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16. Abstract
This document presents methods and results for the Naturalistic Study of Level 2 Driving Automation Functions (L2 NDS). The objective of the L2 NDS project was to investigate, through a naturalistic driving study (NDS), real-world driver interaction with commercially available driving automation systems. Ten vehicles equipped with both lateral and longitudinal automated features were instrumented and loaned to participants for a 4-week period. A total of 120 drivers were recruited over a 14-month data collection period. Participants drove 216,585 miles, with 70,384 miles driven with both lateral and longitudinal control features active. Drivers were observed engaging in non-driving tasks, but these were not related to feature use. Driver behavior was consistent with active driving/supervision of the automated features; drivers were receptive to Request to Intervene (RTI) alerts. No RTIs were associated with any Safety-Critical Events (SCEs; Crashes and Near-Crashes). In total, 5 minor crashes (no injury or visible damage) and 66 near-crashes were observed across the entire data set. No statistical relationship was observed between SCE rates and feature activation level. A sub-study specifically focused on longer drives was also conducted. Results observed in the sub-study were similar to those observed in the broader NDS. Implications per the study research questions are presented herein. Comparisons to related research studies and limitations of the current research effort are also discussed.

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Executive Summary

The objective of the Naturalistic Study of Level 2 Driving Automation Functions (L2 NDS) project was to investigate, through a naturalistic driving study (NDS), real-world driver interaction with commercially available vehicles that include driving automation systems capable of sustaining lateral and longitudinal motion control. The study objectives were to: (1) observe and evaluate how drivers operated vehicles equipped with lateral and longitudinal driving automation features intended for operation in mixed traffic under a variety of roadway types, driving conditions, and speeds and (2) observe and evaluate driver interactions with these features during longer drives. This study was also intended to support the identification and/or refinement of human factors related needs to help encourage the safe operation of vehicles with driving automation features.

Research Focus Areas

The project was designed to address four main focus areas, with specific research questions assigned to each. Focus area 1 investigated ***System Performance***. Sampled and reduced data were used to provide insight into the systems' performance. Focus area 2 investigated ***Driver-System Interaction*** and involved a review of driver behaviors during driving automation system use, specifically the prevalence of non-driving tasks. Focus area 3 investigated ***Driver Performance****.* Driver performance was measured by drivers' responses to Request to Intervene (RTI) alerts generated by the driving automation systems. Focus area 4 investigated ***Driver Engagement***, which includes subjective feedback obtained from participants. The project also included a Longer Drive Sub-Study focused specifically on drives longer than 2 hours. Research questions and results for the Sub-Study are included in the main body of the report.

Vehicles

Two each of the following vehicles were leased for the duration of the study. Each of the selected models allowed drivers to simultaneously activate longitudinal and lateral automation features (relevant packages required are listed). As part of the lateral automation feature, all vehicles generated RTIs informing the driver to return hands to the steering wheel or otherwise administer lateral control input.

- 2017 Audi Q7 Premium Plus 3.0 TFSI Quattro with Driver Assistance Package
- 2015 Infiniti Q50 3.7 AWD Premium with Technology, Navigation, and Deluxe Touring Package
- 2016 Mercedes-Benz E350 Sedan with Premium Package, Driver Assistance Package
- 2015 Tesla Model S P90D AWD with Autopilot Convenience (software version 8.0)
- 2016 Volvo XC90 T6 AWD R with Design and Convenience Packages

Each vehicle was equipped with VTTI's NextGen Data Acquisition System (DAS). The DAS continuously recorded video of the forward roadway, the driver's face, an over-the-shoulder view of the driver's hands and lap area, a view of the footwell, and a rear view. The DAS also recorded vehicle data, including speed, accelerator pedal position, brake application, acceleration, lane position, turn signal activation, and GPS coordinates.

Participants

A total of 120 participants were recruited—12 participants for each of the 10 selected study vehicles. All participants were recruited from the Washington, DC, region, which included both northern Virginia and Maryland suburbs. Participants were balanced across age and gender and were recruited from two age groups, 25 to 39 years old, and 40 to 54 years old, which were the age groups used in previous test track research (Blanco et al., 2015). For each set of 12 participants, 6 were from the younger age group (3 male and 3 female) and 6 were from the older age group (three male and three female).

Approach

Each driver was assigned to one vehicle for the duration of their 4-week participation time in the study. Drivers received training on the vehicles designed to mimic what they would receive at a dealership if purchasing a new car. Training consisted of a static orientation and a two-part test drive. The static orientation included instruction on all of the driving automation system features. During the first part of the test drive, the onsite researcher drove the study vehicle and demonstrated the driving automation features. Once the researcher completed the demonstration of the features, the participant then took over driving the vehicle. The participant was then able to experience features and ask any remaining questions. After completing training, participants drove the study vehicle instead of their own vehicle during the 4-week participation period.

Participant data was saved to a secure server and analyzed once driving periods were complete. Continuously recorded data were then sampled for further annotation and analysis. Trained data reductionists reviewed the sampled recorded video, audio, and parametric data to annotate the driver, vehicle, and environmental factors that were present during each of the sample types (driving automation system use, RTI alerts, and safety-critical events (SCEs).

Results and Key Findings

The L2 NDS was intended to produce an initial understanding of commercially available driving automation systems. This project is the first study sponsored by NHTSA to review driver interaction with vehicles that include lateral and longitudinal automated features in real world settings. This research effort was intended to provide insight into four focus areas: System Performance (during unscripted, on-road driving), Driver System Interaction, Driver Performance, and Driver Engagement. Key findings for each focus area are summarized below.

System Performance

Across all 120 participants, a total of 216,585 miles were driven (1,805 average per participant), with 53,360 miles driven below 40 mph. The remaining 163,226 miles were driven at or above 40 mph. of these, 70,384 miles were driven with both lateral and longitudinal driving automation active, 50,454 with one feature active, and 42,431 with no features active.

The analysis of environmental factors observed indicated that, in the majority of cases, participants were operating the driving automation system-equipped vehicles in a manner consistent with manufacturers' intended use. When operating the vehicles above 40 mph, drivers typically drove with both features active. Drivers were less likely to activate the systems in heavy traffic, on non-interstate roads, and in rainy weather conditions.

