also known as Dynamic Laser Cruise Control on these Toyota models), and do you use it at least once per month on average over the past year? *(Must answer YES to both; use level goal is to have an established pattern of use)*

[Ask 1, if you are not sure they have ACC, ask 2-6 as needed to confirm]:

1) You are driving with your ACC turned on, you have set your speed, and the car in front of you begins to slow. How does your vehicle respond? *(acceptable answers: my vehicle automatically slows, an auditory alert may sound, the icon on the dash may flash)*

2) You are driving with your ACC turned on, and you want to adjust your speed using the control stick, not the accelerator. In how many mph increments does it increase or decrease? *(correct answer is that it changes in increments of 5 mph. The EXCEPTION is the initial change when the system is set for a number ending in 1-4 or 6-9 (e.g. 63 mph); then it bumps up or down, depending on the direction of the speed change, to the nearest increment of 5 (up 2 mph to 65 or down 3 mph to 60, then up or down by 5 mph afterward).*

3) You are driving with ACC turned on, and you want to change the distance between you and the vehicle in front of you. How do you do it? How do you know the distance has changed? *(acceptable answers: push button on steering wheel (may be in a different location); my vehicle slows to increase distance or speeds up to decrease distance; icon on instrument panel changes with more lines for a longer distance and fewer lines for a shorter distance)*

4) What distance setting (also called the gap or headway setting) do you set your vehicle to most often? *(Acceptable answers: Short, Medium, Long; LESS COMMON: numeric values in increments of seconds)*

1) How does your vehicle let you know when you're following a vehicle? *(Acceptable answers: car icon on the display, or the vehicle slows down)*

2) What information is shown on the ACC display? *(Includes: (a) distance setting (indicated by an increasing number of lines as the distance increases) and (b) vehicle detected (car icon present when vehicle is detected); can also include set speed, cruise status)*

[Still not sure if they have ACC? Talk with Jane or Ben.]

General Health Exclusion Criteria

Overview ➢ Because of pre-existing health conditions, some people are not eligible for participation in this
If the subject is female: ➢ **Are you, or is there any possibility that you are pregnant?**
Exclusion criteria: • If there is ANY possibility of pregnancy

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

2) **Have you ever been diagnosed with seizures or epilepsy?**
Exclusion criteria: • A seizure within the past 12 months

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

5) Do you currently suffer from narcolepsy? ➢ If YES, please describe.
Exclusion criteria: • Narcolepsy

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

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

Closing

MEETS ALL CRITERIA

To what email address can I send the consent document? *[if email is not an option, ask:* To what postal address can I send the consent document?]

- Refrain from drinking alcohol and taking any **NEW** prescription or over the counter drugs for the 24 hours preceding your driving session. If you do need to take a new medication 24 hours preceding your driving session, please call us. Ibuprofen, Tylenol, aspirin, and vitamins are acceptable to take prior to driving session.

- Bring Driver's License with you to appointment.

- If you use corrective lenses for driving please bring your glasses or contacts with you to the driving session. Bring reading glasses if needed to fill out questionnaires.

- We ask that cell phones and pagers be turned off or left home as they are not allowed while participating in the driving study.

- Request the following of all participants:
  - Wear flat shoes to drive in
  - No hats worn or gum chewing allowed while driving
  - Refrain from wearing artificial scents (perfume or cologne) as some staff allergic to scents

- You will be required to wear a seat belt while driving.

- If your name is not currently in our recruitment database and you would like to place your name, contact information, birth date, gender, and additional information about you into the database, I would be glad to get that information from you now. (If no time, provide website address: www.drivingstudies.com)

- If your appointment is before 8am or after 5pm, the front door will be locked, therefore, please use the After Hours Call Box located at the right side on the front door. Press the call button and someone will let you in**.**

- Provide directions, explain where to park and ask them to check in at the front desk inside the main entrance.

- Inform participants to call **(319) 335-4313** if they are unable to make this appointment and need to reschedule as soon as possible (prefer 24 hour notice). Please leave a message if they receive voicemail and a staff member will return their call.

DOES NOT MEET CRITERIA:

- Would you like to be added to our recruitment database in order to be considered for future driving research studies? We will list your name, contact information, birth date, gender, and additional information about you into the database. *if yes, fill out NADS database form at www.drivingstudies.com.*

APPENDIX 6: RECRUITMENT MATERIAL – INITIAL POSTCARD

Does your Toyota or Lexus have Dynamic Laser Cruise Control?

The National Advanced Driving Simulator at the University of Iowa would like to invite you to participate in a research study about Adaptive Cruise Control (ACC) (also known as Dynamic Laser Cruise Control) in Iowa City in Spring 2010. You were selected from a list compiled by the Iowa DOT of registered vehicle owners whose Toyota or Lexus may be equipped with ACC. We are seeking owners of select Toyota and Lexus models who use ACC to better understand how it affects driving behavior among early adopters of the technology.

Compensation will be provided. Please contact us today for more information or to see if you qualify to participate:

319-335-4719
recruit@nads-sc.uiowa.edu
www.drivingstudies.com

Does your Toyota or Lexus have Dynamic Laser Cruise Control?

The National Advanced Driving Simulator at the University of Iowa would like to invite you to participate in a research study about Adaptive Cruise Control (ACC) (also known as Dynamic Laser Cruise Control) in Iowa City in Spring 2010. You were selected from a list compiled by the Iowa DOT of registered vehicle owners whose Toyota or Lexus may be equipped with ACC. We are seeking owners of select Toyota and Lexus models who use ACC to better understand how it affects driving behavior among early adopters of the technology.

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Compensation will be provided. Please contact us today for more information or to see if you qualify to participate:

319-335-4719
recruit@nads-sc.uiowa.edu
www.drivingstudies.com

APPENDIX 7: RECRUITMENT MATERIAL – E-MAIL

Dear *insert name here*,

Thank you for your interest in the study evaluating Adaptive Cruise Control (ACC). You are one of a select group of drivers that have cars equipped with ACC and your unique insights will help us understand the impact ACC has on driving safety, as well as identifying potential improvements to its design and use. This study will utilize the world's most sophisticated driving research simulator, located at the University of Iowa in Iowa City. Additional information about the study can be found on our website (www.drivingstudies.com).

We have begun recruitment for this study. If you are interested in participating, we would like to talk with you! Local residents can call us at 319-335-4719. We currently do not have a toll-free phone number, so if you live outside of our area code, we kindly ask that you email us your name, a phone number, and the best time to reach you, and we will do our best to contact you during that time.

Again, thank you for your interest.

Sincerely,

[Recruitment staff]

APPENDIX 8: RECRUITMENT MATERIAL – WEB PAGE

Adaptive Cruise Control Study

Early adopters wanted!

Adaptive Cruise Control (ACC) is one of several new driver assistance technologies on the market in the US. ACC extends standard cruise control functionality by "automatically" adjusting the vehicle speed to maintain a driver-selected distance from the vehicle in the lane ahead, or maintain the driver-selected speed when the lead vehicle moves beyond the sensor range. ACC is available on several recent vehicle models, and is typically offered as a comfort and convenience option. Previous research conducted by the National Highway Traffic Safety Administration (NHTSA) shows it can provide some safety benefits - drivers who use ACC report larger headways, fewer lane changes, and less stress while driving.

The purpose of this research is to examine how such assistive technologies affect our performance behind the wheel. Early adopters – that small segment of the population who are among the first to use emerging technologies – provide a crucial glimpse at the safety benefits and challenges presented by the sustained use of technologies like ACC. Based on their experiences using such systems, early adopters also offer important insights into how people interact with the systems' design, and critically, what improvements can be made to improve safety on our nation's roadways.

Adults ages 25-80 are invited to participate in a driving simulation study that explores how ACC use affects the driving patterns of its early adopters. You may be eligible if you:

- Have a valid U.S. driver's license
- Drive one of the following Toyota or Lexus vehicles:
    - Toyota Sienna XLE model year 2004 or later
    - Toyota Avalon model year 2005 or later
    - Lexus RX model year 2005 or later
- Have ACC in your vehicle and use it, on average, at least once per month per year
- Drive at least 3,000 miles per year
- Are able to attend one study visit for approximately 2.5 hours at our facility in Coralville, Iowa

You will be paid for your time and effort.

The study will be conducted in Spring 2010.

For more information, call **319-335-4719** or email **recruit@nads-sc.uiowa.edu** (please include a daytime phone number in your message).

APPENDIX 9: INFORMED CONSENT DOCUMENT

INFORMED CONSENT DOCUMENT

Project Title: Evaluation of Adaptive Cruise Control (ACC) Interface Requirements on the National Advanced Driving Simulator (NADS)

Principal Investigator: Jane Moeckli

Research Team Contact: Ben Dow, 319-335-4786

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

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

WHAT IS THE PURPOSE OF THIS STUDY?

This is a research study. We are inviting you to participate in this research study because you have experience driving with an adaptive cruise control (ACC) system in your current vehicle, use it on average once per month per year, and have a valid driver's license. In addition, you drive at least 3,000 miles per year, you do not use any special equipment to help you drive, you are between the ages of 25 and 80 years old, and you are in good health.

The purpose of this research study is to evaluate how ACC affects driving among experienced ACC users.

HOW MANY PEOPLE WILL PARTICIPATE?

Approximately 100 people will take part in this study at the University of Iowa.

HOW LONG WILL I BE IN THIS STUDY?

If you agree to take part in this study, your involvement will be one visit for approximately 2.5 hours.

WHAT WILL HAPPEN DURING THIS STUDY?

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

Next, you will be asked to show your driver's license to confirm that it is valid, and then you will fill out a payment form which asks for your social security number. Next, you will be asked to complete a questionnaire that covers some general questions about your driving, demographic, and health history. Driving history questions include the type of vehicles you drive, your license history, driving violations and accidents, and driving habits. Demographic questions ask for your birth date, gender, ethnicity, highest level of education completed, and participation in other driving studies. The general health history questions ask vision correction, hearing aid use, medication, drug, and alcohol use, and history of motion sickness.

You will be asked to fill out a survey asking about your previous experience with ACC, including questions about situations in which you use or do not use ACC, how you feel about the ACC system and its features, and how useful you find ACC. You will then be asked to complete surveys about your driving style and about trust.

Next you will be asked to watch a PowerPoint presentation on a computer that gives you an overview of the simulator cab and drive, and the ACC system you will be interacting with while driving.

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

Then you will be escorted into the simulator and asked to complete a practice drive to become familiar with the simulator, which will last approximately 5 minutes. After the practice drive you will be asked to complete a questionnaire about how you feel. You will then complete the main drive which will last approximately 60 minutes. After the drive, you again will be asked to complete a questionnaire about how you feel.

You will be escorted back to the waiting room and asked to complete a questionnaire evaluating how realistic you found the simulator to be. We will playback video recordings of your drive and you will be asked to recount your thoughts and answer questions about your drive. You will then be asked to complete an additional questionnaire about possible changes that could be made to the ACC system to improve its functionality. A member of the research team will then provide additional information about the study and complete your payment form and you will be free to go.

You may skip any questions that you do not wish to answer on the surveys. During the review of the video recordings of your drive, <u>an audio recording of your description of the event will be made</u>. The audio recording is optional, and you can remain in the study if you do not agree to the recording of your description of the events. Please indicate your choice by placing your initials in the space corresponding to your choice:

[________] Yes [________] No I give you permission to make audio recordings of me during my review of the video recordings of my drive.

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

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

SOCIAL SECURITY NUMBER (SSN) USAGE

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

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

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

WHAT ARE THE RISKS OF THIS STUDY?

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

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

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

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

Risks associated with latex stickers can be dryness, itching, burning, scaling, and lesions of the skin. Risks associated with temporary tattoos can be mild skin irritation during removal.

A survey collects information about alcohol and drug usage. Some of this information may disclose illegal activities. Data collected from questionnaires will remain confidential and can only be identified by a study assigned number.

WHAT ARE THE BENEFITS OF THIS STUDY?

You will not benefit from being in this study. However, we hope that, in the future, other people might benefit from this study because information gained about how ACC is used may lead to improvements to current ACC systems.

WILL IT COST ME ANYTHING TO BE IN THIS STUDY?

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

WILL I BE PAID FOR PARTICIPATING?

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

If you agree to participate in this study, you will be compensated for your time and effort. You will be paid $200 for your time and effort if you complete all study procedures. If you decide to withdraw from the study prior to completion of all study procedures you will be paid $50 for your time and effort.

WHO IS FUNDING THIS STUDY?

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

WHAT ABOUT CONFIDENTIALITY?

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

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

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

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

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

The **audio data** recorded during the debrief session will be used to better understand your cognitive processes while encountering different driving events (e.g., what you were thinking when the event occurred, what your decision-making process was in reaction to the event). Audio data will be transcribed into typed text and stored in accordance with NADS confidentiality and archival procedures. As with other data collected during your study visit, no identifying information will be included in the transcription, and findings will be presented in manner consistent with our confidentiality policy.

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

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

IS BEING IN THIS STUDY VOLUNTARY?

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

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

WHAT IF I HAVE QUESTIONS?

We encourage you to ask questions. If you have any questions about the research study itself, please contact: **Ben Dow, 319-335-4786.** If you experience a research-related injury, please contact Jane Moeckli, 319-335-4672.

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

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

Subject's Name (printed): ____

Do not sign this form if today's date is on or after EXPIRATION DATE: 09/24/10 .

_______________________________________ _____________________________
(Signature of Subject) (Date)

Statement of Person Who Obtained Consent

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

______________________________________ ____________________________

(Signature of Person who Obtained Consent) (Date)

APPENDIX 10: ACC CONSENT COVER LETTER

[date]

National Advanced Driving Simulator
The University of Iowa
2401 Oakdale Blvd.
Iowa City, IA 52242-5003

[Subject name and address]

Dear [subject name],

Thank you for your interest in our driving research study to understand the effect of Adaptive Cruise Control on the driving behavior of people who use the technology before its widespread availability. As per our conversation, please find enclosed a copy of the informed consent document and directions to our facility. Because you may be traveling a substantial distance to participate, we want to give you an opportunity to review additional details about the study and to ask questions prior to your visit. Please wait to sign the informed consent document until we have an opportunity to discuss it with you during your appointment.

Please bring the consent document with you to your appointment at the National Advanced Driving Simulator on:

[Day and Date of appointment] at [time of appointment].

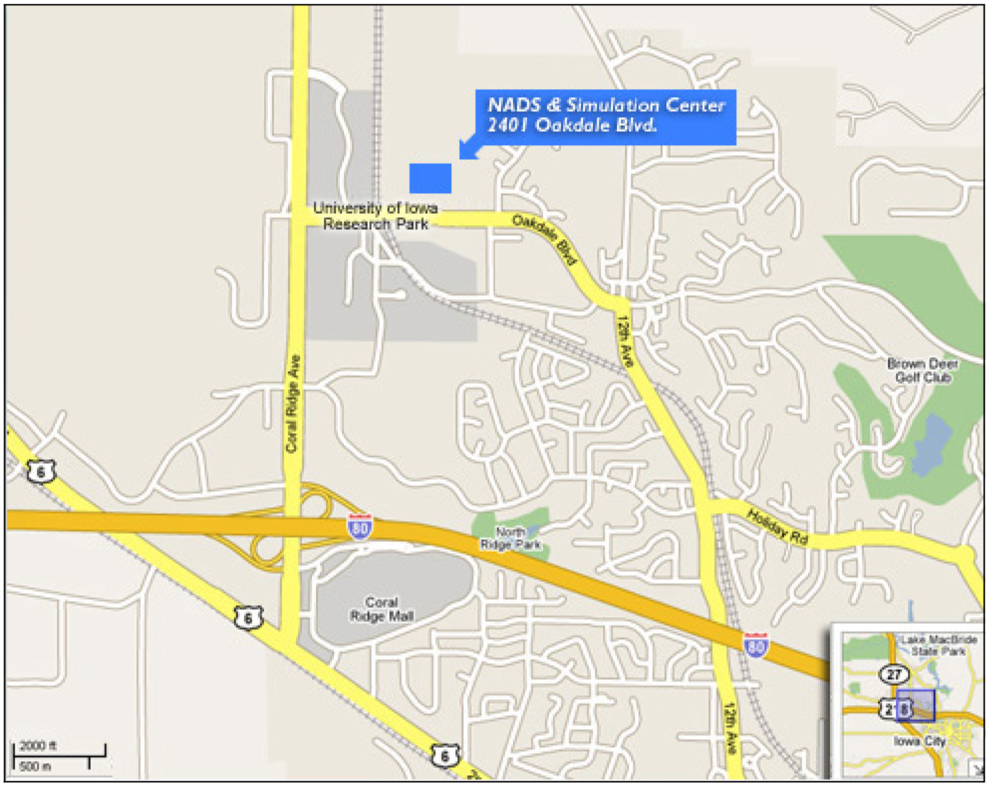
Please note that our street address is different from our postal address. If you are using an on-line mapping service or GPS, our street address is as follows:

National Advanced Driving Simulator
2401 Oakdale Blvd
Coralville, IA 52241

If you have any questions, please contact [member of the research team that is recruiting with phone number & email].

We look forward to seeing you soon! Thank you again for your participation.

Enclosures



Directions to the NADS (common to all approaches):

- Take Interstate 80 to Exit 240 (Coralville at Coral Ridge Mall).
- Turn North on Highway 965 (Coral Ridge Ave).
- Continue on Highway 965 through the Holiday Road intersection (marked with a traffic light – Walgreens and Culvers will be on the left and a gas station on the right). Continue straight on Highway 965 until you see Oakdale Blvd (marked with a traffic light and sign for the University of Iowa Research Park).
- Turn right onto Oakdale Blvd and drive approximately 1/2 mile.
- Cross over the railroad tracks and continue straight ahead to the second building on the left of the road, the NADS & Simulation Center.

Street Address:

2401 Oakdale Blvd
Coralville, Iowa 52241

APPENDIX 11: ACC CONSENT E-MAIL COVER LETTER

Dear [subject name],

Thank you for your interest in our driving research study to understand the effect of Adaptive Cruise Control on the driving behavior of people who use the technology before its widespread availability. As per our conversation, please find attached a copy of the informed consent document. Because you may be traveling a substantial distance to participate, we want to give you an opportunity to review additional details about the study and to ask questions prior to your visit. We will discuss the consent form prior to signing it during your visit, so you do not need to print a copy unless you would like to do so for your own review.

Your appointment at the National Advanced Driving Simulator is scheduled for:

[Day and Date of appointment] at [time of appointment].

Directions to our facility are listed below.

If you have any questions, please contact [member of the research team that is recruiting with phone number & email].

We look forward to seeing you soon! Thank you again for your participation.

<u>Directions to The National Advanced Driving Simulator:</u>

- Take Interstate 80 to Exit 240 (Coralville at Coral Ridge Mall).
- Turn North on Highway 965 (Coral Ridge Ave).
- Continue on Highway 965 through the Holiday Road intersection (marked with a traffic light – Walgreens and Culvers will be on the left and a gas station on the right). Continue straight on Highway 965 until you see Oakdale Blvd (marked with a traffic light and sign for the University of Iowa Research Park).
- Turn right onto Oakdale Blvd and drive approximately 1/2 mile.
- Cross over the railroad tracks and continue straight ahead to the second building on the left of the road, the NADS & Simulation Center.

Please note that our street address is different from our postal address. If you are using an on-line mapping service or GPS, our street address is as follows:

2401 Oakdale Blvd
Coralville, Iowa 52241

APPENDIX 12: VIDEO RELEASE

CONSENT FOR RELEASE OF VIDEO IMAGE AND AUDIO DATA

I, the undersigned, have agreed to participate in a research project to be conducted at the University of Iowa entitled "Evaluation of Adaptive Cruise Control (ACC) Interface Requirements on the National Advanced Driving Simulator (NADS)". The purpose of the study is to evaluate an ACC system and its interface with experienced ACC users.. As part of the informed consent form I have signed for that study, I have agreed to allow the University, the study sponsor, and those acting pursuant to its authority, to record and use for research purposes video image data (including my video-recorded likeness) and audio data (including my voice), as well as, in some views, superimposed performance information (referred to below as "the Recording"). This Consent for Release of Video Image and Audio Data pertains to the following non-research purposes the University, the study sponsor, and those acting pursuant to its authority propose for my video image data (in continuous video or still formats) and associated audio data, either separately or in association with the appropriate engineering data:

1) Public release for regulatory purposes (e.g., to assist in regulating devices);
2) Public release for educational purposes (e.g., to assist with educational campaigns for members of the general public);
3) Public release for outreach purposes (e.g., to nationally-televised programs highlighting traffic safety issues);
4) Public release for legislative purposes (e.g., to assist the U.S. Congress with law-making/rule-making activities).

Engineering or simulator data may also be released individually or in summary with that of others participating in the study, but will not be presented publicly in a way that permits personal identification, except when presented in conjunction with video image data.

I hereby authorize the University of Iowa, the study sponsor, and those acting pursuant to its authority, to use my recorded video image and audio data, with or without related engineering or simulator data, for the non-research purposes specified above.

I transfer and assign to the University of Iowa and the study sponsor any right, title, and interest I may have in and to the Recording, including the copyright, and in and to all works based upon, derived from, or incorporating the recorded data.

I irrevocably waive any right to inspect, edit, or approve said Recording in any of its forms.