Driver System Interaction

Non-driving task prevalence was observed to be similar across all activation levels; there was no increase in non-driving tasks when both lateral and longitudinal control features were active. The most common non-driving tasks observed were interacting with a passenger and monitoring the instrument panel. Furthermore, the types of tasks performed and eyes-off-road time were also similar across activation levels. The observed prevalence of non-driving tasks was high, but it should be noted that the current study used a 15-second reduction window to assess non-driving tasks. Previous estimates of secondary tasks performed as part of the Second Strategic Highway Research Project (SHRP 2) were based on a 6-second reduction window. Additionally, drivers were observed to be monitoring and/or interacting with the instrument panel (center dashboard console and instrument cluster) in about 10 percent of sampled cases; this is consistent with supervisory behaviors as feature activation level (e.g., on or off), settings (e.g., following distance setting), or other system status (e.g., lane marking tracking) were presented in the instrument panel.

Driver Performance

There were 71 SCEs (crashes and near-crashes) observed in the data set. Five SCEs were crashes, and 66 were near-crashes. All crashes were low severity, rated as level 3 or level 4 based on previously adapted SHRP 2 definitions (Virginia Tech Transportation Institute, 2015). No statistical relationships were observed between SCE rates and feature activation level. No RTIs were observed in the context of any SCE. The one observed crash with both features active was a single vehicle crash in which the driver struck a toll lane access gate at low speed (the driver attempted to enter a buses-only entrance). Although both features were active at some point during the reduction window, the driver pressed the brake prior to impact, overriding the driving automation features. The driver was not distracted and had at least one hand on the wheel throughout the event. No damage to the gate or vehicle was observed in this instance.

A total of 449 RTIs were sampled; in 118 of these, drivers were observed to have hands off the wheel. Analysis of reaction times for the RTIs in which drivers had hands off the wheel showed that the average reaction time of 0.94 seconds was within an expected range based on the results of previous research (e.g., Blanco et al., 2015). However, there were some cases that showed longer response times or no intervention from the driver. Examination of these cases revealed that drivers were exploring the boundary conditions associated with the driving automation systems (e.g., intentionally keeping hands off wheel to test RTI duration and lateral control feature capabilities). Drivers were often observed explaining system functionality to passengers in these events, which all occurred when traffic was generally free flowing, weather was clear, and drivers were looking forward and attentive. This is a predicted, and even potentially beneficial behavior.

Driver Engagement

Overall, drivers appeared to trust the driving automation systems, and were comfortable using them. Driver interviews and trust ratings gathered at specific intervals during the 4-week participation period suggested that there was little change in trust in the lateral systems, although summarized comments also indicated that there were situations reported where the lateral systems did not function as expected. Again, these limitations are consistent with how the vehicles were characterized, and it is likely that even after the features were demonstrated, participants still had a higher than realistic expectation of function. Trust in the longitudinal system did increase over time; subjective feedback suggested that drivers learned the limitations of the longitudinal system and were able to use it more effectively after understanding its limitations.

Chapter 1. Introduction

Objective

The objective of the Naturalistic Study of Level 2 Driving Automation Functions (L2 NDS) project was to investigate, through a naturalistic driving study, real-world driver interaction with commercially available vehicles that could sustain lateral and longitudinal motion control. The study objectives were to: (1) observe and evaluate how drivers operated vehicles equipped with lateral and longitudinal driving automation features intended for operation in mixed traffic under a variety of roadway types, driving conditions, and speeds and (2) observe and evaluate driver interactions with these features during longer drives. This study was also intended to support the identification and/or refinement of human factors related needs to help encourage the safe operation of vehicles with driving automation features.

Currently there are several commercially available vehicle models offering optional features that automate at least some portion of lateral and longitudinal vehicle control. Depending on the make of the vehicle, different terms are used to name and describe these automated lateral and longitudinal control features. For example, the lateral control feature may be referred to as steering assist, lane keep assist, or lane centering, while the longitudinal control feature is often termed adaptive cruise control, intelligent cruise control, or advanced cruise control. In some cases, these systems activate together, while other implementations require two separate feature activations. When automated lateral and longitudinal control features are combined, the overall driving automation systems can be considered level 2 (L2), Partial Driving Automation (SAE International, 2016). SAE describes the roles of the driving automation system and the driver during L2 driving automation in standard J3016:

> The Driving Automation System (while engaged): (1) Performs part of the dynamic driving task (DDT) by executing both the lateral and longitudinal vehicle motion control subtasks, and (2) Disengages immediately upon driver request.
>
> The Driver (at all times): (1) Performs the remainder of the DDT not performed by the driving automation system, (2) Supervises the driving automation system and intervenes as necessary to maintain safe operation of the vehicle, and (3) Determines whether/when engagement and disengagement of the driving automation system is appropriate, and immediately performs the entire DDT whenever required or desired (SAE International, 2016).

The research team notes that there is ongoing discussion regarding classification and definitions of driving automation systems and features. Although the report title includes the term “Level 2,” the goal of this research project was not to classify features as level 2, but rather to determine how drivers interact with a range of driving automation features. Given the myriad of terms used to name or brand these types of automation, the general terms “automated lateral control features” and “automated longitudinal control features” are used in this report.

Different implementations of automated features for lateral and longitudinal control likely have different functional envelopes, design intent, capabilities, and RTI strategies. For example, some systems may only operate at highway speeds, have different steering torque limits, or utilize different sensor fusion capabilities. Finally, the design intent of the systems may differ from what the systems afford a driver in real-world settings. For instance, a system that is intended for highway use only may actually operate anywhere there are lane markings.

It is noted that RTI, as specified in the latest J3016 standard (SAE International, 2016), is defined as it relates to driving automation only for driving automation systems at level 3 and above. However, the authors believe it is also appropriate to use the term RTI for L2, as during L2 automation, the driving automation system performs the sustained lateral and longitudinal vehicle motion control and the driver is assigned as the Dynamic Driving Task (DDT) fallback. Given that particular aspects of the DDT cannot be performed without driver intervention, an alert at L2 should still be considered as an RTI directed at the driver.

This document contains chapters which detail multiple facets of the L2 NDS project. Chapter 2 provides a more thorough review of the research questions (RQs) addressed in this project. Chapter 3 contains the study methods, describing the vehicles, participants, and data collection methods for the L2 NDS. Chapter 4 covers the project results. Chapter 5 summarizes the Longer Drive (LD) Sub-Study, and Chapter 6 presents a discussion and study conclusions.

Background & Research Questions

Previous research has evaluated human factors concepts with automated lateral and longitudinal control features in test track settings (Blanco et al., 2015). While these test track studies provide valuable insight into potential benefits and drawbacks of driving automation systems, they can be complemented by NDSs, which provide a method for evaluating new vehicle technologies during daily driving situations. Previous research has shown that, while there is a brief period of time in which participants behave differently due to the presence of cameras in the vehicle, they appear to adapt to the presence of this instrumentation in less than an hour (Dingus et al., 2006). Earlier NDSs have evaluated new technology for collision avoidance systems in heavy vehicles (Grove et al., 2016) and video imaging and camera systems (Wierwille et al., 2011), and studied normal driving performance and behaviors (Klauer et al., 2006; Klauer et al., 2010; Dingus et al., 2015). The current study (Naturalistic Study of Level 2 Driving Automation Functions or L2 NDS), described here, generated practical data to support new understanding of L2 driving automation function use by evaluating a subset of currently available lateral and longitudinal driving automation features as drivers previously unfamiliar with such features experienced them during a 4-week period.

An NDS is an in-situ investigation of driver performance and behavior. By instrumenting vehicles with cameras, sensors, and data recorders, drivers can be continuously recorded as they normally drive over an extended period of time without an experimenter in the vehicle. Naturalistic driving research supports the simultaneous investigation of driver, vehicle, and environmental factors pertaining to transportation safety, and can capture real world driver use of combined lateral and longitudinal driving automation features, including prevalence of non-driving (i.e., secondary) tasks. It also enables the identification of edge cases via the observation of driving automation system operation across various environmental conditions and a wide range of drivers. Finally, it allows for the identification of safety-critical events (SCEs) of different severity levels (e.g., crashes and near-crashes) with and without driving automation system use.

As previously stated, NDSs can address research gaps that test-track research using vehicles equipped with driving automation systems cannot. One such gap is a more complete understanding of the types, durations, and frequencies of non-driving tasks that drivers perform in an uncontrolled setting when driving automation systems are engaged. For example, do drivers improperly use the driving automation features by overly engaging in visual or manual non-driving-related tasks? Duration of exposure or use of driving automation features should also be explored, as longer exposures could result in longer response times to RTIs, which would suggest complacency or an adaptation to the environmental circumstances surrounding the RTI. Additionally, driving automation systems have not been publicly evaluated in nonideal roadway conditions such as heavy traffic or severe weather; thus, their overall performance envelope is not known. Understanding driver trust in the technology before and after using it in real-world situations could greatly inform researchers and system developers as to drivers' willingness to detach from the driving task and attempt to push the system beyond its capabilities.

The approach described in the Methods section (Chapter 2) was designed to address research questions specified by NHTSA. Research questions have been organized into four primary focus areas. As part of study development, the questions were expanded and further detailed in collaboration with NTHSA and stakeholder review; the original language of the research questions is included in Appendix A. The term "request to intervene" has replaced the word "alert." Each focus area has separate questions. A list of acronyms is included in Appendix B. Additional operational definitions for terms can be found in Appendix C. The research questions, including a brief description of the approach used to investigate each, are as follows.

System Performance

Focus area 1 investigated *System Performance*. This focus area was heavily informed by the vehicle characterization effort, but sampled and reduced data also provided insight into the performance of the system. This focus area includes three research questions (RQs).

RQ 1.1: How does the combined lateral and longitudinal control system operate?

Approach: The system operation was investigated during the vehicle characterization effort, and differences between how participant drivers operated the system vs. how the system was characterized were noted.

RQ 1.2: Are there environmental factors that reduce the use of the driving automation system features?

Approach: The impact of environmental factors, such as roadway markings, traffic level of service, and weather, on driving automation system use was investigated.

RQ 1.3: Were there additional system limitations observed during the study?

Approach: Additional system limitations, such as unintended lane departures, are discussed in this report. Additionally, as part of this approach, the RTIs were subdivided using an approach adapted from a previous study (Grove et al., 2016).

Driver System Interaction

Focus area 2 investigated *Driver-System Interaction* and contains one RQ.

RQ 2.1: What driver behaviors are observed when the driving automation systems are engaged?

Approach: Prevalence and types of non-driving tasks performed by drivers when the driving automation systems were engaged compared to times when the systems were not engaged were investigated.

Driver Performance

Focus area 3 investigated *Driver Performance.* Driver performance is measured by drivers' responses to RTIs generated by the driving automation systems, including performance changes over time. Also included as part of driver performance are investigations of unintended use and unintended consequences. This focus area contains five RQs.

RQ 3.1: How do drivers respond to RTIs?

Approach: The sequence and timing of driver responses immediately prior to and then following an RTI until the driver intervenes were investigated.

RQ 3.2: How do drivers change their behavior over time?

Approach: The differences in driver response and intervention times between the different weeks of driving automation system use were investigated.

RQ 3.3: Does using driving automation systems during longer drives change any driving performance measures or otherwise impact driver behavior?

Approach: Based on the overall usage profile that was observed, samples that occurred during longer trips were compared to samples that occurred during shorter trips.

RQ 3.4: What is the prevalence of improper use of the driving automation systems?

Approach: Improper use, defined as any use other than that intended by the OEM, was investigated across the data set.

RQ 3.5: Were there unintended consequences associated with using driving automation systems?

Approach: The primary method for exploring unintended consequences was the prevalence and type of SCEs that were observed when both lateral and longitudinal control features were engaged, a single feature was engaged, or no features were engaged.