I irrevocably release the University of Iowa and the study sponsor, and any of their employees, agents, and assigns, from any and all claims that I may have at any time arising out of, or related to, the Recording or use of the Recording, including, but not limited to, any claims based on the right of privacy, libel, or defamation.

____
Name of Participant

____
Signature of Participant

____
Date

APPENDIX 13: VIDEO RELEASE ALTERED

CONSENT FOR RELEASE OF EDITED/ALTERED VIDEO IMAGE AND AUDIO DATA

I, the undersigned, have agreed to participate in a research project to be conducted at the University of Iowa entitled "Evaluation of Adaptive Cruise Control (ACC) Interface Requirements on the National Advanced Driving Simulator (NADS)". The purpose of the study is to evaluate an ACC system and its interface with experienced ACC users. As part of the informed consent form I have signed for that study, I have agreed to allow the University, the study sponsor, and those acting pursuant to its authority, to record and use for research purposes video image data (including my video-recorded likeness) and audio data (including my voice), as well as, in some views, superimposed performance information (referred to below as "the Recording"). The University, the study sponsor, and those acting pursuant to its authority propose to edit/alter the Recording so that neither my image nor my voice are identifiable and use the altered Recording for the following non-research purposes:

1) Public release for regulatory purposes (e.g., to assist in regulating devices);
2) Public release for educational purposes (e.g., to assist with educational campaigns for members of the general public);
3) Public release for outreach purposes (e.g., to nationally-televised programs highlighting traffic safety issues);
4) Public release for legislative purposes (e.g., to assist the U.S. Congress with law-making/rule-making activities).

Engineering or simulator data may also be released individually or in summary with that of others participating in the study, but will not be presented in a way that permits personal identification.

I hereby authorize the University of Iowa, the study sponsor, and those acting pursuant to its authority, to edit/alter my recorded video image and audio data, with or without related engineering or simulator data, so that neither my image nor my voice are identifiable, and to use the Recording so edited/altered for the non-research purposes specified above.

I transfer and assign to the University of Iowa and the study sponsor any right, title, and interest I may have in and to the edited/altered Recording, including the copyright, and in and to all works based upon, derived from, or incorporating the recorded data.

I irrevocably waive any right to inspect, edit, or approve said edited/altered Recording in any of its forms.

I irrevocably release the University of Iowa and the study sponsor, and any of their employees, agents, and assigns, from any and all claims that I may have at any time arising out of, or related to, the edited/altered Recording or use of the edited/altered Recording, including, but not limited to, any claims based on the right of privacy, libel, or defamation.

____
Name of Participant

____
Signature of Participant

____
Date

APPENDIX 14: PAYMENT VOUCHER

NADS PARTICIPANT COMPENSATION VOUCHER

Department Name: NADS & Simulation Center
Contact Person: Sue Ellen Salisbury
Campus Address: 127 NADS
Campus Phone: 54666

TO RECEIVE COMPENSATION, PLEASE PROVIDE THE FOLLOWING INFORMATION:

Name: ____
LAST FIRST MIDDLE INITIAL

Social Security Number: ☐☐☐ – ☐☐ – ☐☐☐☐

MAILING ADDRESS

____
STREET

______________________ ________ ☐☐☐☐☐
CITY STATE ZIP

(_______)______________________
PHONE

Are you a U.S. citizen? ☐ YES ☐ NO

If NO, Immigration/VISA Status: ___________________________

Immigration/VISA # ________________________ Date of Birth: ☐☐ / ☐☐ / ☐☐☐☐

Tax Residency Country: ____

Permanent Foreign Address: ____

____

FOR NADS STAFF ONLY:

DATE: ☐☐ / ☐☐ / ☐☐☐☐

STUDY TITLE: __Adaptive Cruise Control (ACC) Study_____

TOTAL COMPENSATION: $ ___________________

APPENDIX 15: NADS DRIVING QUESTIONNAIRE

NADS Driving Questionnaire

As part of this study, it is useful to collect information describing each participant. 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 skip questions if you choose.

Demographic Information

1) What is your birth date? __ __ / __ __ /__ __ __ __

2) What is your gender? ❐ Male ❐ Female

Driving History

3) How old were you when you started to drive (including driving before licensure)? ________

4) What year were you first licensed (not issued a permit) to drive a passenger vehicle? _________

5) How often do you drive? (Check the most appropriate category)
   - ❐ Less than once weekly
   - ❐ At least once weekly
   - ❐ At least once daily

6) What speed do you typically drive on highways when the speed limit is 55 miles per hour? ____mph

7) What speed do you typically drive on the interstate when the speed limit is 65 miles per hour? _____mph

8) What speed do you typically drive in suburban areas when the speed limit is 30 miles per hour? ____mph

9) How **frequently** do you drive in the following conditions? (Check the most appropriate answer for each condition)

	Not at All 1	Rarely 2	Sometimes 3	Often 4	Always 5
Clear road conditions with good visibility	❐	❐	❐	❐	❐
Rain*	❐	❐	❐	❐	❐
Snow*	❐	❐	❐	❐	❐
Low/no sunlight*	❐	❐	❐	❐	❐
In heavy – “stop-and-go” – traffic*	❐	❐	❐	❐	❐
In heavy traffic that is flowing*	❐	❐	❐	❐	❐
On interstate highways*	❐	❐	❐	❐	❐
On rural highways	❐	❐	❐	❐	❐
Freeway off-ramps, or when exiting highways*	❐	❐	❐	❐	❐
On city streets with traffic lights*	❐	❐	❐	❐	❐
In residential areas	❐	❐	❐	❐	❐
On curvy roads*	❐	❐	❐	❐	❐
On hilly roads	❐	❐	❐	❐	❐
On roads with lower speed limits*	❐	❐	❐	❐	❐
When tired or when otherwise impaired*	❐	❐	❐	❐	❐
When performing tasks (e.g., using cell phone, map, radio, GPS, etc.)*	❐	❐	❐	❐	❐
When other people are in the vehicle	❐	❐	❐	❐	❐

10) How **comfortable** do you feel when you drive in the following conditions? (Check the most appropriate answer for each condition)

	Very Uncomfortable	Slightly Uncomfortable	Slightly Comfortable	Very Comfortable	Not Applicable
Clear road conditions with good visibility	❒	❒	❒	❒	❒
Rain*	❒	❒	❒	❒	❒
Snow*	❒	❒	❒	❒	❒
Low/no sunlight*	❒	❒	❒	❒	❒
In heavy – "stop-and-go" – traffic*	❒	❒	❒	❒	❒
In heavy traffic that is flowing*	❒	❒	❒	❒	❒
On interstate highways*	❒	❒	❒	❒	❒
On rural highways	❒	❒	❒	❒	❒
Freeway off-ramps, or when exiting highways*	❒	❒	❒	❒	❒
On city streets with traffic lights*	❒	❒	❒	❒	❒
In residential areas	❒	❒	❒	❒	❒
On curvy roads*	❒	❒	❒	❒	❒
On hilly roads	❒	❒	❒	❒	❒
On roads with lower speed limits*	❒	❒	❒	❒	❒
When tired or when otherwise impaired*	❒	❒	❒	❒	❒
When performing tasks (e.g., using cell phone, map, radio, GPS, etc.)*	❒	❒	❒	❒	❒
When other people are in the vehicle	❒	❒	❒	❒	❒

Violations

11) Within the past five years, how many tickets have you received for the following?

	0	1	2	3+
Speeding	❒	❒	❒	❒
Going too slowly	❒	❒	❒	❒
Improper passing	❒	❒	❒	❒
Reckless driving	❒	❒	❒	❒
Following another car too closely	❒	❒	❒	❒
Driving while intoxicated	❒	❒	❒	❒
Other (please specify **type** and **frequency** of violation) ______________________________				

Accidents

12) In the past five years, how many times have you been the driver of a car involved in an accident? If you have had one or more accidents, please describe in the space provided.

- ❒ 0 (Go to question 15)
- ❒ 1
- ❒ 2
- ❒ 3 or more

Accident 1

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

Accident 2

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

Accident 3

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

Health Status

13) 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 15)
- ❒ Single Lens Glasses
- ❒ Bifocals
- ❒ Trifocals
- ❒ Contact Lenses

14) 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
- ❒ Other, explain____

15) Do you have an undiagnosed or diagnosed hearing problem?
- ❒ No (Go to question 17)
- ❒ Undiagnosed but suspected problem
- ❒ Diagnosed but untreated
- ❒ Diagnosed and treated

16) Do you currently use a hearing aid? (Check only one)
- ❒ No
- ❒ Yes

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

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

18) 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

19) Have you taken any medication in the past 48 hours? (Check only one)
- ❒ No
- ❒ Yes (Please list all) ____

____

20) Have you consumed any alcohol or other drugs in the past 24 hours? (Check only one)
- ❒ No
- ❒ Yes (Please list all) ____

Other Studies

21) Have you participated in other driving studies?

❒ No (End of questionnaire)

❒ Yes (please provide details for each study you have participated in below)

Study 1

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

❒ Actual car - only

❒ Another simulator - only

❒ National Advanced Driving Simulator (Motion Simulator)

❒ National Advanced Driving Simulator (Static Simulator)

❒ Actual car and another simulator except Motion Simulator at NADS

❒ Actual car and the National Advanced Driving Simulator (Motion Simulator)

Brief Description:

____

____

Study 2

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

❒ Actual car - only

❒ Another simulator - only

❒ National Advanced Driving Simulator (Motion Simulator)

❒ National Advanced Driving Simulator (Static Simulator)

❒ Actual car and another simulator except Motion Simulator at NADS

❒ Actual car and the National Advanced Driving Simulator (Motion Simulator)

Brief Description:

____

____

APPENDIX 16: ACC QUESTIONNAIRE

Date: _____________

ACC Questionnaire

The following questions ask about you and your experience with Adaptive Cruise Control (ACC). If something is unclear, ask the research assistant for help. Your participation is voluntary and you have the right to skip questions if you choose. Please disregard symbols (*,‡); they are for internal question tracking purposes.

1) What is the production year, make, and model of your vehicle with ACC?*‡

Year (e.g. 2006)	Make (e.g., Toyota)	Model (e.g., Sienna XLE)
___ ___ ___ ___		

2) How long have you owned/ driven this vehicle?* Years _______ Months ________

3) Did you purchase the vehicle new or used?
- ❐ New
- ❐ Used

4) How many miles have been driven in this vehicle since you purchased it (either new or used)? __________

5) What percentage of the miles driven since you purchased this vehicle are yours? ________%

6) How long after you purchased this vehicle did you begin using ACC?
- ❐ Immediately
- ❐ Less than one week after
- ❐ Less than one month after
- ❐ Less than one year after
- ❐ More

7a) On average since you've owned this vehicle, how often do you use ACC while driving? (0 – 100%) ______

7b) On average in the last six months how often do you use ACC while driving? (0 – 100%) _____

8) How does your average frequency of ACC use in the last 6 months compare to your use beforehand?
- ❐ No change
- ❐ I used it less often than I did before
- ❐ I used it more often than I did before
- ❐ I haven't used ACC for more than 6 months

9) Which best describes your motivation for purchasing your vehicle with ACC?
- ❐ I wasn't aware that my vehicle had ACC when I purchased it.
- ❐ I wanted other features included in the optional package, but wasn't specifically interested in ACC.
- ❐ I wanted this vehicle and/or the optional package because it included ACC.
- ❐ I'm a car technology enthusiast and had to have ACC as soon as it became available.

10) How did you initially learn to use ACC? (Please check all that apply)
- ❐ Dealer demonstration
- ❐ Owners Manual
- ❐ Demonstrations or reviews on the internet/ in magazines

❒ Self-taught
❒ Did not learn
❒ Other, please specify ____

11) Was there anything difficult about learning to use ACC?*
❒ No
❒ Yes
If Yes, please explain ____

____

12) What methods did you use to answer additional questions about the system's operation or to learn more about how your ACC system works? (Please check all that apply)
❒ No additional learning
❒ Dealer demonstration
❒ Owners Manual
❒ Demonstrations or reviews on the internet/ in magazines
❒ Self-taught
❒ Other, please specify ____

13) Does ACC create any new driving problems or safety concerns for you?*
❒ No
❒ Yes
If Yes, please explain ____

14) At what following distance do you usually set your ACC?*
❒ At the shortest setting, which is as close to the lead vehicle as my ACC allows
❒ At a medium setting
❒ At the longest setting, which is as far from the lead vehicle as my ACC allows
❒ I don't know

15) Thinking about specific driving environments or conditions, how does the length of your following distance change when not using ACC compared to using ACC?

	Shorter distance than with ACC	About the same as with ACC	Longer distance than with ACC
Residential areas	❒	❒	❒
Urban area/Cities	❒	❒	❒
Rural highways	❒	❒	❒
Interstates/freeways	❒	❒	❒
Interstate exit and entrance ramps	❒	❒	❒
Curves	❒	❒	❒
Hills	❒	❒	❒
Rain	❒	❒	❒
Snow	❒	❒	❒
Low/no sunlight	❒	❒	❒
In heavy – "stop-and-go" – traffic	❒	❒	❒
In heavy traffic that is flowing	❒	❒	❒
Freeway off ramps, or when exiting highways	❒	❒	❒
On city streets with traffic lights	❒	❒	❒
On curvy roads	❒	❒	❒
On roads with lower speed limits	❒	❒	❒

When tired or otherwise impaired	❒	❒	❒
When performing tasks (talking on cell phone, etc.)	❒	❒	❒
When other people are in the vehicle	❒	❒	❒

16) Please rate how often you use ACC in the following situations? *‡ 17) How has your use changed since you began using the system?

	Not at All 1	Rarely 2	Sometimes 3	Often 4	Always 5	Use More Now 1	Use Less Now 2	Use Remains the Same 3
Clear road conditions with good visibility	❒	❒	❒	❒	❒	❒	❒	❒
Rain*	❒	❒	❒	❒	❒	❒	❒	❒
Snow*	❒	❒	❒	❒	❒	❒	❒	❒
Low/no sunlight*	❒	❒	❒	❒	❒	❒	❒	❒
In heavy – "stop-and-go" – traffic*	❒	❒	❒	❒	❒	❒	❒	❒
In heavy traffic that is flowing*	❒	❒	❒	❒	❒	❒	❒	❒
On interstate highways*	❒	❒	❒	❒	❒	❒	❒	❒
On rural highways	❒	❒	❒	❒	❒	❒	❒	❒
Freeway off-ramps, or when exiting highways*	❒	❒	❒	❒	❒	❒	❒	❒
On city streets with traffic lights*	❒	❒	❒	❒	❒	❒	❒	❒
In residential areas	❒	❒	❒	❒	❒	❒	❒	❒
On curvy roads*	❒	❒	❒	❒	❒	❒	❒	❒
On hilly roads	❒	❒	❒	❒	❒	❒	❒	❒
On roads with lower speed limits*	❒	❒	❒	❒	❒	❒	❒	❒
When tired or otherwise impaired*	❒	❒	❒	❒	❒	❒	❒	❒
When performing tasks (e.g., using cell phone, map, radio, GPS, etc.)*	❒	❒	❒	❒	❒	❒	❒	❒
When other people are in the vehicle	❒	❒	❒	❒	❒	❒	❒	❒

18) Please note other changes in your **ACC use** that you've noticed since you began using ACC.

____

____

19) For each of the following statements, please state how much you agree or disagree.*‡

Based on my current use of ACC…	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Not Applicable
I tend to change lanes less often when using ACC*	❒	❒	❒	❒	❒	❒
I set ACC to follow vehicles at high speed and close distances*	❒	❒	❒	❒	❒	❒
I tend to follow the vehicle ahead more closely when I use ACC than when I'm not using ACC	❒	❒	❒	❒	❒	❒
I tend to perform other tasks (e.g., use of cell phone, map, radio, GPS, etc.) **more often** with ACC on*	❒	❒	❒	❒	❒	❒
I tend to change my route so I can use ACC more	❒	❒	❒	❒	❒	❒
Using ACC reduces my stress while driving*	❒	❒	❒	❒	❒	❒
I rely more on ACC than when I first started using it*	❒	❒	❒	❒	❒	❒

20) For each of the following statements, please state how much you agree or disagree.

Compared to when I began using ACC…	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Not Applicable
I tend to change lanes less often when using ACC*	❒	❒	❒	❒	❒	❒
I set ACC to follow vehicles at high speed and close distances*	❒	❒	❒	❒	❒	❒
I tend to follow the vehicle ahead more closely when I use ACC than when I'm not using ACC	❒	❒	❒	❒	❒	❒
I tend to change my route so I can use ACC more	❒	❒	❒	❒	❒	❒
Using ACC reduces my stress while driving*	❒	❒	❒	❒	❒	❒

21) Please note other changes in your **driving** that you've noticed since you began using ACC.

____

____

____

____

22) If you encountered a stopped car ahead in your lane with the ACC system engaged, how do you think the system would react?
- ❒ Detect the vehicle in the lane ahead, start to slow until stopped
- ❒ Detect the vehicle in the lane ahead, start to slow, but the driver needs to stop vehicle
- ❒ System will not detect stopped vehicle
- ❒ Don't know

23) Does the ACC system warn or alert you if you get too close to the vehicle ahead and need to intervene by applying the brakes?
- ❒ No (skip ahead to Question 18)
- ❒ Yes (continue with Question 17)

24) Is the warning only active when the ACC is in use, or is the warning active even when the system is off?
- ❒ The warning is active only when ACC is in use
- ❒ The warning is active regardless of the ACC system's status (on/off)

25) How quickly do you notice and react to unexpected road hazards when ACC is turned on, compared to when it is turned off?* (Please check only one)
- ❒ Much slower
- ❒ Slower
- ❒ Neither slower nor quicker
- ❒ Quicker
- ❒ Much Quicker
- ❒ Don't know

26) For each of the following situations, please rate how much you think that ACC would help you in avoiding a crash with the vehicle in front of you if… *‡

	Not at all	Not very much	Much	Fairly much	Very much	Don't know
You are following the vehicle in stop-and-go traffic*	❒	❒	❒	❒	❒	❒
The vehicle stopped in your lane*	❒	❒	❒	❒	❒	❒
You are following the vehicle on a curvy road*	❒	❒	❒	❒	❒	❒
You are following a vehicle that brakes suddenly, as if in an emergency situation	❒	❒	❒	❒	❒	❒
You are following a vehicle that slows to a stop	❒	❒	❒	❒	❒	❒
You approach a motorcyclist in the lane in front of you	❒	❒	❒	❒	❒	❒
You are following a very dirty vehicle	❒	❒	❒	❒	❒	❒

27) Have you ever hit something in front of your vehicle with ACC turned on?*‡
- ❒ No
- ❒ Yes

If Yes, please describe the situation and what you hit ________________________________

____

28) In driving your own car, did you ever have a crash or near crash because you thought the ACC system was activated, but wasn't?
- ❒ No
- ❒ Yes

29) For each of the following statements, please state how much you agree or disagree.*‡

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Not Applicable
The sounds made by the ACC system are easy to understand*	❒	❒	❒	❒	❒	❒
The lights/symbols on the ACC system are confusing*	❒	❒	❒	❒	❒	❒
The ACC following distance setting is easy to understand*	❒	❒	❒	❒	❒	❒
The ACC cruise speed setting is confusing*	❒	❒	❒	❒	❒	❒

30) Based on your use of ACC, please state how much you agree or disagree with the following statements. *‡

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I feel safe using the ACC system*	❒	❒	❒	❒	❒
I am a safer driver now that I use ACC*	❒	❒	❒	❒	❒
More cars cut me off or pull in front of me when I am using my ACC*	❒	❒	❒	❒	❒
My ACC system is very reliable	❒	❒	❒	❒	❒

APPENDIX 17: DRIVING STYLE QUESTIONNAIRE

Driving Style Questionnaire

The following questions ask about your driving style. 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.

1) Sometimes when driving things happen very quickly. Do you remain calm in such situations?

❒ Never or very infrequently
❒ Quite infrequently
❒ Infrequently
❒ Frequently
❒ Quite frequently
❒ Very frequently or always

2) Do you plan long trips in advance, including places to stop and rest?

❒ Never or very infrequently
❒ Quite infrequently
❒ Infrequently
❒ Frequently
❒ Quite frequently
❒ Very frequently or always

3) Do you dislike people giving you advice about your driving?

❒ Never or very infrequently
❒ Quite infrequently
❒ Infrequently
❒ Frequently
❒ Quite frequently
❒ Very frequently or always

4) Do you exceed the 70 mph limit on Iowa interstates?

❒ Never or very infrequently
❒ Quite infrequently
❒ Infrequently
❒ Frequently
❒ Quite frequently
❒ Very frequently or always

5) Do you ever drive through a traffic light after it has turned to red?

❒ Never or very infrequently
❒ Quite infrequently
❒ Infrequently
❒ Frequently
❒ Quite frequently
❒ Very frequently or always

6) Do you exceed the speed limit in business areas?

❒ Never or very infrequently
❒ Quite infrequently
❒ Infrequently
❒ Frequently
❒ Quite frequently
❒ Very frequently or always

7) Do you ignore passengers urging you to change your speed?

❒ Never or very infrequently
❒ Quite infrequently
❒ Infrequently
❒ Frequently
❒ Quite frequently
❒ Very frequently or always

8) Do you become flustered when faced with sudden dangers while driving?

❒ Never or very infrequently
❒ Quite infrequently
❒ Infrequently
❒ Frequently
❒ Quite frequently
❒ Very frequently or always

9) How often do you set out on an unfamiliar trip without first looking at a map?