Driver Engagement

Focus area 4 investigated *Driver Engagement*, which includes subjective feedback obtained from participants as well as responses to system prompts observed while the driving automation systems were active. This focus area includes six RQs:

RQ 4.1: If available, how do drivers respond to system prompts?

Approach: Prompts were sampled relative to their frequency during the window of time prior to an RTI. (See Appendix C for definitions of prompts and RTIs)

RQ 4.2: Are there specific aspects of the driving automation features' interfaces or communication strategies (e.g., RTIs, audio tones, displays) that drivers find more useful than others? Conversely, are there aspects of driving automation features that are difficult to understand, misleading, or annoying?

Approach: These questions were investigated by asking drivers' opinions regarding specific features of the vehicles to which they were assigned.

RQ 4.3: Do drivers report that the driving automation systems function as they would expect? Furthermore, do they report that they trust the driving automation systems?

Approach: Drivers were asked their opinions of the driving automation features throughout their participation. Changes in their expectations were noted.

RQ 4.4: Do drivers report different expectations across various types of roadways, driving conditions, speeds, etc.? That is to say, when asked for their opinions, did drivers recognize the limitations of the driving automation system to which they were assigned?

Approach: Drivers were asked their opinions of the driving automation features throughout their participation. Drivers' responses regarding system limitations observed were summarized and noted.

RQ 4.5: Do drivers trust the lateral and longitudinal features? In addition, do drivers have any other safety concerns with the features?

Approach: Drivers were asked their opinions of the driving automation features throughout their participation, including overall level of trust as assessed via self-report. Driver trust in lateral and longitudinal control features was investigated. In addition, safety concerns reported by drivers were noted.

RQ 4.6: Are there additional needs for licensing or training that are needed as based on the results of this study?

Approach: General suggestions, based on the training plan implemented in this study, relating to anticipated needs for additional licensing are reported.

Research Questions for Longer Drive Sub-Study

Research questions for the LD Sub-Study are included below, along with a brief description of the approach used to investigate the question. The RQs for the LD Sub-Study are intended to complement those in the NDS, and as such they are numbered the same as their corresponding L2 NDS RQ, with "LD" added as a suffix.

RQ 2.1 (LD): What driver behaviors are observed when the driving automation systems are engaged during long duration drives?

Approach: Prevalence and types of non-driving tasks performed by drivers during the LD Sub-Study were investigated and findings compared to those from the NDS portion of the study

RQ 3.3(LD): Do sampled driving epochs observed in naturalistic settings show differences in driving behavior compared to driving automation system use during long durations on a single trip?

Approach: Sampled epochs for the LD Sub-Study were taken from a single 4-hour trip. Epochs from early instances of driving automation system use as well as RTI epochs were compared to instances of driving automation system use and RTI epochs at the end of the drive. Data observed from the Sub-Study were also compared to comparable drives observed during the NDS portion of the research effort.

Chapter 2. Naturalistic Driving Study

Purpose

This chapter outlines the study methods and procedures used to address project research questions. As outlined in Chapter 1, the objective of the study was to study driver interaction with lateral and longitudinal driving automation in real-world settings.

Virginia Tech Transportation Institute (VTTI) collaborated with a group of industry stakeholders as part of project planning and development to implement the methods outlined in this chapter. Stakeholders provided key input for vehicle characterization and training, as well as general comments on the research methods. The following original equipment manufacturer (OEM) and Tier 1 suppliers agreed to review the study methods and provided input: Bosch, General Motors, Honda, Hyundai, Mercedes-Benz, Nissan, Tesla, Volkswagen, and Volvo. The research team also collaborated with international stakeholders, including ERTICO-ITS Europe, Catapult, and The National Institute of Advanced Industrial Science and Technology. These stakeholder organizations are shown in Figure 1.

Figure 1. Stakeholders for the L2 NDS Project

Vehicles

Since driving automation systems currently available on the market vary in terms of their capabilities and human machine interfaces (HMIs), the study tested vehicles with differing driving automation systems across five different OEMs. Each of the selected models allows drivers to simultaneously activate longitudinal and lateral automation features (relevant packages required are listed). The research team leased two of each vehicle shown in Figure 2.

Figure 2. Vehicles Used in the L2 NDS

At the time the vehicles were selected and leased for the study, these were the newest models available (Tesla software included the latest updates available at the beginning of the data collection process).The following list indicates the specific year and package information for each vehicle.

- 2017 Audi Q7 Premium Plus 3.0 TFSI Quattro with Driver Assistance Package
- 2015 Infiniti Q50 3.7 AWD Premium with Technology, Navigation, and Deluxe Touring Package
- 2016 Mercedes-Benz E350 Sedan with Premium Package, Driver Assistance Package
- 2015 Tesla Model S P90D AWD with Autopilot Convenience (software version 8.0)
- 2016 Volvo XC90 T6 AWD R with Design and Convenience Packages

A characterization of the driving automation systems was conducted for each study vehicle (see Table 1) and was reviewed with each OEM stakeholder to ensure that the research team had an accurate description of each feature. The remainder of the report will aggregate results rather than presenting results by individual vehicle model.

Table 1. Lateral and Longitudinal Control Feature Characterization for Each Vehicle

Vehicle Make & Model	Minimum Speed Lateral Control Feature Engages (mph)	Lateral Control Feature Engages Individually	Lateral Control Activation (Manual or Automatic)	Lateral Deactivation	Minimum Speed Longitudinal Control Feature Engages (mph)	Longitudinal Control Feature Engages Individually	Request to Intervene Source	Prompt	Separate Low Speed Features
2017 Audi Q7	40	Yes	Auto with/toggle button	Brake	20	Yes*	Hands on Wheel	No	Yes
2015 Infiniti Q50	45	Yes	Manual- Button	Brake	20	No	Lane Departure warning	No	No
2016 Mercedes E350	37	No	Manual- Lever	Brake	20	No	Hands on Wheel	Yes	Yes
2015 Tesla Model S	20	No	Manual- Lever	Brake or Steering Wheel	20	Yes	Hands on Wheel	Yes	Yes
2016 Volvo XC90	40	Yes	Auto-System Menu	Brake	20	Yes*	Hands on Wheel	Yes	Yes

*Although the longitudinal control feature can technically activate alone, this would only occur if a driver took additional steps to manually de-activate the lateral control feature.

For each driving automation system, the general operational envelope was ascertained in various driving environments. The longitudinal control features utilize a forward-looking set of sensors (typically radar-based; for some vehicles, forward camera data is also included). None of the longitudinal control features directly responded to traffic ahead in adjacent lanes. Following distance could be adjusted by the driver, with following distance settings having an approximately 2–3 second headway.

Lateral control features varied in their overall capability. In some cases, the lateral control feature would initiate steering as the study vehicle approached a lane marking, while in others the system operated more akin to a “lane centering” feature, with active steering from the feature. Lateral control features utilized a forward-looking camera with a vehicle-specific machine vision algorithm to track lane markings.

Regardless of overall capability, all features required active monitoring from the driver and frequent intervention. For all vehicles, the intended use of the lateral control features required the driver's hands on the wheel, and drivers were warned not to use the driving automation systems in poor visibility conditions, weather related or otherwise. As noted, the vehicles varied somewhat in feature availability and activation; in some cases, the lateral control feature was only available if the longitudinal control feature was already engaged, or the two features engaged simultaneously. For the majority of the vehicles, the following feature generalizations are most relevant for the current report.

- Driving automation systems were intended for use in highway driving environments with clear weather
- Lateral control features were generally available above 40 mph with visible lane markings
    - Lateral control features were based on a vehicle-specific machine vision system to track lane markings
    - Additional sensors (e.g., ultrasonic) may be used for lateral safety systems such as blind spot warning
- Longitudinal control features were available above 20 mph
    - Longitudinal control features were forward-radar based
    - No vehicles included corner or side-facing radar units
- RTIs were all generated as part of the lateral driving automation feature
    - Timing was based on the lack of detected steering inputs from the driver and/or crossing a detected lane marking
    - RTIs were multi-modal, including both a visual and auditory component (no RTIs included a haptic component)

Although some vehicles tested included a "low speed" version of driving automation (i.e., traffic jam assist, pilot assist, autopilot), baseline epochs for this effort were sampled from the speeds outlined above for lateral and longitudinal control features. However, RTIs and SCEs were included from all speeds.

Focus area 4 includes questions about vehicle prompts. Previous test track research (Blanco et al., 2015) used prototype L2 features with a prompting system designed to keep the driver looking forward (this prompting system was separate from any RTI). In the present study, prompts and RTIs were distinguished by the level of control maintained by the lateral and longitudinal automation. A prompt notified the driver to perform an action, such as placing hands on the steering wheel, to remain engaged in the driving task, while the lateral automation remained engaged. An RTI indicated that the driving automation system required driver intervention because it was not able to detect hands on the wheel (four vehicles) or detected a lane departure (one vehicle). Three of the five vehicles did include a multi-stage RTI process; the L2 NDS defined these early alert stages as prompts. Definitions of prompts and RTIs are also included in Appendix C.

Characterization also included training VTTI-developed machine-vision algorithms to detect driving automation system operation and active safety RTIs from the instrument cluster, and also identified systems that prompted the driver to remain engaged. The characterization results were used to inform both the data reduction process and the interpretation of results. Appendix D includes an outline of the characterization procedures and images of icons for each vehicle feature and RTI, along with timing information relevant to vehicle HMI.

Each vehicle was equipped with VTTI's NextGen DAS, the same system used in the Second Strategic Highway Research Program Naturalistic Driving Study (SHRP 2 NDS; Dingus et al., 2015). The DAS continuously recorded video of the forward roadway, the driver's face, an over-the-shoulder view of the driver's hands and lap area, a view of the footwell, and a rear view (see Figure 3). A separate video feed (not pictured) recorded a view of the instrument cluster. In addition to video feeds, the DAS continuously recorded audio in the vehicle. Continuous audio recording captured any auditory RTIs, prompts, voice commands, and cell phone use that occurred. With regard to cell phone use, the focus of this study was on the prevalence and duration of non-driving-related tasks, not on the content of cell phone calls.

The DAS also recorded vehicle data, including speed, throttle position, brake application, acceleration, lane position, turn signal activation, and GPS coordinates. As previously noted, the DAS also recorded a camera view to capture driving automation system activations, which was then processed via a VTTI-developed machine vision algorithm to supplement information contained on the vehicle network.

Figure 3. Data Acquisition System Camera Views

Participants

A total of 120 participants were required to complete the study design, accommodating a sample of 12 participants for each of the 10 selected study vehicles. All participants were recruited from the Washington, DC region, which included both northern Virginia and Maryland suburbs. An existing database of individuals who had previously submitted their information to be considered for studies was used to identify potential participants; in addition, publicity regarding this study was disseminated to various group email lists and via paper flyers. Participants were balanced across age and gender and were recruited from two age groups, 25 to 39 years old, and 40 to 54 years old, which were the age groups used in in previous test track research (Blanco et al., 2015). For each set of 12 participants, 6 were from the younger age group (3 male and 3 female) and 6 were from the older age group (3 male and 3 female).

All participants were required to hold a valid driver's license. Additional requirements to participate included the following.

- Must not have driver's license suspension within the last 7 years
- Must not have been convicted of more than two driving violations in the past 3 years
- Must not have been involved in an at-fault crash causing injury within the past 3 years
- Must agree to submit to a driving history check to confirm/verify driving history
- Must agree to fill out and submit a frequency and risky driving behavior survey
- Must drive at least 60 miles per weekday (14,400 per year average)
- Must own and use a smartphone with Bluetooth capability
- Must have normal or corrected to normal vision
- Must have normal or corrected to normal hearing

Figure 4 shows the total number of contacted, screened, eligible, and selected participants. Additional screening criteria were also used; a full list is included in Appendix E. Note that some criteria are institutional in nature. Because VTTI leased the vehicles, they were considered state vehicles. As such, participants needed to meet the same criteria as state employees in order to be allowed to drive the vehicles. To ensure that participants accurately reported their driving history, research team members verified driving histories in collaboration with Virginia Tech Human Resources; this check was intended to mitigate risk of damage to the study vehicles in a way that would negatively impact the project timeline.