❒ Never or very infrequently
❒ Quite infrequently
❒ Infrequently
❒ Frequently
❒ Quite frequently
❒ Very frequently or always

10) Are you happy to receive advice from people about your driving?

❒ Never or very infrequently
❒ Quite infrequently
❒ Infrequently
❒ Frequently
❒ Quite frequently
❒ Very frequently or always

11) Do you drive cautiously?

❒ Never or very infrequently
❒ Quite infrequently
❒ Infrequently
❒ Frequently
❒ Quite frequently
❒ Very frequently or always

12) Do you find it easy to ignore distractions while driving?

- ❒ Never or very infrequently
- ❒ Quite infrequently
- ❒ Infrequently
- ❒ Frequently
- ❒ Quite frequently
- ❒ Very frequently or always

13) Do you drive fast?

- ❒ Never or very infrequently
- ❒ Quite infrequently
- ❒ Infrequently
- ❒ Frequently
- ❒ Quite frequently
- ❒ Very frequently or always

14) Do you pass vehicles on a four lane roadway if you have the opportunity?

- ❒ Never or very infrequently
- ❒ Quite infrequently
- ❒ Infrequently
- ❒ Frequently
- ❒ Quite frequently
- ❒ Very frequently or always

15) Is your driving affected by pressure from other drivers?

- ❒ Never or very infrequently
- ❒ Quite infrequently
- ❒ Infrequently
- ❒ Frequently
- ❒ Quite frequently
- ❒ Very frequently or always

APPENDIX 18: TRUST IN AUTOMATION QUESTIONNAIRE

Trust in Automation Questionnaire

The following questions ask about your degree of trust in inanimate objects. Just as with people, we are capable for forming relationships of trust with objects we encounter in everyday life. To answer the survey questions, please place a perpendicular line along the axis to indicate your answer. First complete the PRACTICE QUESTIONS, before completing the SURVEY QUESTIONS. 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.

PRACTICE QUESTIONS

To what extent do you trust your watch to display the correct time?

Not at All Extremely High

To what extent does your calculator produce the correct answer?

Not at All Extremely High

To what extent does your oven bake at a temperature indicated by the dial?

Not at All Extremely High

SURVEY QUESTIONS

1. To what extent does the ACC system perform its function properly?

   Not at All Extremely High

2. To what extent can the ACC system's behavior be predicted from moment to moment?

   Not at All Extremely High

3. To what extent can you count on the ACC system to do its job?

   Not at All Extremely High

4. To what extent does the ACC system perform the task it was designed to do?

Not at All | Extremely High

5. To what extent does the ACC system respond similarly to similar circumstances at different points in time?

Not at All | Extremely High

6. What is your degree of *faith* that the ACC system will be able to cope with future driving situations?

None at All | Extremely High

7. What is your degree of *trust* in the ACC system to *respond* accurately?

None at All | Extremely High

8. What is your degree of *trust* in the ACC system's *display*?

None at All | Extremely High

9. What is your *overall degree of trust* in the ACC system?

None at All | Extremely High

10. What is your degree of *trust* in your cooperation with the ACC system?

None at All | Extremely High

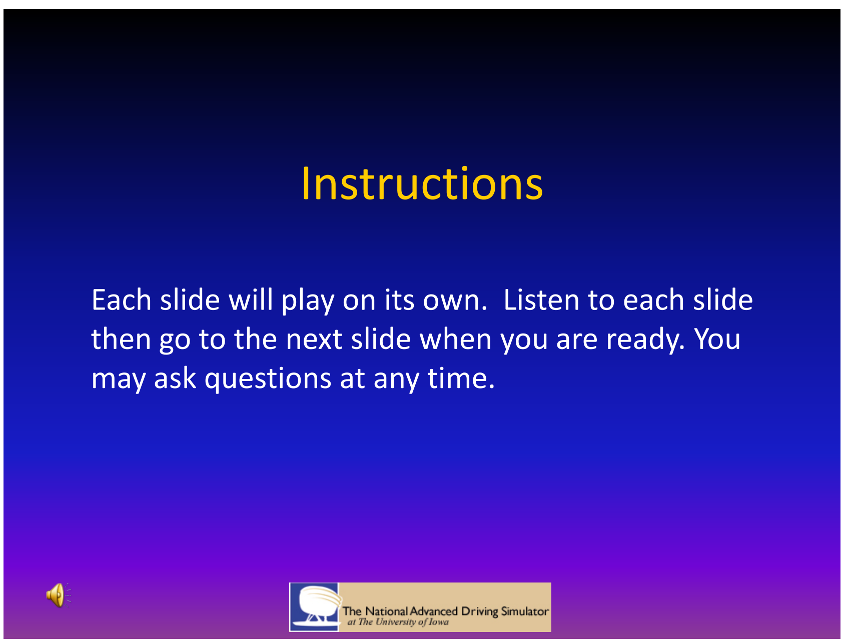
11. How confident do you feel about your previous trust ratings?

None at All | Extremely High

12. What is your degree of self-confidence to manually intervene with the ACC system?

None at All | Extremely High

APPENDIX 19: TRAINING PRESENTATION



"Each slide will play on its own. Listen to each slide then go to the next slide when you are ready. You may ask questions at any time."

"Today you will be driving a 1997 Chevy Malibu."

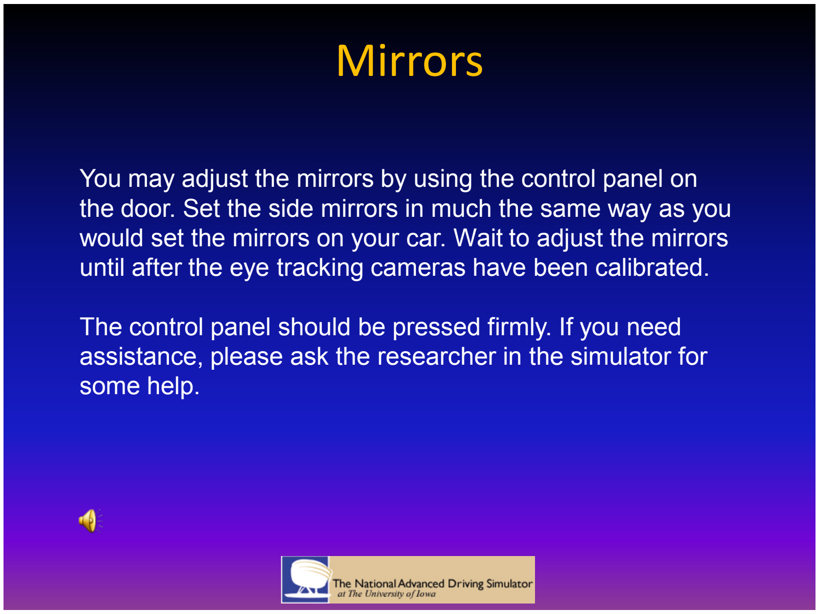
"When you are escorted to the simulator, a researcher will open the door for you and at that time you may be seated in the car. The Malibu has an automatic transmission and the gear lever is in the center console."

"Once you are seated, please adjust the seat and the steering wheel so you are in a comfortable driving position. Move the power seat lever in the direction that you would like the seat to go. Adjust the angle of the seatback using the long lever."

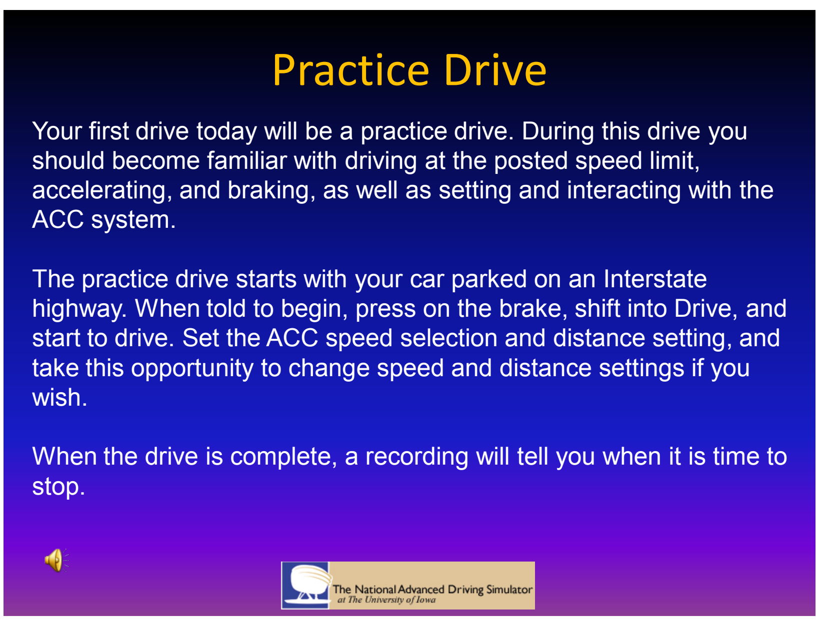
"Adjust the steering wheel so you are comfortable, however, you must be able to view the speedometer by glancing downward rather than by moving your head. (pause) The lever is located above your left knee. It will help the eye tracking process if you adjust the wheel as low as possible while still considering your comfort."

"Once the adjustments to your driving position have been made, please fasten your seatbelt."

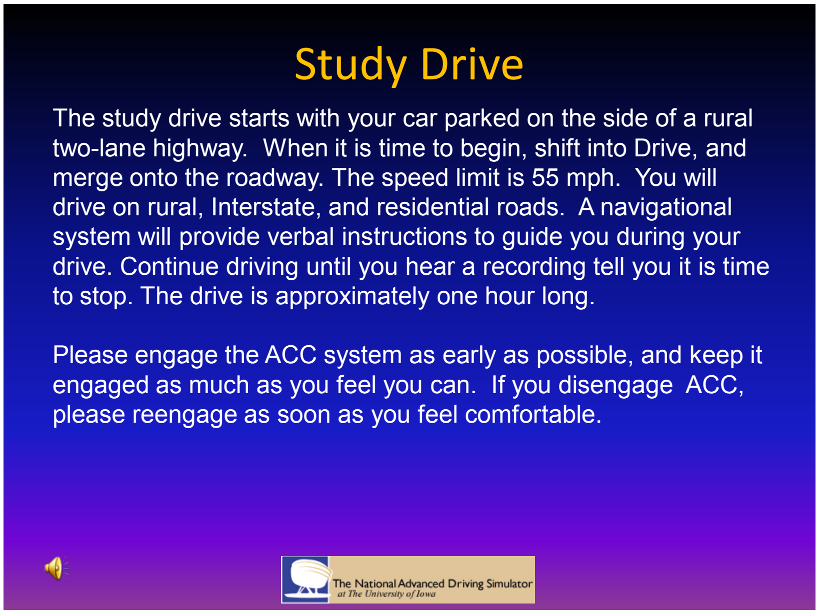
"During the time that you are not driving, we ask that you sit in the "resting position", with your hands off of the steering wheel and your feet pulled back and away from the pedals."



"You may adjust the mirrors by using the control panel on the door. Set the side mirrors in much the same way as you would set the mirrors on your car. Wait to adjust the mirrors until after the eye tracking cameras have been calibrated. The control panel should be pressed firmly. If you need assistance, please ask the researcher in the simulator for some help."



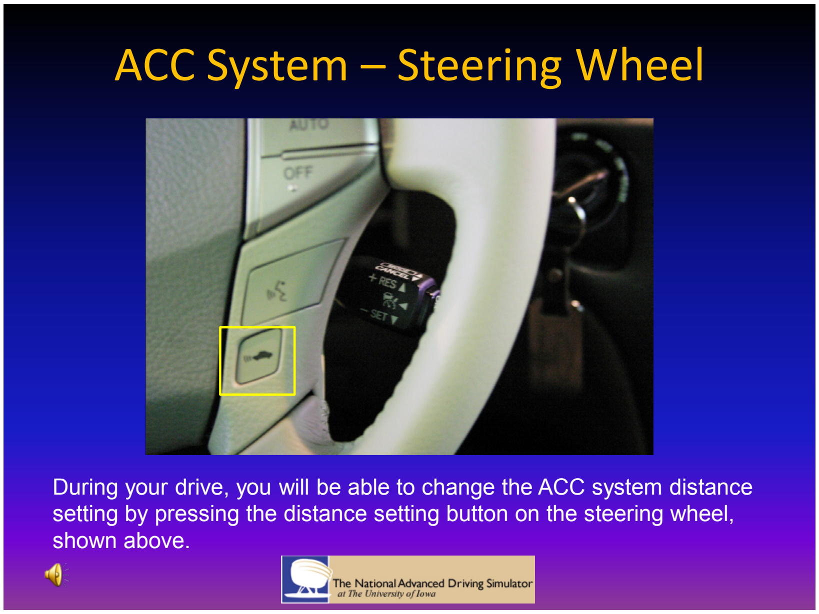
"Your first drive today will be a practice drive. During this drive you should become familiar with driving at the posted speed limit, accelerating, and braking, as well as setting and interacting with the ACC system. The practice drive starts with your car parked on an Interstate highway. When told to begin, press on the brake, shift into Drive, and start to drive. Set the ACC speed selection and distance setting, and take this opportunity to change speed and distance settings if you wish. When the drive is complete, a recording will tell you when it is time to stop."



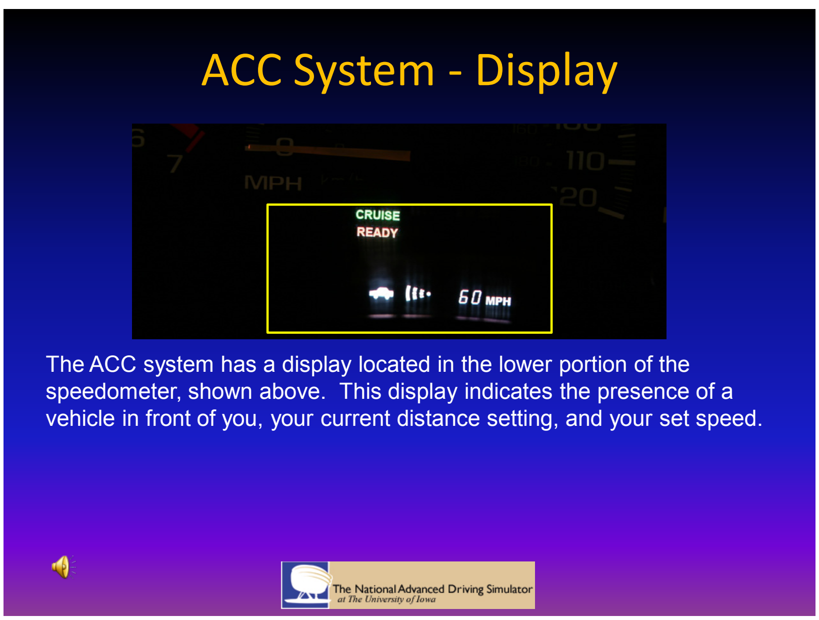
"The study drive starts with your car parked on the side of a rural two-lane highway. When it is time to begin, shift into Drive, and merge onto the roadway. The speed limit is 55 mph. You will drive on rural, Interstate, and residential roads. A navigational system will provide verbal instructions to guide you during your drive. Continue driving until you hear a recording tell you it is time to stop. The drive is approximately one hour long. Please engage the ACC system as early as possible, and keep it engaged as much as you feel you can. If you disengage ACC, please reengage as soon as you feel comfortable."

“The ACC system you will use today will be familiar, but not identical, to the ACC in your personal vehicle. The controls for the ACC system are shown below. To turn on the ACC system, press the “ON - OFF” button.”

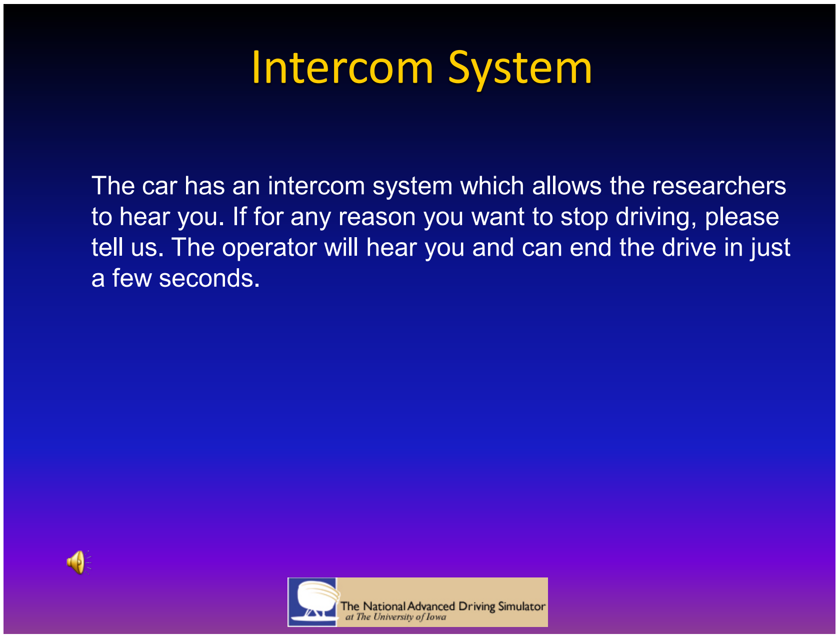
“To set the speed, accelerate to your desired speed and push the lever down in the “- SET down ” direction. You can increase the speed by pushing the lever in the “+ RES up ” direction, or decrease the set speed by pushing the lever down in the “- SET down ” direction. To cancel the set speed you can pull the lever towards you in the “CANCEL” direction, depress the brake pedal, or press the “ON – OFF” button.”



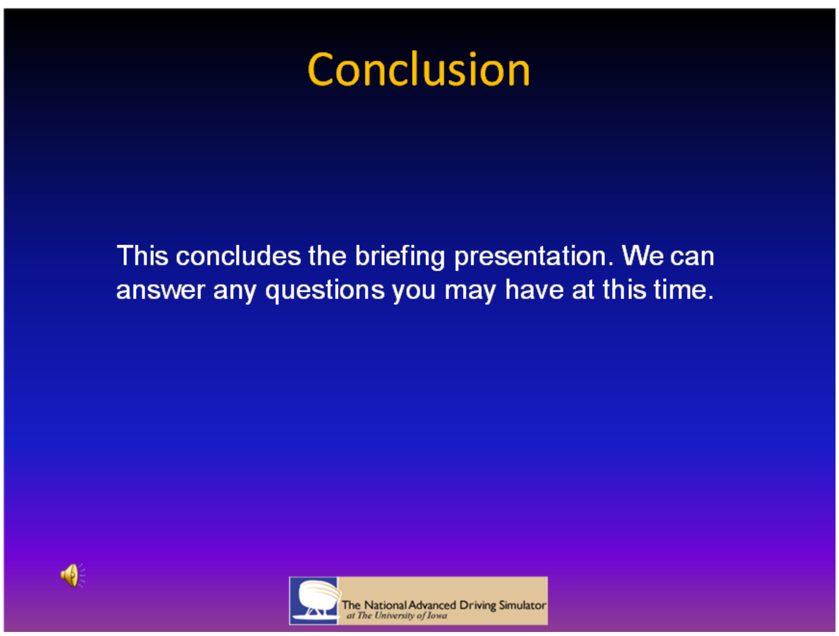
"During your drive, you will be able to change the ACC system distance setting by pressing the distance setting button on the steering wheel, shown above."



"The ACC system has a display located in the lower portion of the speedometer, shown above. This display indicates the presence of a vehicle in front of you, your current distance setting, and your set speed."



"The car has an intercom system which allows the researchers to hear you. It is already adjusted for the drive today. If for any reason you want to stop driving, please tell us. The operator will hear you and can end the drive in just a few seconds."



"This concludes the briefing presentation. We can answer any questions you may have at this time."

APPENDIX 20: WELLNESS QUESTIONNAIRE

WELLNESS QUESTIONNAIRE

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.

APPENDIX 21: REALISM QUESTIONNAIRE

REALISM QUESTIONNAIRE

For each of the following items, circle the number that best indicates how closely the simulator resembles an actual car in terms of appearance, sound, and response. If an item is not applicable, circle NA.