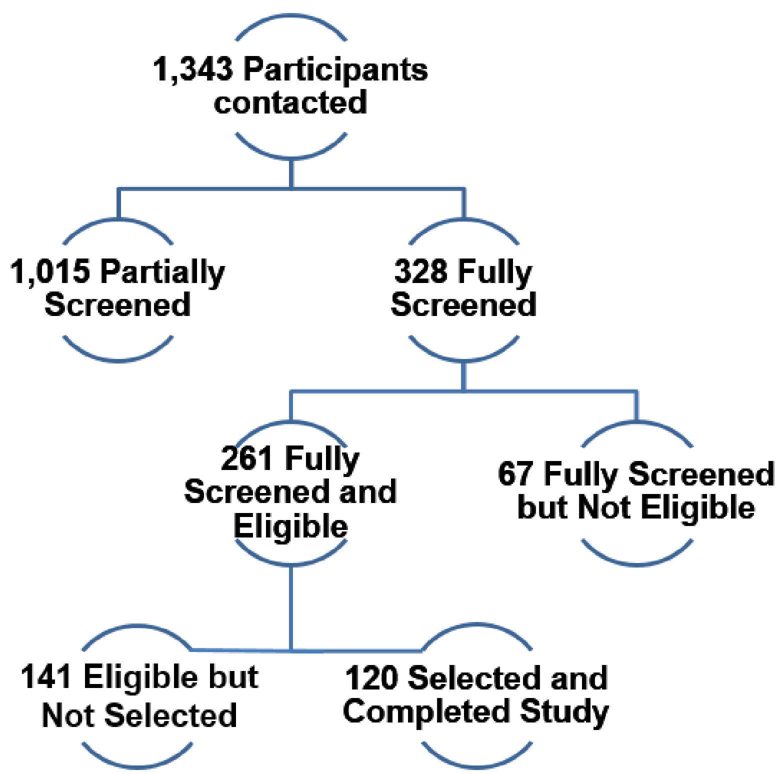

Figure 4. Flowchart of Contacted, Screened, Eligible, and Selected Participants

To confirm miles driven, researchers verified that the distance between a participant's work and home address was 60 miles round trip (i.e., a 30-mile work commute each way) or the equivalent if the participant drove while at work. Drivers were provided an incentive to drive more than 1,200 miles during their participation. If participants reported that they owned one of the vehicle make used in the study, they were not assigned to that make of vehicle during their participation period.

All 120 study participants filled out a demographic questionnaire (See Appendix F for questionnaires). Participants reported that they had been daily smartphone users for at least 2 years, with 98 percent reporting more than 4 years of use (n = 118). The majority (84 percent; n = 101) reported using their smartphones while paired with their personal vehicle. Participants were asked to report previous experience with driver assistance systems, and 39 percent of the participants (n = 47) reported they had driven a vehicle with crash avoidance systems, with the majority having little to no direct experience with any driving automation systems or other driver assistance systems. A total of 31 percent of the participants (n = 38) reported that they had driven a vehicle with longitudinal control features, and 29 percent of the participants (n = 35) reported that they had driven a vehicle with a lateral control feature of some type. The majority of participants were indirectly aware of driving automation systems; a total of 63 percent of the participants (n = 75) reported that they had heard of an "automated vehicle system" of some type, with the most common answer being a Tesla (n = 60). Note that this questionnaire was administered after screening, so participants were aware of the vehicles used in the present study.

Participants received training to mimic the information they would receive at a dealership. To this end, the research team developed training outlines based on experiences characterizing the study vehicles, collaboration with OEM stakeholders, review of owner's manuals, dealership site visits, and online training materials. Training outlines for each study vehicle are included in Appendix G. Note that the individual training modules were similar, but covered features specific to each vehicle. Care was taken to develop training that was not overly in-depth, but still adequately covered the use of driving automation system features. Training was kept as similar as possible across vehicles to avoid any potential bias from training differences.

Drivers were compensated for their participation based on their total mileage driven and questionnaire completion. No monetary incentive was provided to use the driving automation systems specifically. Participants were compensated up to $500 as follows: (1) up to $300 if their total mileage was under or equal to 1,200 miles ($0.25 per mile) or (2) $440 flat if they exceeded 1,200 miles. Participants were further compensated at a rate of $20 per weekly questionnaire (three in all), totaling $500 for complete participation ($360 for the lower mileage participants). Each vehicle was also equipped with a transponder that provided access to the high-occupancy toll lanes and other toll roads in the region. This presented additional opportunities for drivers to reach the speeds required for driving automation system activation, and also served as further incentive to participate in the study. Questionnaires are included in Appendix F.

All study screening, recruitment, training, compensation, and data collection activities were approved by the Virginia Tech Institutional Review Board (IRB) prior to study execution. A copy of the IRB-approved version of the informed consent document is located in Appendix H.

Study Design

Each driver was assigned to one vehicle for the duration of their 4-week participation time in the study. Note that the driving automation system capabilities were made available to all participants at the time the vehicle was assigned to them. Data collection began in September 2016 and was completed in December 2017. When possible, participant age groups and genders were alternated between deployments to reduce seasonal effects. Participation ended early for one participant assigned to a Tesla vehicle. In this instance, a DAS failure took the vehicle out of service mid-study for repairs. In order to have a complete 4-week data collection for 12 participants with this vehicle, one additional participant was recruited to complete the study design and replace the participant with the shorter exposure.

Procedures

Potential participants were contacted by the research team's recruitment group and screened for their eligibility to participate (See Appendix E for screening criteria). Upon completing the initial screening process, potential participants who were deemed eligible and agreed to continue then underwent a driving history check and also completed a questionnaire assessing perceptions and frequency of risky driving behavior, as adapted from previous research (Dingus et al., 2015). Scores from the risk assessment questionnaire were used to balance the overall risk score across vehicles in order to help limit any confounding factors between vehicles. Potential participants who passed the driving history check were placed into the eligible participant pool spreadsheet. The onsite researcher then called and scheduled a date to meet with the participant at their home or work.

Upon arriving at the participant's house/work location at the scheduled meeting time, the onsite researcher verified the participant had a valid driver's license and began the consent process. This consent process informed the participants of their rights and responsibilities as a participant in the study. As part of the consent process, potential participants were instructed that they alone (as consented drivers) were authorized to drive the study vehicle. Participants reviewed and signed the consent form after all questions had been answered, then completed a demographics questionnaire and a W-9 for compensation purposes.

At the home/work visit, each driver received an orientation to their assigned vehicle as well as training regarding the use of the driving automation system features. Training consisted of a static orientation and a two-part test drive. The static orientation started with a description, location, and operation of all of the basic vehicles controls (e.g., seat adjustment controls, windshield wiper controls) followed by any comfort features (e.g., seat warmer, navigation, entertainment system). Additionally, participants received instruction on what to do if they were involved in a crash (a yellow envelope in the glove box provided details on this for future reference). Participants were then informed that the study vehicle was equipped with an EZ-pass transponder that allowed the use of any express and/or toll roads in the study region. The last step of the static orientation consisted of instruction on all of the driving automation system features. This included verbal instruction as well as pointing out the use and operation of any associated buttons, levers, auditory alerts, visual alerts, and haptic alerts. This instruction was similar to what one would expect a dealer might provide when purchasing a new car. The onsite researcher ensured all participants were comfortable in activating and deactivating the driving automation features for safety reasons.

After the static orientation was completed, the onsite researcher then took the participant on a two-part test drive. During the first part of the test drive, the onsite researcher drove the study vehicle and demonstrated the driving automation features. While demonstrating these features, the following instructional information was provided.

- Review of the buttons, levers, menus, RTIs, and other alerts that may have been encountered (e.g., blind spot alerts)
- Proper use, including hands on wheel at all times
- Examples of situations when the features may be unavailable or not work as expected
    - Heavy rain

- Snow/ice
- Fog
- Glare
- Curvy roads
- Absence of or faded road markings

Once the researcher completed the demonstration of the features, the participant then took over driving the vehicle. The participant was instructed when to activate the features and was given a chance to drive the study vehicle until comfortable with the driving automation features. Once the researcher had answered all of the participant's questions and the participant indicated that he or she felt comfortable driving the study vehicle, the participant was instructed to safely exit the roadway and park in the nearest parking lot or return to their driveway. At this point, a questionnaire was administered to gather initial opinions of the driving automation features and the participant's trust in the systems (Questionnaires are included in Appendix F.) Finally, the experimenter then verified the vehicle's condition using an inspection sheet (Appendix I), and photographed any issues with the vehicle. The total time for the home visit and training was approximately 1.5 hours. After completing all training, questionnaires, and verifying vehicle conditions, participants were loaned the study vehicles for the 4-week participation period.

Drivers were contacted via phone after the first, second, and third weeks of their participation (Weekly Check-in Interview in Appendix F). The subjective data collected from the questionnaires was analyzed to assess drivers' trust in the vehicle automation and their understanding of the driving automation systems' operation. This questionnaire was adapted from previous test track studies using driving automation systems (Blanco et al., 2015). Collecting questionnaire responses at multiple times throughout participation also allowed insight into changes in trust and perception of the systems over time. At the end of the 4-week participation period, research team members took possession of the vehicle, verified the vehicle's condition, and administered the final questionnaires to the participant (Deluxe Post-Experiment Questionnaire and Deluxe Post-Experiment Follow-up in Appendix F; Note: Deluxe was the short project name used when recruiting and interacting with participants). Once the questionnaires were completed and the vehicle was returned, the research team transferred the collected data to a secure data storage server.

Chapter 3. Data Sampling, Reduction, and Analysis

Data Sampling

NDSs provide continuous data recording while participants are driving. The focus of this section is to describe the approach to sampling, reducing, and analyzing continuously recorded data. Established kinematic algorithms (e.g., hard decelerations, lane departures, high yaw rates) were used to identify potential SCEs. Trained data reductionists (see below) then inspected the videos associated with these events to verify the occurrence of an SCE. For baseline driving samples, 15-second epochs were sampled from the continuously recorded data. The 15 seconds were divided into 10 seconds prior to and 5 seconds after the time of interest. Samples were taken during instances in which both the lateral and longitudinal driving automation features were engaged, during instances in which the driving automation system was available but not engaged, and during instances in which both features of the driving automation system were available but only one was engaged. Instances in which an RTI was issued were also sampled. Driving automation was available when the vehicle was traveling above the speed required for activation (see Table 11 in Vehicles section above) on a road with visible lane markings. The sampling approach was as follows.

- All periods in which the driving automation system was available for use and also active were identified using a VTTI-developed machine-vision algorithm combined or available vehicle network information.
- Up to twelve 15-second epochs per driver were randomly sampled from the periods in which the driving automation system was active (samples were stratified by each week of participation). It was determined that 12 samples per driver were needed to provide a reliable statistical estimate of driver performance, and 15-second samples allowed for the assessment of drivers' visual behavior and engagement in non-driving-related tasks; this sampling method was adapted from a previous NDS (Dingus et al., 2015).
- Up to 12 epochs per driver of instances in which the driving automation system was available, but only one feature (either lateral or longitudinal) was active, were sampled These were instances where only lateral or only longitudinal control was automated, but vehicle speed was above 40 mph and data reductionist-verified lane markings were present.
- Up to 12 epochs per driver of instances in which both functions of the driving automation system were available, but neither lateral nor longitudinal control automation was active, were sampled. These were instances where the vehicle speed was above 40 mph and data reductionist-verified lane markings were present.
- Up to 12 RTI epochs per driver per week were sampled. These were instances where an RTI was issued by the vehicle's HMI.
- All SCEs that were observed in the dataset were analyzed. See the Results section below for details regarding the total number and type of SCEs (crashes and near-crashes) observed during data collection.