	General Driving	Not at all realistic					Completely Realistic	
1	Response of the seat adjustment levers	0	1	2	3	4	5	6	NA
2	Response of the mirror adjustment levers	0	1	2	3	4	5	6	NA
3	Response of the door locks and handles	0	1	2	3	4	5	6	NA
4	Response of the fans	0	1	2	3	4	5	6	NA
5	Response of the gear shift	0	1	2	3	4	5	6	NA
6	Response of the brake pedal	0	1	2	3	4	5	6	NA
7	Response of accelerator pedal	0	1	2	3	4	5	6	NA
8	Response of the speedometer	0	1	2	3	4	5	6	NA
9	Response of the steering wheel while driving straight	0	1	2	3	4	5	6	NA
10	Response of the steering wheel while driving on curves	0	1	2	3	4	5	6	NA
11	Feel when accelerating	0	1	2	3	4	5	6	NA
12	Feel when braking	0	1	2	3	4	5	6	NA
13	Feel when passing other cars	0	1	2	3	4	5	6	NA
14	Feel when driving straight	0	1	2	3	4	5	6	NA
15	Feel when driving on curves	0	1	2	3	4	5	6	NA
16	Feel of approximate speed when driving 30 mph	0	1	2	3	4	5	6	NA
17	Feel of approximate speed when driving 45 mph	0	1	2	3	4	5	6	NA
18	Feel of approximate speed when driving 55 mph	0	1	2	3	4	5	6	NA
19	Feel of approximate speed when driving 65 mph	0	1	2	3	4	5	6	NA
20	Sound of the car	0	1	2	3	4	5	6	NA
21	Sound of other vehicles	0	1	2	3	4	5	6	NA
22	Sound of ACC deceleration limit exceedance alert	0	1	2	3	4	5	6	NA
23	Sound of ACC termination alert	0	1	2	3	4	5	6	NA
24	Appearance of roads and road markings	0	1	2	3	4	5	6	NA
25	Appearance of intersections	0	1	2	3	4	5	6	NA
26	Appearance of car interior	0	1	2	3	4	5	6	NA
27	Appearance of other vehicles	0	1	2	3	4	5	6	NA
28	Appearance of rear-view mirror image	0	1	2	3	4	5	6	NA
29	Appearance of rural scenery	0	1	2	3	4	5	6	NA

30	Appearance of residential scenery	0	1	2	3	4	5	6	NA
31	Appearance of interstate scenery	0	1	2	3	4	5	6	NA
32	Appearance of signs	0	1	2	3	4	5	6	NA
33	Ability to read road and warning signs	0	1	2	3	4	5	6	NA
34	Ability to negotiate curves	0	1	2	3	4	5	6	NA
35	Ability to keep straight in your lane	0	1	2	3	4	5	6	NA
36	Ability to respond to traffic	0	1	2	3	4	5	6	NA
37	Ability to maintain control while driving straight	0	1	2	3	4	5	6	NA
38	Ability to maintain control while in curve	0	1	2	3	4	5	6	NA
39	Similarity of ACC display to your own vehicle	0	1	2	3	4	5	6	NA
40	Similarity of ACC controls to your own vehicle	0	1	2	3	4	5	6	NA
41	Similarity of ACC feel to your own vehicle	0	1	2	3	4	5	6	NA
42	Similarity of ACC headway distance to your own vehicle (distance between your vehicle and the one ahead of you)	0	1	2	3	4	5	6	NA
43	Similarity of ACC’s performance around curves to your own vehicle	0	1	2	3	4	5	6	NA
44	Similarity of ACC speed control to your own vehicle	0	1	2	3	4	5	6	NA
45	Overall similarity of simulated ACC to your own vehicle	0	1	2	3	4	5	6	NA
46	Overall appearance of driving scenes	0	1	2	3	4	5	6	NA
47	Overall feel of the car when driving	0	1	2	3	4	5	6	NA
48	Overall similarity to real driving	0	1	2	3	4	5	6	NA

APPENDIX 22: ACC VERBAL REPORT SCRIPT

ACC Post-Drive Verbal Report
Researcher Instructions

[Prep Video Clip 1 while participant completes Realism Survey]

To play video clip:

- Open My Computer on desktop
- Click Open "acc_video on 'nads-vidcap' (V:)"
  - Double-click on VCAP 1 (quad split with titler)
  - Find and open (double-click) folder with participant's number (PL1XX or MN1XX)
  - Find and open (double-click) the desired drive (PL1XX_SCNX).
  - Expand the screen. Turn volume up on speaker.
  - Find Events (see below) on titler. Video start/stop times are estimates.
    - Events are on the 4th line of the titler display, after the "E:". The possible values are 0 (when there is no event), and 411-431.
    - Elecard time is a count of time passed since beginning of drive. Time on titler is the actual time. For events, titler time is recorded on the Scenario Checklist, but notes for each event also give estimates of time passed since beginning of drive.

Video Clip 1

- Event 416
  - SCN1: approximately 9-11 minutes into drive; SCN2: 3-5 minutes into drive.
  - Find the point where the lead vehicle brake lights turn on (about 10 seconds after the Event 416 begins), and start playing the video from a few seconds before this point.
  -
- *RAP READ: We are going to watch three short video clips from your study drive. While we watch each clip, I would like you to talk me through what you were thinking as you experienced this driving situation, including what you were paying attention to and what actions you took as you responded to the driving situation. Think of this as providing a play-by-play commentary of your drive.*

  We can watch each clip as many times as you'd like.

  After watching each clip, I will have you fill out a questionnaire about that driving situation.

  I will be recording you while you talk. If you would like for me to stop recording, just ask.

  [If the participant doesn't say anything or focuses his/her response on the simulator (motion, visuals, etc) instead of on the event, you can ask follow-up questions to prompt them to respond. These questions include but are not limited to:

  - What was your response in this situation?
  - What were you responding to?]

- Begin recording by saying "ACC Pilot Verbal Report, Video Clip 1, participant # XXX"
- Click Play on Elecard player. You can use the controls to stop, pause, rewind, and fast forward.
- When participant finishes, turn off recorder
- Administer Post-Drive Questionnaire, Video Clip 1
- Prep Video Clip 2 while participant completes PDQ, VC1

Video Clip 2

- Event 421
    - SCN1 and SCN2: approximately 14-17 minutes into drive.
    - Start playing the video at the point where Event 421 begins.

- *RAP READ: Again, I'd like you to think aloud while watching this next video clip from your study drive. We can watch it more than once, if needed.*

- Begin recording by saying "ACC Pilot Verbal Report, Video Clip 2, participant # XXX"
- Click Play.
- When participant finishes, turn off recorder.
- Administer Post-Drive Questionnaire, Video Clip 2
- Prep Video Clip 3 while participant completes PDQ, VC2

Video Clip 3

- Event 431
    - SCN1and SCN2: approximately 27-32 minutes into drive. This is the last event.
    - Find the point where the stopped vehicle becomes visible (about 35-45 seconds after Event 431), and start playing the video from a few seconds before this point.

- *RAP READ: Again, I'd like you to think aloud while watching this next video clip from your study drive. We can watch it more than once, if needed.*

- Begin recording by saying "ACC Pilot Verbal Report, Video Clip 3, participant # XXX"
- Click Play.
- When participant finishes, turn off recorder.
- Administer Post-Drive Questionnaire, Video Clip 3

APPENDIX 23: ACC POST DRIVE QUESTIONNAIRE, VIDEO CLIP 1

ACC Post-Drive Questionnaire, Video Clip 1

The following questions address the video clip you just watched. If something is unclear, ask the research assistant for help. Your participation is voluntary and you have the right to skip questions if you choose.

1) Is your speed selection typical for how you would drive with ACC in a similar situation in the real world?
   - ❒ Yes
   - ❒ No. If NO, how is it different? (describe below)

   ____

   ____

   ____

2) Is your distance setting typical for how you would drive with ACC in a similar situation in the real world?
   - ❒ Yes
   - ❒ No. If NO, how is it different? (describe below)

   ____

   ____

   ____

3) Did you take over control of the vehicle in this situation?
   - ❒ Yes
   - ❒ No

   What factors played a role in you choosing to intervene/not to intervene?

   ____

   ____

   ____

4) Do you remember receiving an alert in this situation?
   - ❒ Yes
   - ❒ No

   Why did/didn't you receive an alert in this situation?

   ____

   ____

   ____

5) To what extent did you trust the ACC system in this situation?
   - ❒ Not at all
   - ❒ Slightly
   - ❒ Moderately
   - ❒ Very Much
   - ❒ Extremely

   What factors led to this degree of trust?

   ____

   ____

   ____

6) To what extent did you rely on the ACC system in this situation?
   - ❒ Not at all
   - ❒ Slightly
   - ❒ Moderately
   - ❒ Very Much
   - ❒ Extremely

   What factors led to this degree of reliance?

   ____

   ____

   ____

7) How would you rate your level of comfort during this event?
   - ❒ Not at all comfortable
   - ❒ Slightly comfortable
   - ❒ Moderately comfortable
   - ❒ Very comfortable
   - ❒ Extremely comfortable

   What affected your level of comfort during this event?

   ____

   ____

   ____

8) How reliable was the ACC system in this situation?
   - ❒ Not at all reliable
   - ❒ Slightly reliable
   - ❒ Moderately reliable
   - ❒ Very reliable
   - ❒ Extremely reliable

What about the ACC system's operation in this situation influenced how you rated its reliability?

____

____

____

9) What was your level of confidence in the ACC system in this situation?
- ❒ Not at all confident
- ❒ Slightly confident
- ❒ Moderately confident
- ❒ Very confident
- ❒ Extremely confident

What about the ACC system in this situation influenced how you rated your confidence in its operation?

____

____

____

10) What was your degree of self confidence to handle this situation?
- ❒ Not at all confident
- ❒ Slightly confident
- ❒ Moderately confident
- ❒ Very confident
- ❒ Extremely confident

APPENDIX 24: ACC COUNTERMEASURE QUESTIONNAIRE

Countermeasure Questionnaire

We would like your feedback on your ACC system. Please answer in the space provided; ask the researcher for additional paper if needed.

1. Please list problems or challenges you have experienced with your ACC system where it worked differently than you thought it should. In the accompanying column, suggest any recommendations you would make to change the system's functionality or design.

	Issues with your ACC system	Suggested solutions for associated problem/challenge
Issue 1		
Issue 2		
Issue 3		
Issue 4		
Issue 5		
Issue 6		
Issue 7		

2. If you haven't already, tell us what you like/dislike about your vehicle's ACC interface. For example, what additional information would you like to receive when the ACC system is activated? Would you change anything about the levers and buttons used to activate, modify, and deactivate the system?

   Like____

   Dislike____

3. If you haven't already, tell us what you like/dislike about the alerts issued by your ACC system. For example, are there times when you don't hear or see the auditory or visual alerts but you believe they should have been triggered?

   Like____

   Dislike____

4. If you purchased this same vehicle again, would you want it to have ACC?*
   - ❐ Yes
   - ❐ No
   - ❐ I don't know

APPENDIX 25: DEBRIEF STATEMENT

ACC Debrief Statement

This study looks at how early adopters of Adaptive Cruise Control (ACC) use the technology, and how ACC may affect drivers' performance and behavior. In the consent document and training materials you were told that the drive would last 60 minutes, but instead it lasted roughly 30 minutes. We could not tell you the actual length of the drive because if you anticipated the drive's end, your response to the parked vehicle at the end of the drive might have been affected.

We need drivers to be surprised by what happens in the study drive, so please do not tell others about what happens during the study drive until after June 30, 2010 when we expect this study to be over.

Thank you for participating in the study!

APPENDIX 26: SCENARIO EVENTS

This section describes each event in detail. The order of events is different for the two main study scenarios. The detailed information for each event can be seen below, in Appendices 27 through 40. Each section contains tables with the details of the event and a timeline for the event, including the distance of the participant's vehicle from the event vehicle during the event for each gap setting at the minimum and maximum accommodated speeds (50 mph to 70 mph for rural, 60 mph to 80 mph for interstate, and 25 mph to 45 mph for residential). These tables provide the expected distances between the vehicles at each Logstream 4 value. Actual distances will vary according to individual driver's actions (e.g. lane deviations, steering angle through curves, manual intervention, etc).

Each section also contains images of the event and their location within the environment. In these images the participant's vehicle is always green, while the other event vehicles are white (except the slow moving vehicle which only has a green model). In events where the relative position of the participant's vehicle and the lead vehicle is expected to change throughout the event, two event images are included: an image before the event starts is located to the left or above the environment layout; an image during the event is located to the right or below the environment layout. All event images are enlarged versions of the environment layout and are linked to the environment layout by four lines. The position of the events and distance between vehicles within these images are not exact, and will vary by participant based upon traveling speed, gap setting, and individual driving characterist4ics.

APPENDIX 27: RURAL EVENT 411: CURVE ENTERING DETECTION RANGE

This event will occur during the rural environment. The participant will encounter a slower moving lead vehicle in a curve and begin to follow it. The detailed information about this event can be seen in Table 18. The timeline for this event can be seen in Table 19. Figure 24, below, contains images of this event and the environment layout.

Table 18: Rural Event 411 Details

Rural Event 411: Curve Entering Detection Range	
ROAD NETWORK REQUIREMENTS	Overall minimum length/distance needed to support event (in feet): straight 2,000, curve 1,800 Road type (lanes, surface): 2 rural driving lanes Speed limit (in mph): 55 Range of speeds accommodated (in mph): 50-70 Curvature: radius of 1,862 ft entering; 1,011 ft during and exiting
PREPARATION	A vehicle will be traveling in front of the participant, such that it will be 500 feet in front of the participant as it enters the curve. The lead vehicle will then begin traveling 10 mph slower than the participant. Oncoming traffic will be present at a rate of approximately one vehicle per 20 seconds. (The participant is initially traveling between 50 and 70 mph).
START CONDITIONS	The participant is 1,000 feet from the entrance to the curve.
ACTUAL EVENT	Logstream 1 is incremented, logstream 2 is set to 411 The lead vehicle enters the curve traveling 500 feet in front of the participant, and decelerates such that it is traveling 10 mph slower than the participant. The participant approaches the lead vehicle; the ACC system detects the lead vehicle at a distance of approximately 360 feet, less than the 400 feet detection range due to the road curvature. The ACC system detects the lead vehicle and slows down to maintain the preset time gap, while not exceeding the deceleration authority.

<table>
<tr><th colspan="4">Rural Event 411: Curve Entering Detection Range</th></tr>
<tr><td>LOGSTREAM 4</td><td colspan="3">set to 1 when the start condition has been met
set to 2 when the participant has entered the curve
set to 3 when the lead vehicle has entered the detection region of the ACC system
set to 4 when the participant has exited the curve
set to 0 when the end condition has been met</td></tr>
<tr><td rowspan="6">DEPENDENT MEASURES</td><td>Name</td><td>Description</td><td>Unit</td></tr>
<tr><td>Minimum Acceleration</td><td>The minimum acceleration (maximum deceleration) during the event</td><td>meters/second^2</td></tr>
<tr><td>Maximum Brake Pedal Force</td><td>The maximum Force exerted on the brake pedal during the event</td><td>Newtons</td></tr>
<tr><td>Adjusted Minimum Time-To-Collision (AMTTC)</td><td>The amount of spare time the driver had based on the avoidance response chosen</td><td>Seconds</td></tr>
<tr><td>Relative Velocity at Collision</td><td>The difference between the participant and lead vehicle velocities at the time of collision</td><td>meters/second</td></tr>
<tr><td>Minimum Time Headway</td><td>The minimum time it would take the participant’s vehicle to travel the distance between the participant and lead vehicles given the participant vehicle’s current velocity during the event</td><td>Seconds</td></tr>
<tr><td>ASSUMED BEHAVIOR</td><td colspan="3">The participant is assumed to allow the ACC system to slow the vehicle and not to intervene. If the participant does not intervene the ACC system deceleration authority will not be exceeded.</td></tr>
<tr><td>END CONDITIONS</td><td colspan="3">The participant is 1,000 feet past the end of the curve.</td></tr>
</table>

Table 19: Rural Event 411 Distances From Participant's Vehicle to Lead Vehicle

Gap Setting	Participant Vehicle's Velocity	Distance at Logstream 4 = 1	Distance at Logstream 4=2	Distance at Logstream 4 = 3	Distance at Logstream 4 = 4
Short	50	530	390	362	68
	70	623	414	362	142
Medium	50	530	390	362	114
	70	623	414	362	204
Long	50	530	390	362	172
	70	623	414	362	236

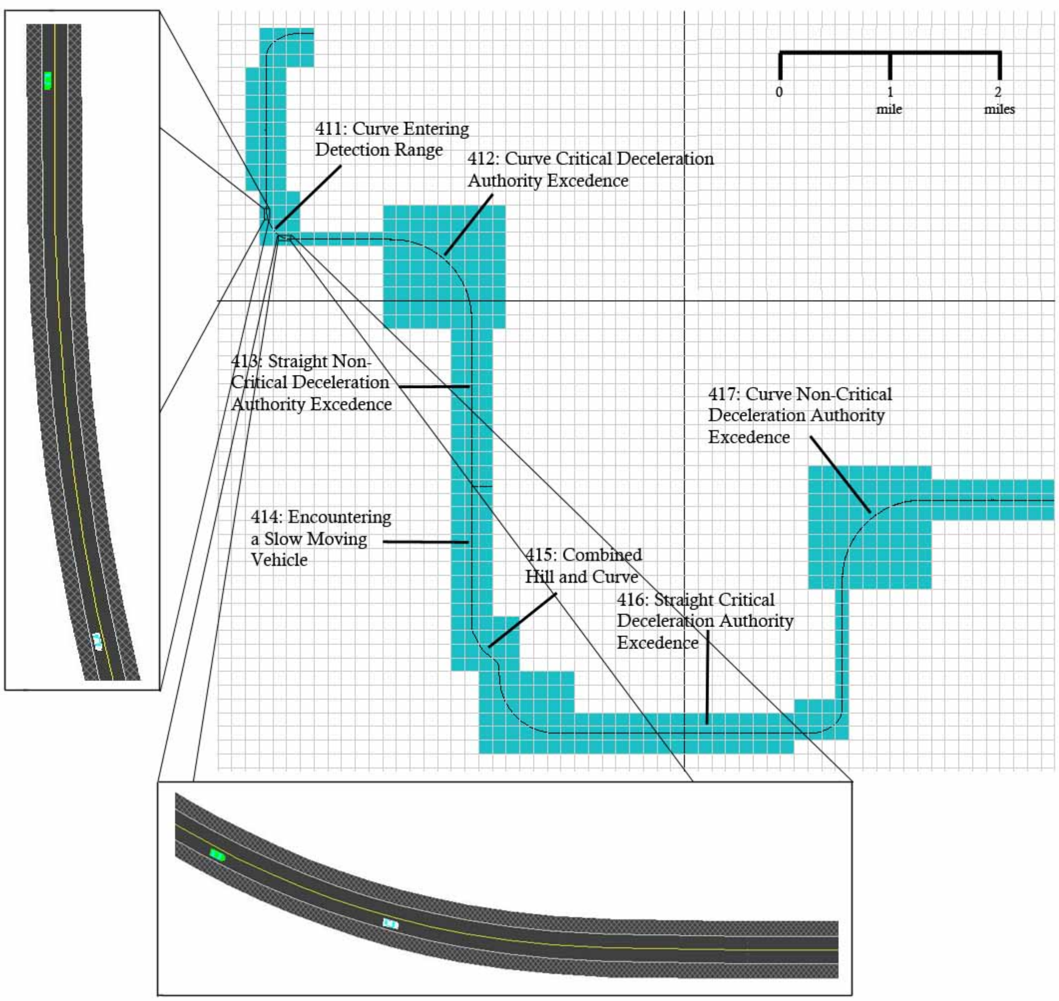


Figure 24: Images of Rural Event 411 Linked to Environment

APPENDIX 28: RURAL EVENT 412: CURVE CRITICAL DECELERATION AUTHORITY EXCEEDANCE

This event will occur in one of the paired large radius curves in the rural environment. The participant will follow a lead vehicle that decelerates at a rate that will require the participant's vehicle to exceed the ACC system deceleration authority. The detailed information about this event can be seen in Table 20. The timeline for this event is displayed in Table 21. Figure 25 contains images of this event and the environment layout.

Table 20: Rural Event 412 Details

Rural Event 412: Curve Critical Deceleration Authority Exceedance	
ROAD NETWORK REQUIREMENTS	Overall minimum length/distance needed to support event (in feet): straight 2,000, curve 1,600 Road type (lanes, surface): 2 rural driving lanes Speed limit (in mph): 55 Range of speeds accommodated (in mph): 50-70 Curvature: radius of 3,850 ft
PREPARATION	The participant is driving in the rural environment with a lead vehicle traveling at the participant's preset speed and time gap. Oncoming traffic will be present at a rate of approximately one vehicle per 20 seconds. (The participant is initially traveling between 50 and 70 mph).
START CONDITIONS	The participant is 1,000 feet from the entrance to the curve.

<table>
<tr><th colspan="4">Rural Event 412: Curve Critical Deceleration Authority Exceedance</th></tr>
<tr><td>ACTUAL EVENT</td><td colspan="3">Logstream 1 is incremented, logstream 2 is set to 412

The participant enters the curve while the lead vehicle is traveling at the participant's preset speed and time gap. Five seconds after the participant has entered the curve the lead vehicle decelerates at a rate of 0.4g if the gap setting is set to 1.24s, 0.55g if the gap setting is set to 2.04s, or 0.75g if the gap setting is set to 3.04s. In each case the lead vehicle decelerates until the warning has gone off, the lead vehicle has decelerated down to a velocity of 20 mph, or six seconds have elapsed. The lead vehicle then accelerates at 0.09g until 13.5 seconds have elapsed since it began braking.</td></tr>
<tr><td>LOGSTREAM 4</td><td colspan="3">set to 1 when the start condition has been met
set to 2 when the participant has entered the curve
set to 3 when the lead vehicle begins to decelerate
set to 4 when the lead vehicle begins to accelerate
set to 5 when the lead vehicle has attained its original velocity
set to 6 when the participant has exited the curve
set to 0 when the end condition has been met</td></tr>
<tr><td rowspan="6">DEPENDENT MEASURES</td><td>Name</td><td>Description\</td><td>Unit</td></tr>
<tr><td>Steering Response</td><td>0 for no steering response;
1 for steering response</td><td>binary</td></tr>
<tr><td>Brake Response</td><td>0 for no brake response;
1 for brake response</td><td>binary</td></tr>
<tr><td>Initial Response Time</td><td>The time elapsed from when Logstream 4 is set to 3 to when the ACC system has been disengaged</td><td>seconds</td></tr>
<tr><td>Response Time from Alert</td><td>The time elapsed from the onset of the deceleration exceedance alert to when the ACC system has been disengaged</td><td>seconds</td></tr>
<tr><td>Minimum Acceleration</td><td>The minimum acceleration (maximum deceleration) during the event</td><td>meters/second^2</td></tr>
</table>

Rural Event 412: Curve Critical Deceleration Authority Exceedance			
	Maximum Brake Pedal Force	The maximum Force exerted on the brake pedal during the event	newtons
	Adjusted Minimum Time-To-Collision (AMTTC)	The amount of spare time the driver had based on the avoidance response chosen	seconds
	Relative Velocity at Collision	The difference between the participant and lead vehicle velocities at the time of collision	meters/second
	Minimum Time Headway	The minimum time it would take the participant's vehicle to travel the distance between the participant and lead vehicles given the participant vehicle's current velocity during the event	seconds
ASSUMED BEHAVIOR	The participant is assumed to intervene after the ACC deceleration authority exceedance alert has sounded, but before the lead vehicle begins to accelerate. If the participant does not intervene they will not collide with lead vehicle.		
END CONDITIONS	The participant is 600 feet past the end of the curve.		

Table 21: Rural Event 412 Distances From Participant's Vehicle to Lead Vehicle

Gap Setting	Participant Vehicle's Velocity	Distance at Logstream 4 = 1	Distance at Logstream 4=2	Distance at Logstream 4 = 3	Distance at Logstream 4 = 4	Distance at Logstream 4 = 5	Distance at Logstream 4 = 6
Short	50	91	91	91	44	122	87
	70	127	127	127	70	140	123
Medium	50	150	150	150	92	152	144
	70	209	209	209	129	156	203
Long	50	223	223	223	158	176	214
	70	312	312	312	210	176	303

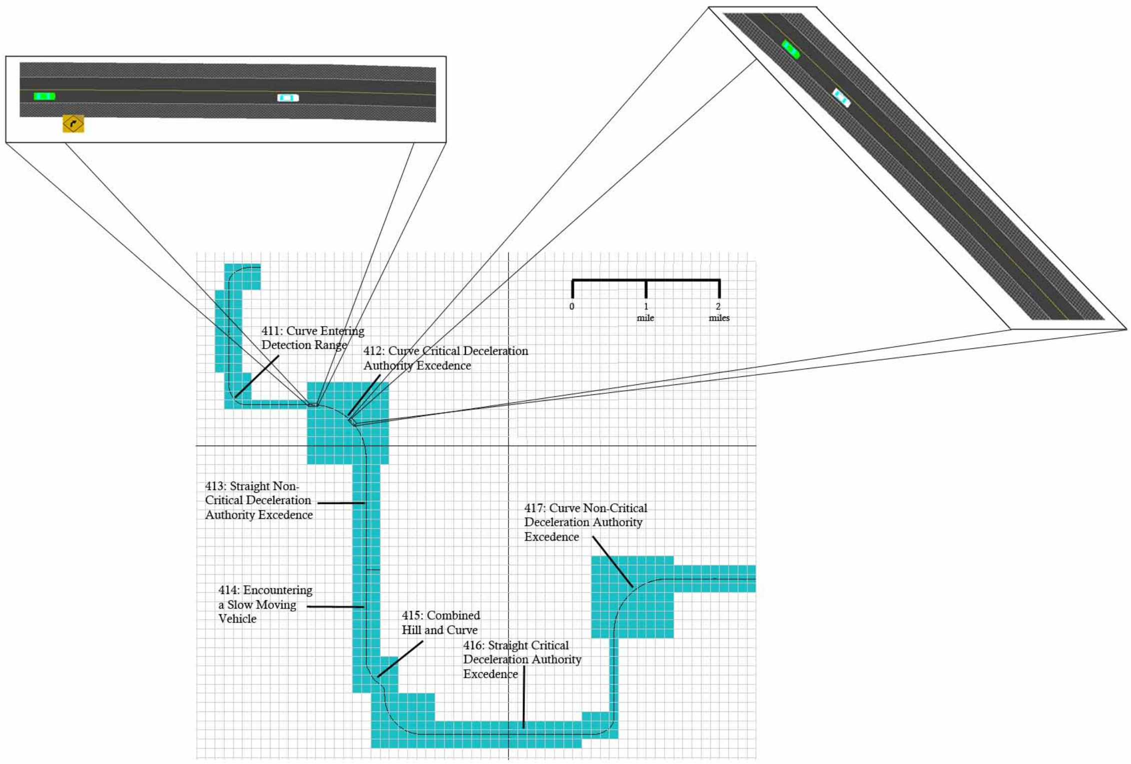


Figure 25: Images of Rural Event 412 Linked to Environment

APPENDIX 29: RURAL EVENT 413: STRAIGHT NON-CRITICAL DECELERATION AUTHORITY EXCEEDANCE

This event will occur in one of the paired straight segments in the rural environment. The participant will follow a lead vehicle that decelerates at a rate that does not require the participant's vehicle to exceed the ACC system deceleration authority. The detailed information about this event can be seen in Table 22. The timeline for this event can be seen in Table 23. Figure 26 contains images of this event and the environment layout.

Table 22: Rural Event 413 Details

Rural Event 413: Straight Non-Critical Deceleration Authority Exceedance	
ROAD NETWORK REQUIREMENTS	Overall minimum length/distance needed to support event (in feet): 2,600 Road type (lanes, surface): 2 rural driving lanes Speed limit (in mph): 55 Range of speeds accommodated (in mph): 50-70 Curvature: NA
PREPARATION	The participant is driving in the rural environment with a lead vehicle traveling at the participants preset speed and time gap. Oncoming traffic will be present at a rate of approximately one vehicle per 10 seconds once the lead vehicle begins decelerating. (The participant is initially traveling between 50 and 70 mph).
START CONDITIONS	The participant is 1,000 feet prior to the point of the lead vehicle deceleration.
ACTUAL EVENT	Logstream 1 is incremented, logstream 2 is set to 413 The participant is following a lead vehicle that is traveling at the participant's preset speed and time gap. The lead vehicle decelerates at a rate of 0.2g for 2.67 seconds, and then accelerates at a rate of 0.09g until the lead vehicle is traveling at the same speed as it was at the onset of the event.

Rural Event 413: Straight Non-Critical Deceleration Authority Exceedance			
LOGSTREAM 4	set to 1 when the start condition has been met set to 2 when the lead vehicle begins to decelerate set to 3 when the lead vehicle begins to accelerate set to 4 when the lead vehicle has attained its original velocity set to 0 when the end condition has been met		
DEPENDENT MEASURES	Name	Description	Unit
	Steering Response	0 for no steering response; 1 for steering response	binary
	Brake Response	0 for no brake response; 1 for brake response	binary
	Initial Response Time	The time elapsed from when Logstream 4 is set to 3 to when the ACC system has been disengaged	seconds
	Minimum Acceleration	The minimum acceleration (maximum deceleration) during the event	meters/second^2
	Maximum Brake Pedal Force	The maximum Force exerted on the brake pedal during the event	newtons
	Adjusted Minimum Time-To-Collision (AMTTC)	The amount of spare time the driver had based on the avoidance response chosen	seconds
	Relative Velocity at Collision	The difference between the participant and lead vehicle velocities at the time of collision	meters/second
	Minimum Time Headway	The minimum time it would take the participant's vehicle to travel the distance between the participant and lead vehicles given the participant vehicle's current velocity during the event	seconds

Rural Event 413: Straight Non-Critical Deceleration Authority Exceedance	
ASSUMED BEHAVIOR	The participant is assumed to allow the ACC system to slow the vehicle and not to intervene. If the participant does not intervene the ACC system deceleration authority will not be exceeded.
END CONDITIONS	Ten seconds have elapsed since the lead vehicle re-attained the participant's previous speed.

Table 23: Rural Event 413 Distances From Participant's Vehicle to Lead Vehicle

Gap Setting	Participant Vehicle's Velocity	Distance at Logstream 4 = 1	Distance at Logstream 4=2	Distance at Logstream 4 = 3	Distance at Logstream 4 = 4
Short	50	87	87	75	75
	70	123	123	117	117
Medium	50	144	144	131	127
	70	203	203	197	197
Long	50	214	214	202	199
	70	303	303	297	296

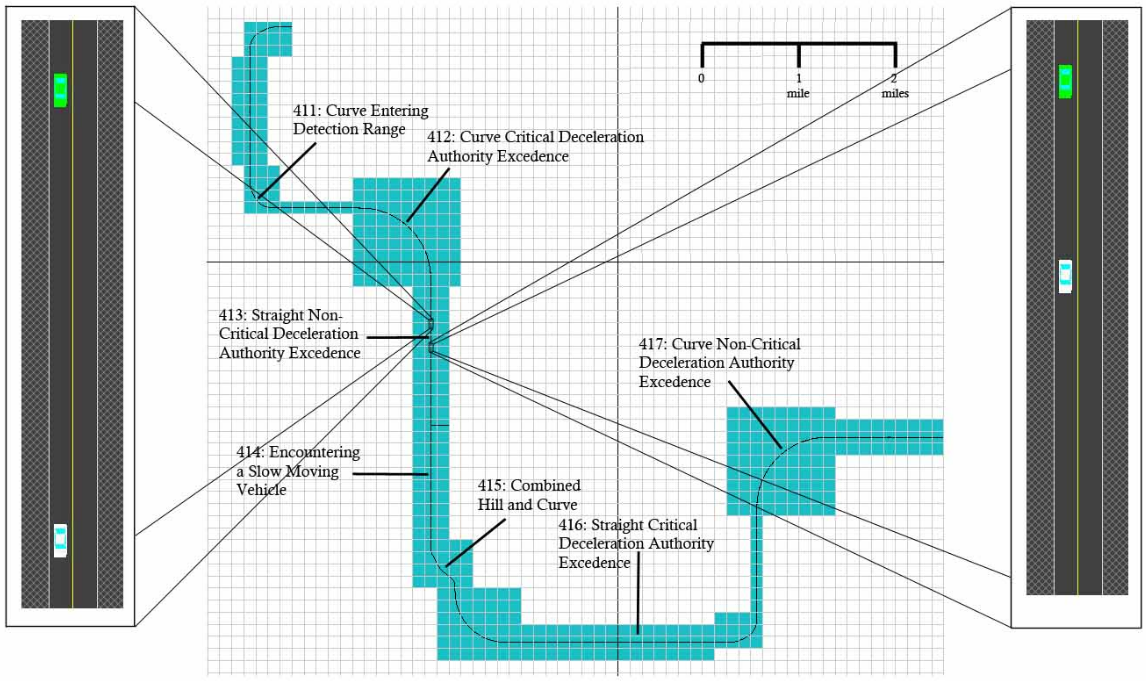


Figure 26: Images of Rural Event 413 Linked to Environment

APPENDIX 30: RURAL EVENT 414: ENCOUNTERING A SLOW MOVING VEHICLE

This event will occur in the rural environment. The participant will encounter a slow moving farm vehicle in the roadway. The detailed information about this event can be seen in Table 24. The timeline for this event can be seen in Table 25. Figure 27 contains images of this event and the environment layout.

Table 24: Rural Event 414 Details

Rural Event 414: Encountering a Slow Moving Vehicle	
ROAD NETWORK REQUIREMENTS	Overall minimum length/distance needed to support event (in feet): 7,000 Road type (lanes, surface): 2 rural driving lanes Speed limit (in mph): 55 Range of speeds accommodated (in mph): 50-70 Curvature: NA
PREPARATION	The participant is driving in the rural environment with no lead vehicle within the ACC detection range. The previous lead vehicle has accelerated to be out of the ACC detection range. Oncoming traffic will be present at a rate of approximately one vehicle per 20 seconds. (The participant is initially traveling between 50 and 70 mph).
START CONDITIONS	The participant is 5,000 feet prior to the slow moving vehicle entering the ACC system detection range (400 ft) assuming the participant is traveling the speed limit.

Rural Event 414: Encountering a Slow Moving Vehicle			
ACTUAL EVENT	Logstream 1 is incremented, logstream 2 is set to 414 The participant approaches a slow moving farm vehicle that is in the roadway, traveling 25 mph. The previous lead vehicle overtakes the slow moving farm vehicle ahead of the participant but within view. An oncoming vehicle will be approaching such that it will be 700 feet in front of the participant as they pass the slow moving farm vehicle, if the participant does not allow ACC to decelerate or manually adjust their speed. The slow moving farm vehicle will pull off onto the shoulder as the oncoming vehicle passes.		
LOGSTREAM 4	set to 1 when the start condition has been met set to 2 when the lead vehicle begins to pass the slow moving vehicle set to 3 when the slow moving vehicle has entered the ACC detection range set to 4 when the participant has passed the slow moving vehicle set to 0 when the end condition has been met		
DEPENDENT MEASURES	Name	Description	Unit
	Steering Response	0 for no steering response; 1 for steering response	binary
	Brake Response	0 for no brake response; 1 for brake response	binary
	Initial Response Time	The time elapsed from when Logstream 4 is set to 3 to when the ACC system has been disengaged	seconds
	Minimum Acceleration	The minimum acceleration (maximum deceleration) during the event	meters/second^2
	Maximum Brake Pedal Force	The maximum Force exerted on the brake pedal during the event	newtons
	Adjusted Minimum Time-To-Collision (AMTTC)	The amount of spare time the driver had based on the avoidance response chosen	seconds

Rural Event 414: Encountering a Slow Moving Vehicle			
	Relative Velocity at Collision	The difference between the participant and lead vehicle velocities at the time of collision	meters/second
ASSUMED BEHAVIOR	The participant is assumed to allow the ACC system to slow the vehicle, and to either pass the slow moving farm vehicle before the oncoming vehicle approaches, or wait until after the oncoming vehicle has passed and the slow moving farm vehicle has pulled off the road.		
END CONDITIONS	The participant is 600 feet past the slow moving farm vehicle.		

Table 25: Rural Event 414 distances from participant's vehicle to the slow moving farm vehicle

Gap Setting	Participant Vehicle's Velocity	Distance at Logstream 4 = 1	Distance at Logstream 4=2	Distance at Logstream 4 = 3	Distance at Logstream 4 = 4
Short	50	2102	1469	400	NA
	70	2720	587	400	NA
Medium	50	2102	1514	400	NA
	70	2720	663	400	NA
Long	50	2102	1565	400	NA
	70	2720	1122	400	NA

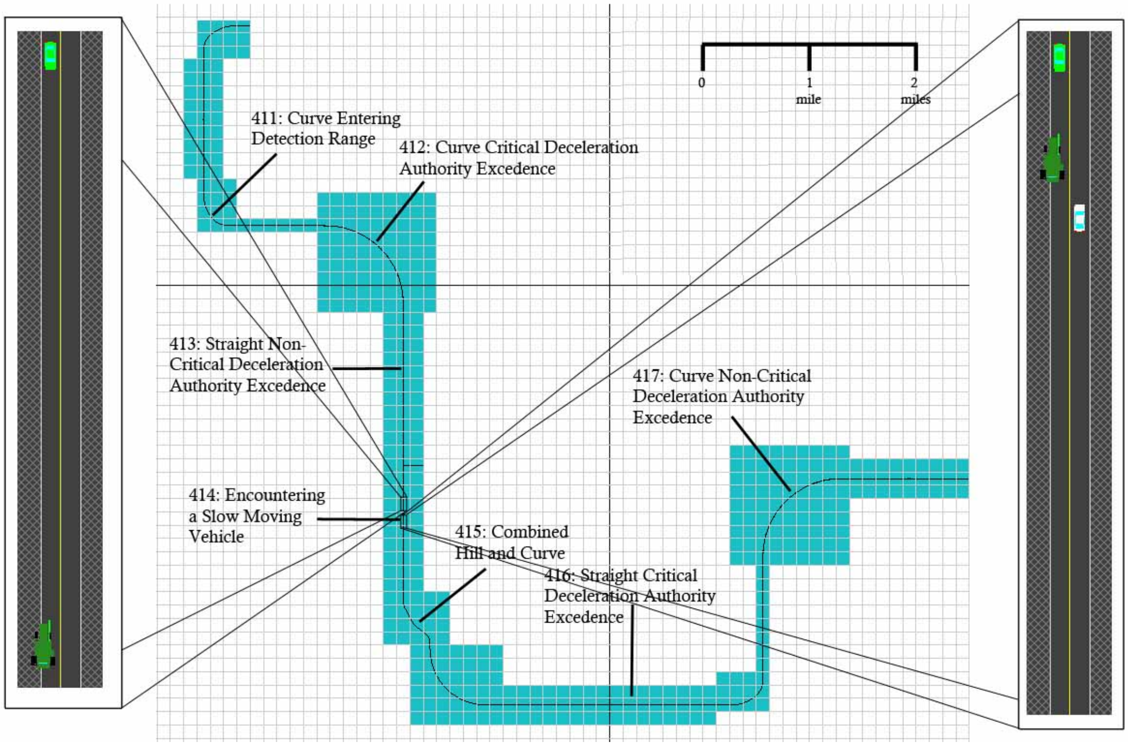


Figure 27: Images of Rural Event 414 Linked to Environment

APPENDIX 31: RURAL EVENT 415: COMBINED HILL AND CURVE

This event will occur in the combined hill and curve present in the rural environment. The participant will follow a lead vehicle that does not change velocity during the event. The detailed information about this event can be seen in Table 26. The timeline for this event can be seen in Table 27. Figure 28 contains images of this event and the environment layout.

Table 26: Rural Event 415 Details

Rural Event 415: Combined Hill and Curve	
ROAD NETWORK REQUIREMENTS	Overall minimum length/distance needed to support event (in feet): 4,000 Road type (lanes, surface): 2 rural driving lanes Speed limit (in mph): 55 Range of speeds accommodated (in mph): 50-70 Curvature: radius 946 ft entering, 1,500 ft during, 600 ft exiting
PREPARATION	The participant is driving in the rural environment and approaches a lead vehicle that is traveling 5 mph below the participant's preset speed, or 55 mph, whichever is lower. This is to allow the lead vehicle and participant to negotiate the curve at a safe speed. Oncoming traffic will be present at a rate of approximately one vehicle per 20 seconds. (The participant is initially traveling between 50 and 70 mph).
START CONDITIONS	The participant is 1,000 feet from the entrance to the curve.
ACTUAL EVENT	Logstream 1 is incremented, logstream 2 is set to 415 The participant enters the curve while the lead vehicle is traveling at 5 mph below the participant's preset speed, or 55 mph, whichever is lower.

Rural Event 415: Combined Hill and Curve			
LOGSTREAM 4	set to 1 when the start condition has been met set to 2 when the participant has entered the curve set to 3 when the participant has exited the curve set to 0 when the end condition has been met		
DEPENDENT MEASURES	Name	Description	Unit
	Minimum Acceleration	The minimum acceleration (maximum deceleration) during the event	meters/second^2
	Maximum Brake Pedal Force	The maximum Force exerted on the brake pedal during the event	newtons
	Adjusted Minimum Time-To-Collision (AMTTC)	The amount of spare time the driver had based on the avoidance response chosen	seconds
	Relative Velocity at Collision	The difference between the participant and lead vehicle velocities at the time of collision	meters/second
	Minimum Time Headway	The minimum time it would take the participant's vehicle to travel the distance between the participant and lead vehicles given the participant vehicle's current velocity during the event	seconds
ASSUMED BEHAVIOR	The participant is assumed to keep the ACC system engaged and not to intervene. Depending on the participant's selected gap setting and speed, the lead vehicle may temporarily leave the ACC system detection region.		
END CONDITIONS	The participant is 1,000 feet past the end of the curve.		

Table 27: Rural Event 415 Distances From Participant's Vehicle to Lead Vehicle

Gap Setting	Participant Vehicle's Velocity	Distance at Logstream 4 = 1	Distance at Logstream 4=2	Distance at Logstream 4 = 3
Short	50	91	73	80
	70	127	78	97
Medium	50	150	127	130
	70	209	141	159
Long	50	223	199	141
	70	313	189	197

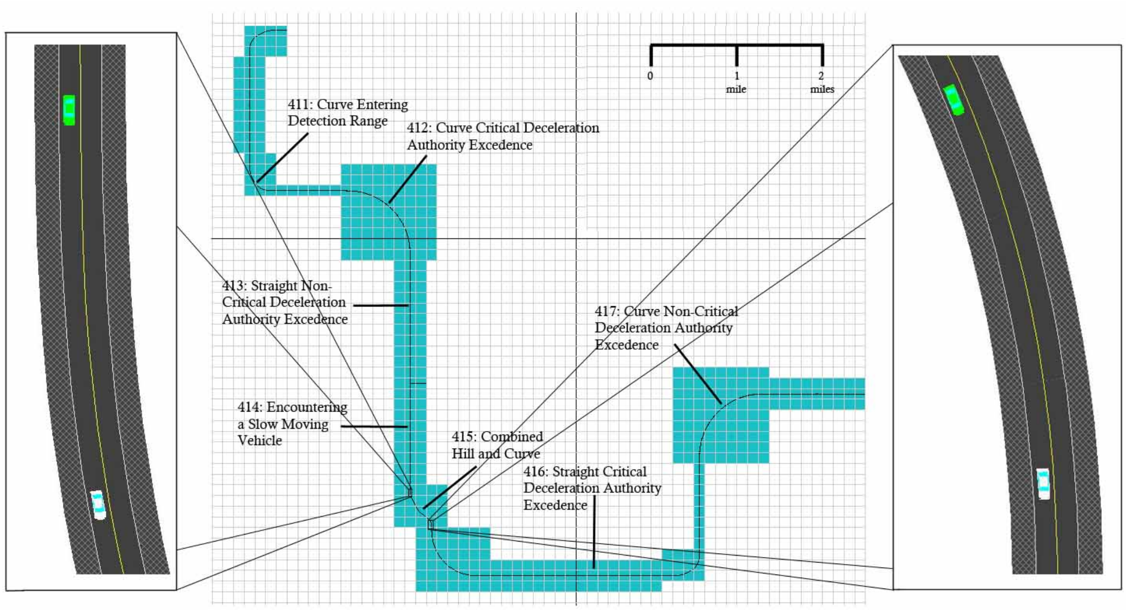


Figure 28: Images of Rural Event 415 Linked to Environment

APPENDIX 32: RURAL EVENT 416: STRAIGHT CRITICAL DECELERATION AUTHORITY EXCEEDANCE

This event will occur in one of the paired straight segments in the rural environment. The participant will follow a lead vehicle that decelerates at a rate that will require the participant's vehicle to exceed the ACC system deceleration authority. The detailed information about this event can be seen in Table 28. The timeline for this event can be seen in Table 29. Figure 29 contains images of this event and the environment layout.

Table 28: Rural Event 416 Details

Rural Event 416: Straight Critical Deceleration Authority Exceedance	
ROAD NETWORK REQUIREMENTS	Overall minimum length/distance needed to support event (in feet): 2,800 Road type (lanes, surface): 2 rural driving lanes Speed limit (in mph): 55 Range of speeds accommodated (in mph): 50-70 Curvature: NA
PREPARATION	The participant is driving in the rural environment with a lead vehicle traveling at the participant's preset speed and time gap. Oncoming traffic will be present at a rate of approximately one vehicle per 10 seconds once the lead vehicle begins decelerating. (The participant is initially traveling between 50 and 70 mph).
START CONDITIONS	The participant is 1,000 feet prior to the point of the lead vehicle deceleration.

Rural Event 416: Straight Critical Deceleration Authority Exceedance			
ACTUAL EVENT	Logstream 1 is incremented, logstream 2 is set to 416 The participant is following a lead vehicle that is traveling at the participant's preset speed and time gap. The lead vehicle decelerates at a rate of 0.4g if the gap setting is set to 1.24s, 0.55g if the gap setting is set to 2.04s, or 0.75g if the gap setting is set to 3.04s. In each case the lead vehicle decelerates until the warning has gone off, the lead vehicle has decelerated down to a velocity of 20 mph, or six seconds have elapsed. The lead vehicle then accelerates at 0.09g until 13.5 seconds have elapsed since it began braking.		
LOGSTREAM 4	set to 1 when the start condition has been met set to 2 when the lead vehicle begins to decelerate set to 3 when the lead vehicle begins to accelerate set to 4 when the lead vehicle has attained its original velocity set to 0 when the end condition has been met		
DEPENDENT MEASURES	Name	Description	Unit
	Steering Response	0 for no steering response; 1 for steering response	binary
	Brake Response	0 for no brake response; 1 for brake response	binary
	Initial Response Time	The time elapsed from when Logstream 4 is set to 3 to when the ACC system has been disengaged	seconds
	Response Time from Alert	The time elapsed from the onset of the deceleration exceedance alert to when the ACC system has been disengaged	seconds
	Minimum Acceleration	The minimum acceleration (maximum deceleration) during the event	meters/s econd^2
	Maximum Brake Pedal Force	The maximum Force exerted on the brake pedal during the event	newtons

Rural Event 416: Straight Critical Deceleration Authority Exceedance			
	Adjusted Minimum Time-To-Collision (AMTTC)	The amount of spare time the driver had based on the avoidance response chosen	seconds
	Relative Velocity at Collision	The difference between the participant and lead vehicle velocities at the time of collision	meters/s econd
	Minimum Time Headway	The minimum time it would take the participant's vehicle to travel the distance between the participant and lead vehicles given the participant vehicle's current velocity during the event	seconds
ASSUMED BEHAVIOR	The participant is assumed to intervene after the ACC deceleration authority exceedance alert has sounded, but before the lead vehicle begins to accelerate. If the participant does not intervene they will not collide with lead vehicle.		
END CONDITIONS	Ten seconds have elapsed since the lead vehicle re-attained the participant's previous speed.		

Table 29: Rural Event 416 Distances From Participant's Vehicle to Lead Vehicle

Gap Setting	Participant Vehicle's Velocity	Distance at Logstream 4 = 1	Distance at Logstream 4=2	Distance at Logstream 4 = 3	Distance at Logstream 4 = 4
Short	50	87	87	38	117
	70	125	125	65	136
Medium	50	144	144	90	170
	70	203	203	126	155
Long	50	214	214	75	140
	70	304	304	219	173

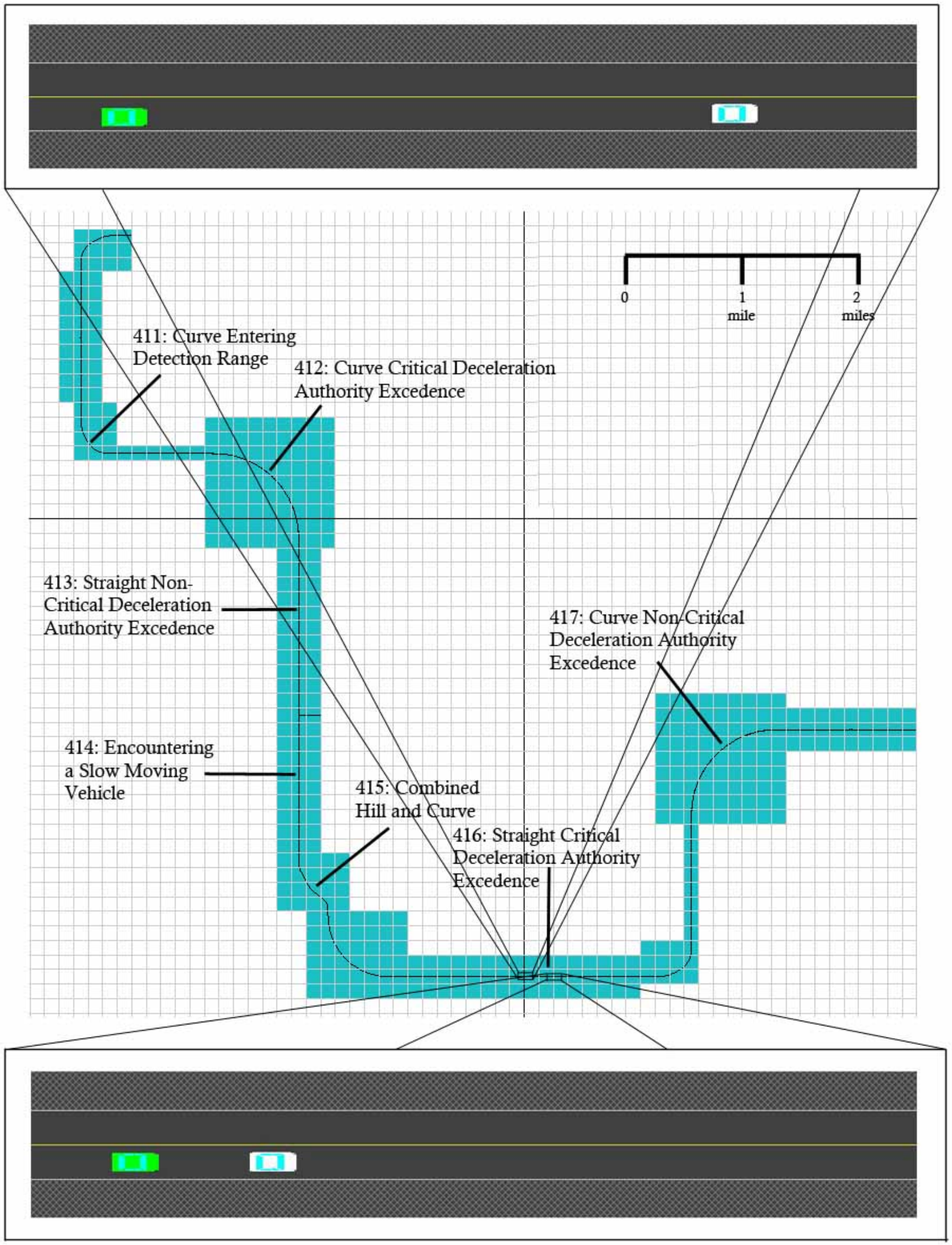


Figure 29: Images of Rural Event 416 Linked to Environment

APPENDIX 33: RURAL EVENT 417: CURVE NON-CRITICAL DECELERATION AUTHORITY EXCEEDANCE

This event will occur in one of the paired large radius curves in the rural environment. The participant will follow a lead vehicle that decelerates at a rate that does not require the participant's vehicle to exceed the ACC system deceleration authority. The detailed information about this event can be seen in Table 30. The timeline for this event can be seen in Table 31. Figure 30 contains images of this event and the environment layout.

Table 30: Rural Event 417 Details

Rural Event 417: Curve Non-Critical Deceleration Authority Exceedance	
ROAD NETWORK REQUIREMENTS	Overall minimum length/distance needed to support event (in feet): straight 2,000, curve 1,200 Road type (lanes, surface): 2 rural driving lanes Speed limit (in mph): 55 Range of speeds accommodated (in mph): 50-70 Curvature: radius of 3,850 ft
PREPARATION	The participant is driving in the rural environment with a lead vehicle traveling at the participant's preset speed and time gap. Oncoming traffic will be present at a rate of approximately one vehicle per 20 seconds. (The participant is initially traveling between 50 and 70 mph).
START CONDITIONS	The participant is 1,000 feet from the entrance to the curve.
ACTUAL EVENT	Logstream 1 is incremented, logstream 2 is set to 417 The participant enters the curve while the lead vehicle is traveling at the participant's preset speed and time gap. Three seconds after the participant has entered the curve the lead vehicle decelerates at a rate of 0.2g for 2.67 seconds, and then accelerates at a rate of 0.09g until the lead vehicle is traveling at the same speed as it was at the onset of the event.

Rural Event 417: Curve Non-Critical Deceleration Authority Exceedance			
LOGSTREAM 4	set to 1 when the start condition has been met set to 2 when the participant has entered the curve set to 3 when the lead vehicle begins to decelerate set to 4 when the lead vehicle begins to accelerate set to 5 when the lead vehicle has attained its original velocity set to 6 when the participant has exited the curve set to 0 when the end condition has been met		
DEPENDENT MEASURES	Name	Description	Unit
	Steering Response	0 for no steering response; 1 for steering response	binary
	Brake Response	0 for no brake response; 1 for brake response	binary
	Initial Response Time	The time elapsed from when Logstream 4 is set to 3 to when the ACC system has been disengaged	seconds
	Minimum Acceleration	The minimum acceleration (maximum deceleration) during the event	meters/second^2
	Maximum Brake Pedal Force	The maximum Force exerted on the brake pedal during the event	newtons
	Adjusted Minimum Time-To-Collision (AMTTC)	The amount of spare time the driver had based on the avoidance response chosen	seconds
	Relative Velocity at Collision	The difference between the participant and lead vehicle velocities at the time of collision	meters/second
	Minimum Time Headway	The minimum time it would take the participant's vehicle to travel the distance between the participant and lead vehicles given the participant vehicle's current velocity during the event	seconds

Rural Event 417: Curve Non-Critical Deceleration Authority Exceedance	
ASSUMED BEHAVIOR	The participant is assumed to allow the ACC system to slow the vehicle and not to intervene. If the participant does not intervene the ACC system deceleration authority will not be exceeded.
END CONDITIONS	The participant is 1,000 feet past the end of the curve.

Table 31: Rural Event 417 Distances From Participant's Vehicle to Lead Vehicle

Gap Setting	Participant Vehicle's Velocity	Distance at Logstream 4 = 1	Distance at Logstream 4=2	Distance at Logstream 4 = 3	Distance at Logstream 4 = 4	Distance at Logstream 4 = 5	Distance at Logstream 4 = 6
Short	50	91	91	91	80	76	91
	70	127	127	127	119	115	127
Medium	50	150	150	150	139	130	150
	70	209	209	209	198	190	209
Long	50	223	223	223	212	203	223
	70	313	313	313	301	285	313

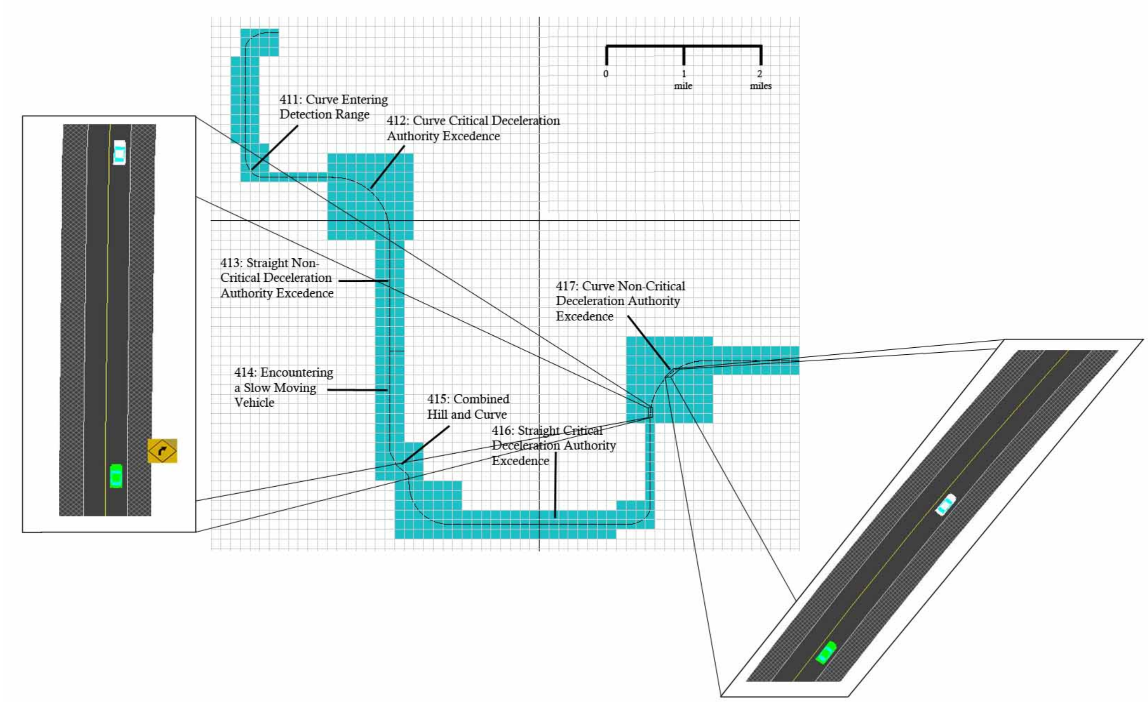


Figure 30: Images of Rural Event 417 Linked to Environment

APPENDIX 34: INTERSTATE EVENT 421: ENTERING AN INTERSTATE WITH A LEAD VEHICLE

This event will be in the transition between the rural and interstate environments. The participant will follow a lead vehicle onto the interstate entrance ramp through a 270 degree turn, and merge onto the interstate. The detailed information about this event can be seen in Table 32. The timeline for this event can be seen in Table 33. Figure 31 contains images of this event and the environment layout.

Table 32: Interstate Event 421 Details

Interstate Event 421: Entering an Interstate With a Lead Vehicle	
ROAD NETWORK REQUIREMENTS	Overall minimum length/distance needed to support event (in feet): 4,000 Road type (lanes, surface): Interstate entrance ramp Speed limit (in mph): 55 prior to the ramp, 35 on the ramp, 65 after the ramp Range of speeds accommodated (in mph): 30-80 Curvature: radius 310 ft entering, 370 ft during, and 302 ft exiting
PREPARATION	The participant is driving in the rural environment with a lead vehicle traveling at the participant's preset speed and time gap. The participant will have recently received instructions to enter the interstate. (The participant is initially traveling between 50 and 70 mph).
START CONDITIONS	The participant is 1,000 feet from interstate entrance ramp.
ACTUAL EVENT	Logstream 1 is incremented, logstream 2 is set to 421 The participant will take the entrance ramp following a lead vehicle. The lead vehicle will be traveling 35 mph through the entrance ramp and may leave the detection region. The participant will continue to follow the lead vehicle, and will merge onto the interstate at the end of the entrance ramp.

Interstate Event 421: Entering an Interstate With a Lead Vehicle			
LOGSTREAM 4	set to 1 when the start condition has been met set to 2 when the participant has entered the entrance ramp set to 3 when the participant has entered the interstate set to 0 when the end condition has been met		
DEPENDENT MEASURES	Name	Description	Unit
	Minimum Acceleration	The minimum acceleration (maximum deceleration) during the event	meters/second^2
	Maximum Brake Pedal Force	The maximum Force exerted on the brake pedal during the event	newtons
	Adjusted Minimum Time-To-Collision (AMTTC)	The amount of spare time the driver had based on the avoidance response chosen	seconds
	Relative Velocity at Collision	The difference between the participant and lead vehicle velocities at the time of collision	meters/second
	Minimum Time Headway	The minimum time it would take the participant's vehicle to travel the distance between the participant and lead vehicles given the participant vehicle's current velocity during the event	seconds
ASSUMED BEHAVIOR	The participant is assumed to allow the ACC system to slow the vehicle and not to disengage while on the rural road. The participant is assumed to allow the ACC system to remain engaged and to slow the vehicle during the entrance ramp.		
END CONDITIONS	The participant is 1,000 feet past the end entrance ramp.		

Table 33: Interstate Event 421 Distances From Participant's Vehicle to Lead Vehicle

Gap Setting	Participant Vehicle's Velocity	Distance at Logstream 4 = 1	Distance at Logstream 4=2	Distance at Logstream 4 = 3
Short	50	89	73	201
	70	119	54	214
Medium	50	147	126	201
	70	197	93	199
Long	50	221	188	209
	70	292	171	204

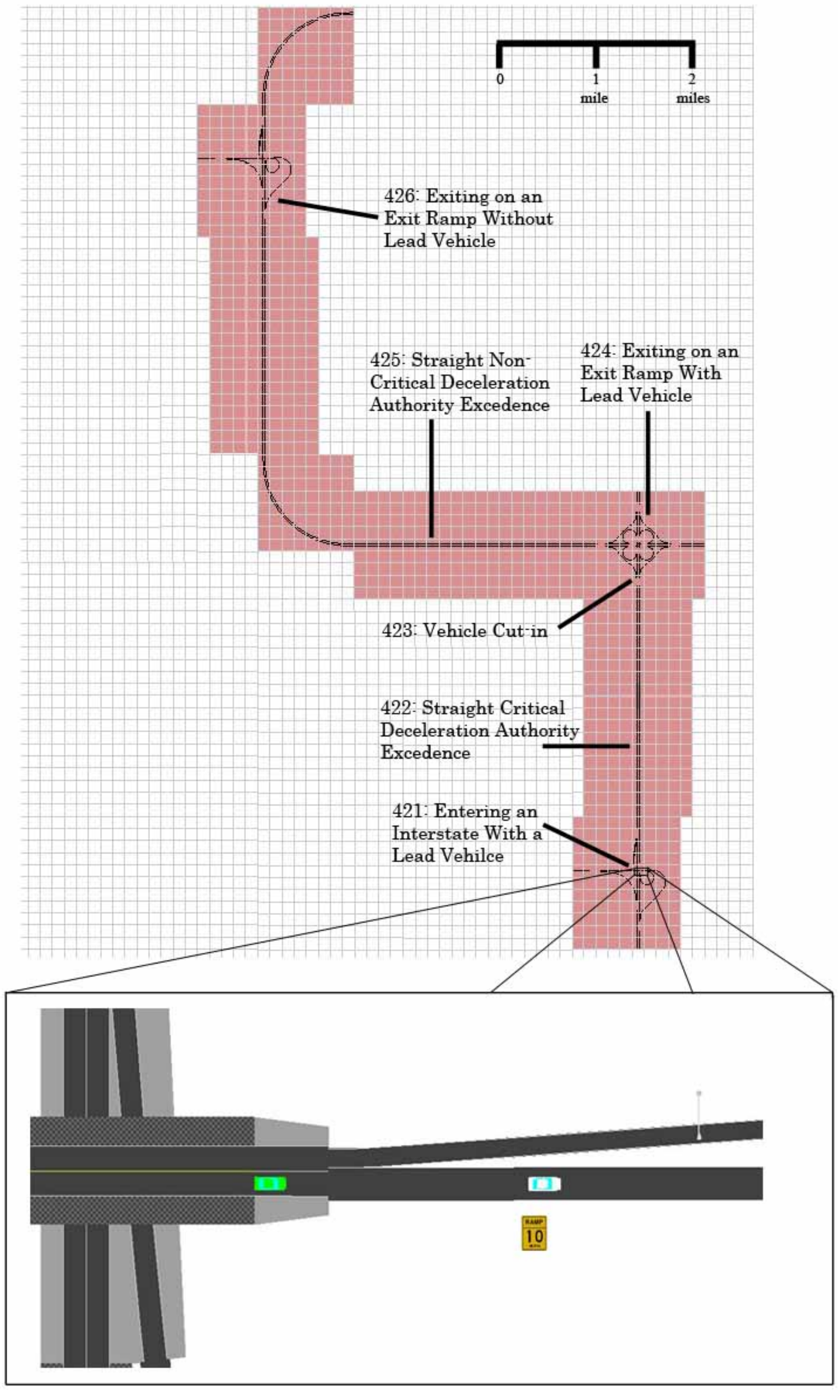


Figure 31: Image of Interstate Event 421 Linked to Environment

APPENDIX 35: INTERSTATE EVENT 422: STRAIGHT CRITICAL DECELERATION AUTHORITY EXCEEDANCE

This event will occur in one of the paired straight segments in the interstate environment. The participant will follow a lead vehicle that decelerates at a rate that will require the participant's vehicle to exceed the ACC system deceleration authority. The detailed information about this event can be seen in Table 34. The timeline for this event can be seen in Table 35. Figure 32 contains images of this event and the environment layout.

Table 34: Interstate Event 422 Details

Interstate Event 422: Straight Critical Deceleration Authority Exceedance	
ROAD NETWORK REQUIREMENTS	Overall minimum length/distance needed to support event (in feet): 3,000 Road type (lanes, surface): 4 interstate driving lanes Speed limit (in mph): 65 Range of speeds accommodated (in mph): 60-80 Curvature: NA
PREPARATION	The participant is driving in the interstate environment with a lead vehicle traveling at the participant's preset speed and time gap. Vehicles will be present in the adjacent lane, traveling faster than the participant with small gaps between vehicles, discouraging the participant from changing lanes around the lead vehicle during the event. (The participant is initially traveling between 60 and 80 mph).
START CONDITIONS	The participant is 1,000 feet prior to the point of the lead vehicle deceleration.

Interstate Event 422: Straight Critical Deceleration Authority Exceedance	
ACTUAL EVENT	Logstream 1 is incremented, logstream 2 is set to 422 The participant is following a lead vehicle that is traveling at the participant's preset speed and time gap. The lead vehicle decelerates at a rate of 0.4g if the gap setting is set to 1.24s, 0.55g if the gap setting is set to 2.04s, or 0.75g if the gap setting is set to 3.04s. In each case the lead vehicle decelerates until the warning has gone off, the lead vehicle has decelerated down to a velocity of 20 mph, or six seconds have elapsed. The lead vehicle then accelerates at 0.09g until 13.5 seconds have elapsed since it began braking. The vehicles in the adjacent lane continue to travel faster than the participant.
LOGSTREAM 4	set to 1 when the start condition has been met set to 2 when the lead vehicle begins to decelerate set to 3 when the lead vehicle begins to accelerate set to 4 when the lead vehicle has attained its original velocity set to 0 when the end condition has been met

DEPENDENT MEASURES	Name	Description	Unit
	Steering Response	0 for no steering response; 1 for steering response	binary
	Brake Response	0 for no brake response; 1 for brake response	binary
	Initial Response Time	The time elapsed from when Logstream 4 is set to 3 to when the ACC system has been disengaged	seconds
	Response Time from Alert	The time elapsed from the onset of the deceleration exceedance alert to when the ACC system has been disengaged	seconds
	Minimum Acceleration	The minimum acceleration (maximum deceleration) during the event	meters/second^2
	Maximum Brake Pedal Force	The maximum Force exerted on the brake pedal during the event	newtons

Interstate Event 422: Straight Critical Deceleration Authority Exceedance			
	Adjusted Minimum Time-To-Collision (AMTTC)	The amount of spare time the driver had based on the avoidance response chosen	seconds
	Relative Velocity at Collision	The difference between the participant and lead vehicle velocities at the time of collision	meters/second
	Minimum Time Headway	The minimum time it would take the participant's vehicle to travel the distance between the participant and lead vehicles given the participant vehicle's current velocity during the event	seconds
ASSUMED BEHAVIOR	The participant is assumed to intervene after the ACC deceleration authority exceedance alert has sounded, but before the lead vehicle begins to accelerate. If the participant does not intervene they will not collide with lead vehicle.		
END CONDITIONS	Ten seconds have elapsed since the lead vehicle re-attained the participant's previous speed.		

Table 35: Interstate Event 422 Distances From Participant's Vehicle to Lead Vehicle

Gap Setting	Participant Vehicle's Velocity	Distance at Logstream 4 = 1	Distance at Logstream 4=2	Distance at Logstream 4 = 3	Distance at Logstream 4 = 4
Short	60	109	109	52	126
	80	145	145	64	128
Medium	60	180	180	109	139
	80	239	239	141	156
Long	60	268	268	189	185
	80	356	356	253	184

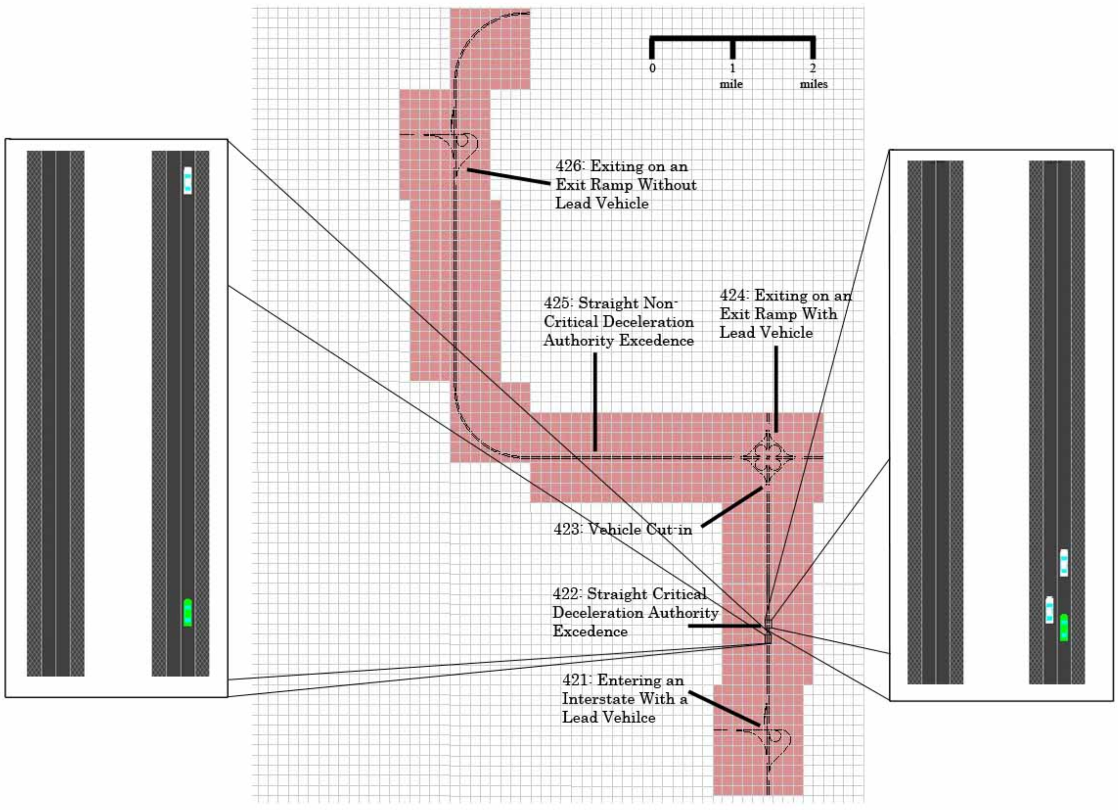


Figure 32: Images of Interstate Event 422 Linked to Environment

APPENDIX 36: INTERSTATE EVENT 423: VEHICLE CUT-IN

This event will occur in the interstate environment shortly before the participant takes the first interstate exit. The participant will be following a lead vehicle, and a vehicle in the adjacent lane will pull in front of the participant, behind the lead vehicle, and exit from the interstate. The detailed information about this event can be seen in Table 36. The timeline for this event can be seen in Table 37. Figure 33 contains images of this event and the environment layout. The cut-in vehicle's path is indicated with yellow arrows.

Table 36: Interstate Event 423 Details

Interstate Event 423: Vehicle Cut-in	
ROAD NETWORK REQUIREMENTS	Overall minimum length/distance needed to support event (in feet): 4,000 Road type (lanes, surface): 4 interstate driving lanes Speed limit (in mph): 65 Range of speeds accommodated (in mph): 60-80 Curvature: NA
PREPARATION	The participant is driving in the interstate environment with a lead vehicle traveling at the participant's preset speed and time gap. The participant will be instructed to take the second exit from the interstate. (The participant is initially traveling between 60 and 80 mph).
START CONDITIONS	The participant is 2,000 feet from the point where the vehicle cut-in occurs.
ACTUAL EVENT	Logstream 1 is incremented, logstream 2 is set to 423 The participant is following a lead vehicle and approaching the exit to the interstate. A vehicle in the adjacent lane will change lanes, cutting in front of the participant 50 feet behind the lead vehicle, traveling at the same speed as the participant. The cut-in vehicle will initiate the lane change 760 feet before the interstate exit ramp. At 260 feet prior to the exit ramp the cut-in vehicle will decelerate at 0.5g for 2.1 seconds, and then exit the interstate via the exit ramp. The participant will continue on the interstate, and take the next exit.

<table>
<tr><th colspan="4">Interstate Event 423: Vehicle Cut-in</th></tr>
<tr><td>LOGSTREAM 4</td><td colspan="3">set to 1 when the start condition has been met
set to 2 when the cut-in vehicle begins moving towards the participant's travel lane
set to 3 when the cut-in vehicle begins to exit onto the exit ramp
set to 4 when the cut-in vehicle has left the detection range
set to 0 when the end condition has been met</td></tr>
<tr><td rowspan="9">DEPENDENT MEASURES</td><td>Name</td><td>Description</td><td>Unit</td></tr>
<tr><td>Steering Response</td><td>0 for no steering response;
1 for steering response</td><td>binary</td></tr>
<tr><td>Brake Response</td><td>0 for no brake response;
1 for brake response</td><td>binary</td></tr>
<tr><td>Initial Response Time</td><td>The time elapsed from when Logstream 4 is set to 3 to when the ACC system has been disengaged</td><td>seconds</td></tr>
<tr><td>Response Time from Alert</td><td>The time elapsed from the onset of the deceleration exceedance alert to when the ACC system has been disengaged</td><td>seconds</td></tr>
<tr><td>Minimum Acceleration</td><td>The minimum acceleration (maximum deceleration) during the event</td><td>meters/second^2</td></tr>
<tr><td>Maximum Brake Pedal Force</td><td>The maximum Force exerted on the brake pedal during the event</td><td>newtons</td></tr>
<tr><td>Adjusted Minimum Time-To-Collision (AMTTC)</td><td>The amount of spare time the driver had based on the avoidance response chosen</td><td>seconds</td></tr>
<tr><td>Relative Velocity at Collision</td><td>The difference between the participant and lead vehicle velocities at the time of collision</td><td>meters/second</td></tr>
</table>

Interstate Event 423: Vehicle Cut-in			
	Minimum Time Headway	The minimum time it would take the participant's vehicle to travel the distance between the participant and lead vehicles given the participant vehicle's current velocity during the event	seconds
ASSUMED BEHAVIOR	The participant is assumed to allow ACC system to slow the vehicle and not to intervene		
END CONDITIONS	The participant is 1,000 feet past the interstate exit ramp entrance.		

Table 37: Interstate Event 423 distances from participant's vehicle to the closest of the lead vehicle or the cut-in vehicle

Gap Setting	Participant Vehicle's Velocity	Distance at Logstream 4 = 1	Distance at Logstream 4=2	Distance at Logstream 4 = 3	Distance at Logstream 4 = 4
Short	60	60	60	26	296
	80	60	60	38	339
Medium	60	60	60	72	405
	80	60	60	51	502
Long	60	60	60	39	510
	80	60	60	84	506

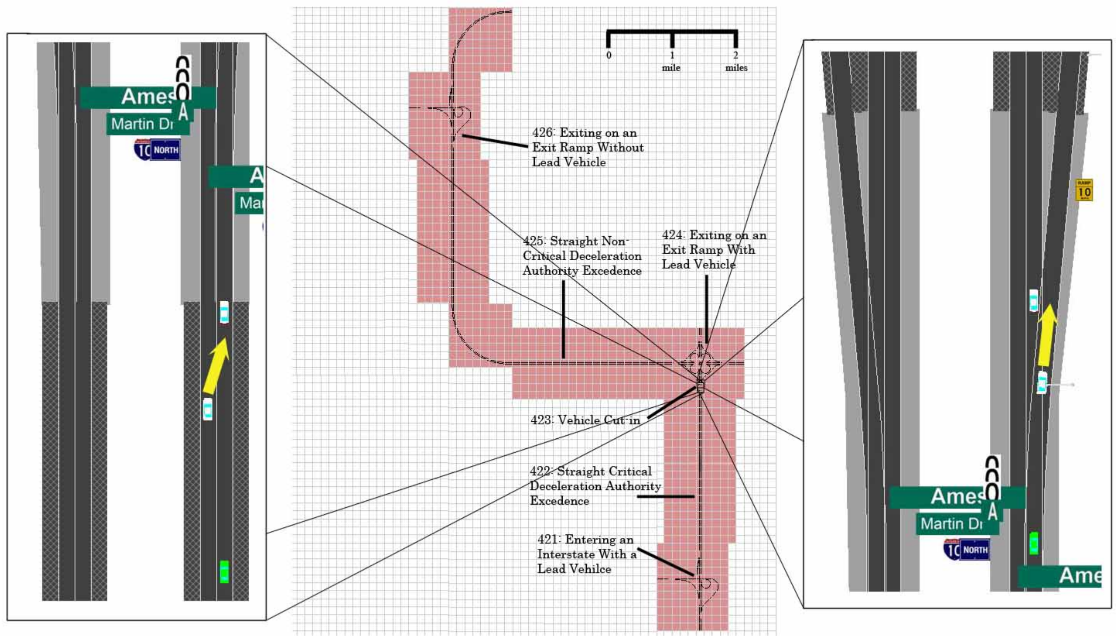


Figure 33: Images of Interstate Event 423 Linked to Environment

APPENDIX 37: INTERSTATE EVENT 424: EXITING ON AN EXIT RAMP WITH A LEAD VEHICLE

This event will be in the interstate environment. This event will be similar to Event 21, except that the participant will transition between two interstate roads in this event, rather than a rural road to an interstate as in Event 21. The participant will be in the right lane, and will follow a lead vehicle onto the exit ramp through a 270 degree turn, and merge onto another interstate. The detailed information about this event can be seen in Table 38. The timeline for this event can be seen in Table 39. Figure 34 contains images of this event and the environment layout.

Table 38: Interstate Event 424 Details

Interstate Event 424: Exiting on an Exit Ramp With a Lead Vehicle	
ROAD NETWORK REQUIREMENTS	Overall minimum length/distance needed to support event (in feet): 4,000 Road type (lanes, surface): Interstate exit ramp Speed limit (in mph): 65 prior to the ramp, 35 on the ramp, 65 after the ramp Range of speeds accommodated (in mph): 30-80 Curvature: radius 321 ft entering, 400 ft during, and 300 ft exiting
PREPARATION	The participant is driving in the interstate environment with a lead vehicle traveling at the participant's preset speed and time gap. The participant will have recently received instructions to exit on the exit ramp. (The participant is initially traveling between 60 and 80 mph).
START CONDITIONS	The participant is 1,000 feet from interstate exit ramp.
ACTUAL EVENT	Logstream 1 is incremented, logstream 2 is set to 424 The participant will take the exit ramp following a lead vehicle. The lead vehicle will be traveling 35 mph through the exit ramp and may leave the detection region. The participant will continue to follow the lead vehicle, and will merge onto the next interstate at the end of the exit ramp.

<table>
<tr><th colspan="4">Interstate Event 424: Exiting on an Exit Ramp With a Lead Vehicle</th></tr>
<tr><td>LOGSTREAM 4</td><td colspan="3">set to 1 when the start condition has been met
set to 2 when the participant has entered the exit ramp
set to 3 when the participant has entered the interstate
set to 0 when the end condition has been met</td></tr>
<tr><td rowspan="6">DEPENDENT MEASURES</td><td>Name</td><td>Description</td><td>Unit</td></tr>
<tr><td>Minimum Acceleration</td><td>The minimum acceleration (maximum deceleration) during the event</td><td>meters/second^2</td></tr>
<tr><td>Maximum Brake Pedal Force</td><td>The maximum Force exerted on the brake pedal during the event</td><td>newtons</td></tr>
<tr><td>Adjusted Minimum Time-To-Collision (AMTTC)</td><td>The amount of spare time the driver had based on the avoidance response chosen</td><td>seconds</td></tr>
<tr><td>Relative Velocity at Collision</td><td>The difference between the participant and lead vehicle velocities at the time of collision</td><td>meters/second</td></tr>
<tr><td>Minimum Time Headway</td><td>The minimum time it would take the participant's vehicle to travel the distance between the participant and lead vehicles given the participant vehicle's current velocity during the event</td><td>seconds</td></tr>
<tr><td>ASSUMED BEHAVIOR</td><td colspan="3">The participant is assumed to allow the ACC system to slow the vehicle and not to disengage while on the interstate. The participant is assumed to allow the ACC system to remain engaged and to slow the vehicle during the exit ramp.</td></tr>
<tr><td>END CONDITIONS</td><td colspan="3">The participant is 1,000 feet past the end exit ramp.</td></tr>
</table>

Table 39: Interstate Event 424 distances from participant's vehicle to the lead vehicle

Gap Setting	Participant Vehicle's Velocity	Distance at Logstream 4 = 1	Distance at Logstream 4=2	Distance at Logstream 4 = 3
Short	60	248	136	94
	80	341	98	115
Medium	60	362	250	106
	80	490	205	141
Long	60	441	145	155
	80	330	200	192

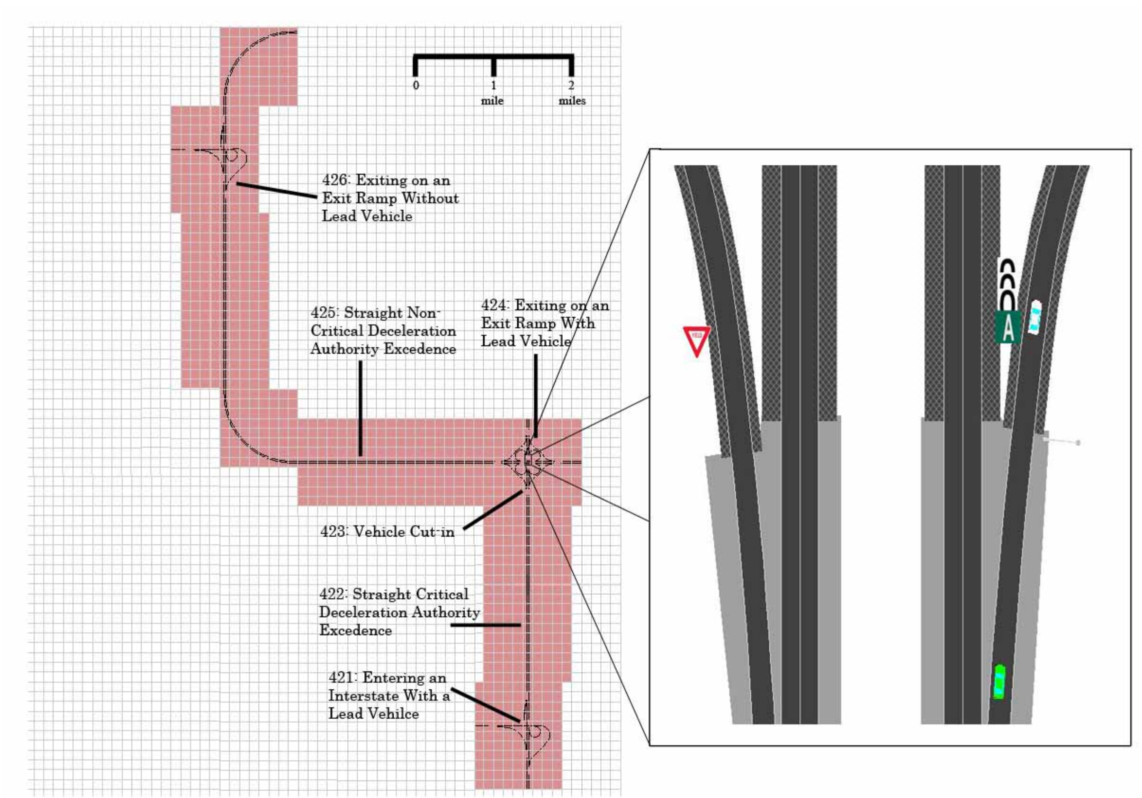


Figure 34: Image of Interstate Event 424 Linked to Environment

APPENDIX 38: INTERSTATE EVENT 425: STRAIGHT NON-CRITICAL DECELERATION AUTHORITY EXCEEDANCE

This event will occur in one of the paired straight segments in the interstate environment. The participant will follow a lead vehicle that decelerates at a rate that does not require the participant's vehicle to exceed the ACC system deceleration authority. The detailed information about this event can be seen in Table 40. The timeline for this event can be seen in Table 41. Figure 35 contains images of this event and the environment layout.

Table 40: Interstate Event 425 Details

Interstate Event 425: Straight Non-Critical Deceleration Authority Exceedance	
ROAD NETWORK REQUIREMENTS	Overall minimum length/distance needed to support event (in feet): 2,800 Road type (lanes, surface): 4 interstate driving lanes Speed limit (in mph): 65 Range of speeds accommodated (in mph): 60-80 Curvature: NA
PREPARATION	The participant is driving in the interstate environment with a lead vehicle traveling at the participant's preset speed and time gap. A vehicle will be present in the adjacent lane, traveling faster than the participant, discouraging the participant from changing lanes around the lead vehicle during the event. (The participant is initially traveling between 60 and 80 mph).
START CONDITIONS	The participant is 1,000 feet prior to the point of the lead vehicle deceleration.
ACTUAL EVENT	Logstream 1 is incremented, logstream 2 is set to 425 The participant is following a lead vehicle that is traveling at the participant's preset speed and time gap. The lead vehicle decelerates at a rate of 0.2g for 2.67 seconds, and then accelerates at a rate of 0.09g until the lead vehicle is traveling at the same speed as it was at the onset of the event. The vehicles in the adjacent lane continue to travel at their initial speeds.

<table>
<tr><th colspan="4">Interstate Event 425: Straight Non-Critical Deceleration Authority Exceedance</th></tr>
<tr><td>LOGSTREAM 4</td><td colspan="3">set to 1 when the start condition has been met
set to 2 when the lead vehicle begins to decelerate
set to 3 when the lead vehicle begins to accelerate
set to 4 when the lead vehicle has attained its original velocity
set to 0 when the end condition has been met</td></tr>
<tr><td rowspan="9">DEPENDENT MEASURES</td><td>Name</td><td>Description</td><td>Unit</td></tr>
<tr><td>Steering Response</td><td>0 for no steering response;
1 for steering response</td><td>binary</td></tr>
<tr><td>Brake Response</td><td>0 for no brake response;
1 for brake response</td><td>binary</td></tr>
<tr><td>Initial Response Time</td><td>The time elapsed from when Logstream 4 is set to 3 to when the ACC system has been disengaged</td><td>seconds</td></tr>
<tr><td>Minimum Acceleration</td><td>The minimum acceleration (maximum deceleration) during the event</td><td>meters/second^2</td></tr>
<tr><td>Maximum Brake Pedal Force</td><td>The maximum Force exerted on the brake pedal during the event</td><td>newtons</td></tr>
<tr><td>Adjusted Minimum Time-To-Collision (AMTTC)</td><td>The amount of spare time the driver had based on the avoidance response chosen</td><td>seconds</td></tr>
<tr><td>Relative Velocity at Collision</td><td>The difference between the participant and lead vehicle velocities at the time of collision</td><td>meters/second</td></tr>
<tr><td>Minimum Time Headway</td><td>The minimum time it would take the participant’s vehicle to travel the distance between the participant and lead vehicles given the participant vehicle’s current velocity during the event</td><td>seconds</td></tr>
<tr><td>ASSUMED BEHAVIOR</td><td colspan="3">The participant is assumed to allow the ACC system to slow the vehicle and not to intervene. If the participant does not intervene the ACC system deceleration authority will not be exceeded.</td></tr>
</table>

Interstate Event 425: Straight Non-Critical Deceleration Authority Exceedance	
END CONDITIONS	Ten seconds have elapsed since the lead vehicle has re-attained the participant's previous speed.

Table 41: Interstate Event 425 Distances From Participant's Vehicle to Lead Vehicle

Gap Setting	Participant Vehicle's Velocity	Distance at Logstream 4 = 1	Distance at Logstream 4=2	Distance at Logstream 4 = 3	Distance at Logstream 4 = 4
Short	60	109	109	98	96
	80	145	145	138	138
Medium	60	180	180	169	167
	80	239	239	231	231
Long	60	268	268	256	253
	80	356	356	346	344

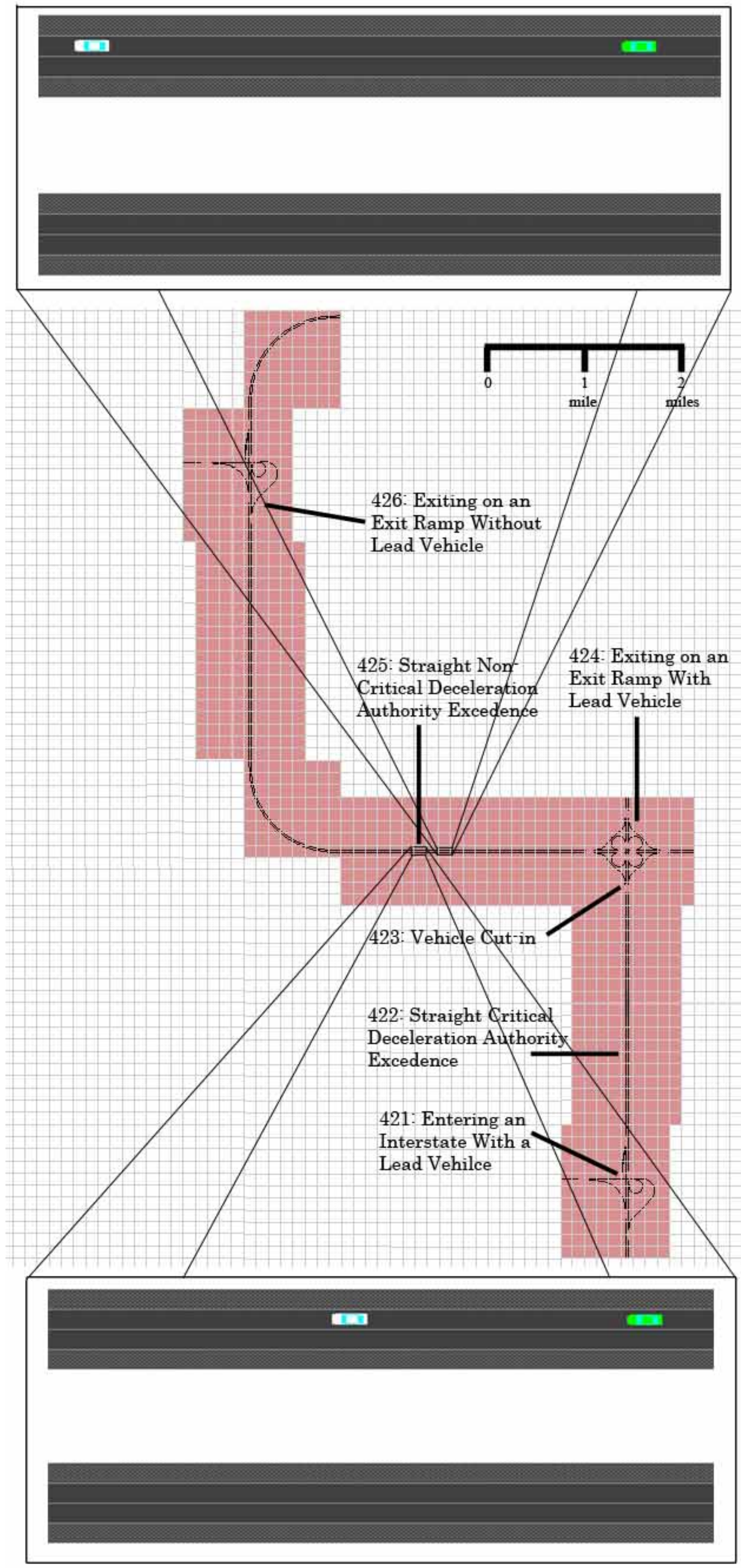


Figure 35: Images of Interstate Event 425 Linked to Environment

APPENDIX 39: INTERSTATE EVENT 426: EXITING ON AN EXIT RAMP WITHOUT A LEAD VEHICLE

This event will occur at the end of the interstate environment. The participant will be in the right lane, following several vehicles that are driving below the participant's preset speed, and will exit onto the exit ramp. No other vehicles will exit the interstate. The detailed information about this event can be seen in Table 42. The timeline for this event can be seen in Table 43. Figure 36 contains images of this event and the environment layout.

Table 42: Interstate Event 426 Details

Interstate Event 426: Exiting on an Exit Ramp Without a Lead Vehicle	
ROAD NETWORK REQUIREMENTS	Overall minimum length/distance needed to support event (in feet): 7,500 Road type (lanes, surface): Interstate exit ramp Speed limit (in mph): 65 prior to the ramp, 45 on the ramp, 45 after the ramp Range of speeds accommodated (in mph): 30-80 Curvature: radius of 985 ft entering, 664 ft exiting
PREPARATION	The participant is driving in right lane the interstate environment with a lead vehicle traveling at the participant's preset speed and time gap. The participant will have recently received instructions to exit on the next exit ramp. Traffic will be present in the both lanes. Several lead vehicles will be in front of the participant. (The participant is initially traveling between 60 and 80 mph).
START CONDITIONS	The participant is 5,000 feet from interstate exit ramp.
ACTUAL EVENT	Logstream 1 is incremented, logstream 2 is set to 426 The participant will be following a number of vehicles that decelerate at a rate of 0.1g until they are traveling at 50 mph. Traffic in the left lane will pass the participant and lead vehicles. The participant will take the exit ramp with no lead vehicles present and continue onto the next roadway. No other vehicles will take the exit ramp.

Interstate Event 426: Exiting on an Exit Ramp Without a Lead Vehicle			
LOGSTREAM 4	set to 1 when the start condition has been met set to 2 when the participant has entered the exit ramp set to 3 when the participant has reached the has entered the next roadway set to 0 when the end condition has been met		
DEPENDENT MEASURES	Name	Description	Unit
	Minimum Acceleration	The minimum acceleration (maximum deceleration) during the event	meters/second^2
	Maximum Brake Pedal Force	The maximum Force exerted on the brake pedal during the event	newtons
	Adjusted Minimum Time-To-Collision (AMTTC)	The amount of spare time the driver had based on the avoidance response chosen	seconds
	Relative Velocity at Collision	The difference between the participant and lead vehicle velocities at the time of collision	meters/second
	Minimum Time Headway	The minimum time it would take the participant's vehicle to travel the distance between the participant and lead vehicles given the participant vehicle's current velocity during the event	seconds
ASSUMED BEHAVIOR	The participant is assumed to allow the ACC system to slow the vehicle and not to disengage while on the interstate. The participant is assumed to have ACC engaged, with a higher preset speed when they enter the exit ramp. The ACC system will begin to increase the participant vehicle's speed until the participant disengages the ACC system. The participant will then continue onto the next roadway, and re-engage ACC.		
END CONDITIONS	The participant is 1,000 feet past the end exit ramp.		

Table 43: Interstate Event 426 Distances From Participant's Vehicle to Lead Vehicle

Gap Setting	Participant Vehicle's Velocity	Distance at Logstream 4 = 1	Distance at Logstream 4=2	Distance at Logstream 4 = 3
Short	60	91	91	NA
	80	45	91	NA
Medium	60	145	146	NA
	80	89	150	NA
Long	60	217	217	NA
	80	142	223	NA

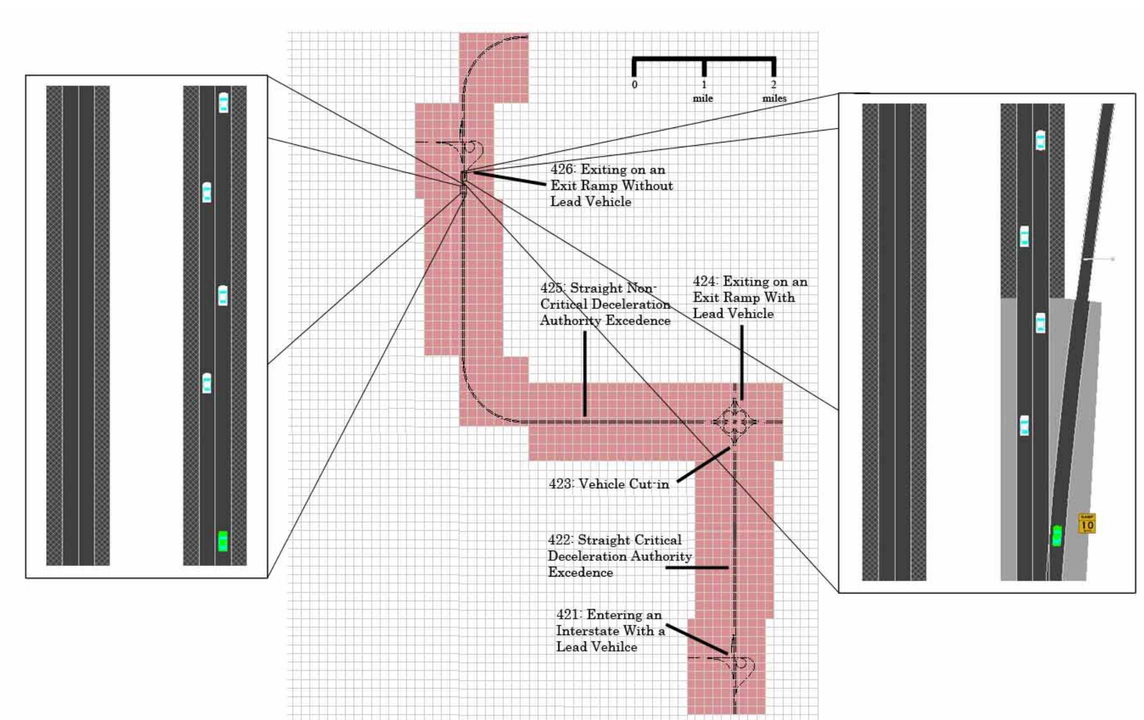


Figure 36: Images of Interstate Event 426 Linked to Environment

APPENDIX 40: RESIDENTIAL EVENT 431: ENCOUNTERING A STOPPED VEHICLE

This event will occur in residential environment. The participant will encounter a vehicle that is stopped in the middle of the roadway. This will be the final event of the drive. The detailed information about this event can be seen in Table 44. The timeline for this event can be seen in Table 45. Figure 37 contains images of this event and the environment layout.

Table 44: Residential Event 431 Details

Residential Event 431: Encountering a Stopped Vehicle			
ROAD NETWORK REQUIREMENTS	Overall minimum length/distance needed to support event (in feet): 3,500 Road type (lanes, surface): 2 residential driving lanes Speed limit (in mph): 30 Range of speeds accommodated (in mph): 25-45 Curvature: radius of 1,500 ft		
PREPARATION	The participant is driving in the residential environment with no lead vehicle present. (The participant is initially traveling between 25 and 45 mph).		
START CONDITIONS	The participant is 3,000 feet from the stopped vehicle.		
ACTUAL EVENT	Logstream 1 is incremented, logstream 2 is set to 431 The participant will be traveling down the residential roadway, and will encounter a vehicle that is stopped in the roadway. Oncoming traffic will be present such that the participant is not able to pass the stopped vehicle without decelerating.		
LOGSTREAM 4	set to 1 when the start condition has been met set to 2 when the stopped vehicle is first visible set to 3 when the participant is within 100 feet of the stopped vehicle set to 0 when the end condition has been met		
DEPENDENT	Name	Description	Unit

Residential Event 431: Encountering a Stopped Vehicle			
MEASURES	Steering Response	0 for no steering response; 1 for steering response	binary
	Brake Response	0 for no brake response; 1 for brake response	binary
	Initial Response Time	The time elapsed from when Logstream 4 is set to 3 to when the ACC system has been disengaged	seconds
	Minimum Acceleration	The minimum acceleration (maximum deceleration) during the event	meters/second^2
	Maximum Brake Pedal Force	The maximum Force exerted on the brake pedal during the event	newtons
	Adjusted Minimum Time-To-Collision (AMTTC)	The amount of spare time the driver had based on the avoidance response chosen	seconds
	Relative Velocity at Collision	The difference between the participant and lead vehicle velocities at the time of collision	meters/second
	Minimum Time Headway	The minimum time it would take the participant's vehicle to travel the distance between the participant and lead vehicles given the participant vehicle's current velocity during the event	seconds
	Response to Stopped Vehicle	0 for AMTTC to the stopped vehicle greater than 2.75 seconds before the end of the first response; 1 for AMTTC to the stopped vehicle less than 2.75 seconds before the end of the first response;	binary
ASSUMED BEHAVIOR	The ACC system will not detect the stopped vehicle. The participant is assumed to disengage the ACC system and slow down, passing the stopped vehicle when a sufficient gap in the oncoming lane is present.		

Residential Event 431: Encountering a Stopped Vehicle	
END CONDITIONS	The participant has stopped before, collided with, or passed the stopped vehicle.

Table 45: Residential Event 431 Distances From Participant's Vehicle to Lead Vehicle

Gap Setting	Participant Vehicle's Velocity	Distance at Logstream 4 = 1	Distance at Logstream 4=2	Distance at Logstream 4 = 3
Short	25	3000	777	100
	45	3000	777	100
Medium	25	3000	777	100
	45	3000	777	100
Long	25	3000	777	100
	45	3000	777	100

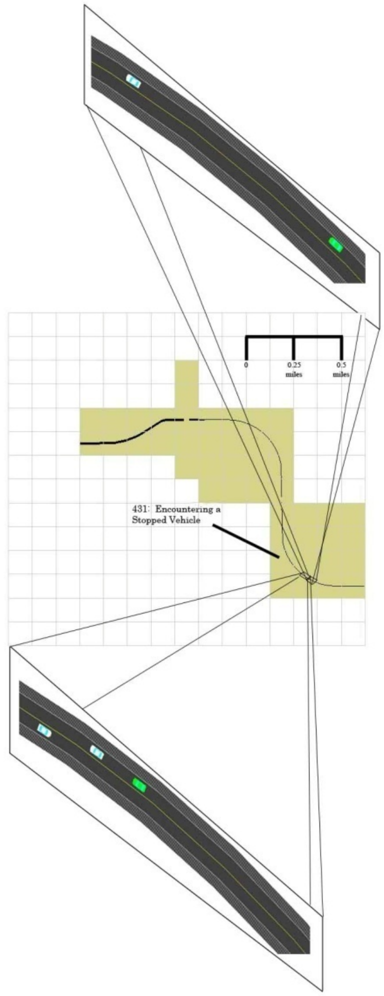


Figure 37: Images of Residential Event 431 Linked to Environment

APPENDIX 41: COUNTERMEASURE DATA

Table 46: Subject-identified ACC Problems and Countermeasures

Problem	Possible Countermeasure	Occurrences
Doesn't work in rain	different location for sensor	8
Accelerates too rapidly	More gradual acceleration	4
Cars pull into the gap in front of you	Switch to CCC. Decrease following distance	4
No warning if LV gradually slows down	Provide warning	3
Display is hard to see, poorly placed	Make brighter, move higher on dash	3
Speed adjustment too coarse	Allow 1 mph increments	2
Doesn't work in snow	Different location for sensor	2
Doesn't work in bright sun		2
Picks up cars in the next lane	Narrow the beam of the laser	2
Brakes too rapidly	Better note closing speed to prevent overbraking	1
Brakes too slowly	Manually apply brakes	1
Works intermittently in fog		1
Sensors damaged by rock chips	Different location for sensor	1
Forget that it's not there when change cars		1
Doesn't work at slower speeds		1
Following distance setting too coarse	Allow more gap choices	1
Difficult to switch from ACC to CCC		1
White lines cause false positive warnings	Redirect laser?	1
Don't feel that the shorter gap settings are safe	Only use longest gap setting	1
Sometimes system 'errors out'	Switch to CCC	1
At higher speeds, system reacts to LVs too far out		1
Poor front detection. Does not alert	More sensitive laser, redirect laser?	1
Doesn't work with dirty car	Wash car more often	1

APPENDIX 42: ADJUSTED TIME TO COLLISION AND MINIMUM TIME HEADWAY VALUES FOR EACH ERROR CASE

Participant Number	Event Number	Error	Minimum Time Headway	Adjusted Minimum Time to Collision
MN101	415	2	2.027764	18.36624
MN101		2	2.969809	915.1887
MN101	415	3	2.027764	18.36624
MN103	411	2	2.805766	20.77732
MN103		2	2.970037	583.8945
MN105	415	2	1.978927	16.54045
MN105		2	2.986936	285.1178
MN105	415	3	1.978927	16.54045
MN106	415	2	2.398108	37.47812
MN106	424	2	3.216357	31.95855
MN106	415	3	2.398108	37.47812
MN108		2	2.939647	42.35879
MN109		2	2.959459	473.2904
MN111	431	4	0.005947	0.005946
MN112	416	1	1.896247	3.888625
MN112	423	1	0.416139	2.904488
MN112	415	2	2.974063	233.7845
MN112		2	2.960967	37678.05
MN112	415	3	2.974063	233.7845
MN112	431	4	2.002662	2.002571
MN113		2	2.970425	605.7203
MN114		2	2.957779	739.812
MN118		2	2.96964	800.7197
MN120	415	2	15.14529	22.30699

Participant Number	Event Number	Error	Minimum Time Headway	Adjusted Minimum Time to Collision
MN121	431	4	2.675529	2.675408
MN139		2	1.614571	28.0832
MN139	411	2	2.58207	18.8564
MN140	411	2	2.61443	19.62685
MN141		2	2.969802	836.5852
MN148	415	2	2.92094	17.20712

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