This sampling strategy was implemented to allow comparisons of driver behavior and roadway scenarios between levels of driving automation system engagement (when such activation is available). As noted, for each epoch type, 12 epochs per driver week were planned. In practice, 12 epochs were not observed in all cases for all vehicles; Table 2 shows the number of samples collected. In cases where there were fewer than 12 samples for a week, all instances of that activation were reduced.

Table 2. Total Epochs Samples and Average Samples per Driver

Epoch	Total	Average Samples Per Driver	Average Samples per Week per Driver
Both Features Engaged	1,295	11	3
No Features Engaged, Both Features Available	1,052	9	2
One Feature Engaged, Both Features Available	1,083	9	2
RTIs	449	4	1
SCEs	71		

Additionally, for each driver, up to twelve 15-second epochs were randomly sampled from the time periods in which RTIs were issued (RTIs were sampled during each week of participation). All RTIs were analyzed regardless of vehicle speed. A total of 449 RTIs were issued across all 120 drivers. These 449 samples were used to assess how long drivers took to intervene once an RTI was issued (RQ 1).

Equal amounts of each type of epoch were selected from each week in the study within each driver's data. The exception is the set of SCEs which, as noted above, included all SCEs that were identified. The sampling strategy was neither designed nor adjusted for exposure rate of driving automation per driver. There are three reasons for this. First, the primary research objective was to make inferences about drivers and, thus, drivers are the population of interest. As such, as much information as possible about each driver's behavior during driving automation system use was desired. Second, of interest was drivers' performance under different driving automation systems, depending on the vehicle. Sampling too little from some drivers may have resulted in a loss of information about a particular system. Third, insufficient information was available to predict driving automation use, and sampling was performed as data arrived.

As shown in Figure 5, for vehicles that prompted the driver, prompts were reviewed as they occurred prior to an RTI in order to address RQ 2. For a sampled RTI, any responses to the early stage prompt that occurred prior to the RTI were assessed.

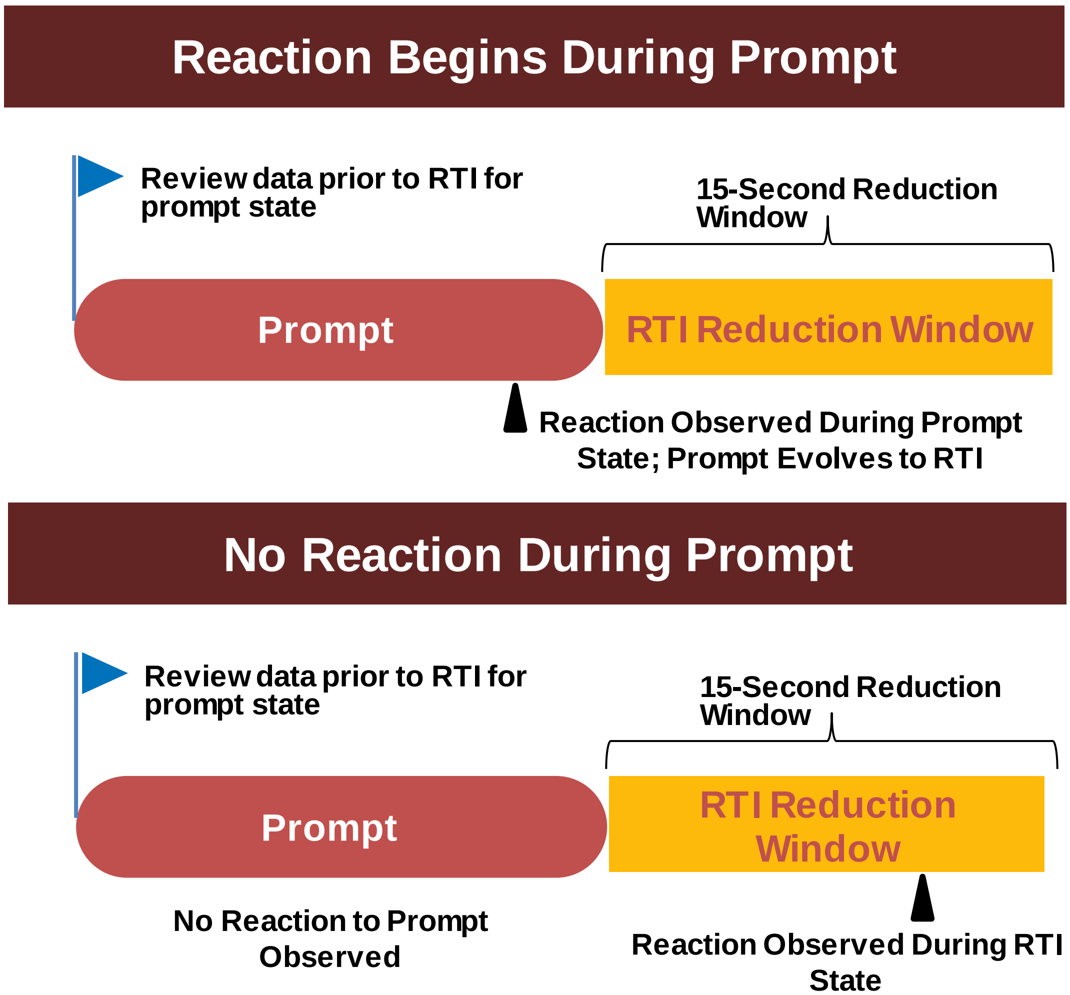

Figure 5. Methods Used to Determine Reaction (Top) or No Reaction (Bottom) to Prompts

Data Reduction

For each sampled epoch, trained data reductionists (Figure 6) used the recorded video, audio, and parametric data to annotate the driver, vehicle, and environmental factors that existed during each of the sampled driving automation system activations, RTIs, and valid SCEs. VTTI has published the most recent data dictionary (VTTI, 2015), which includes definitions used as part of the reduction process, as well as descriptions of environmental variables and examples of possible non-driving task categories. Video, kinematic, and vehicle data was synchronized by the DAS and reviewed at a rate of 15 frames per second. Reductionists were limited to shifts of 6 hours or less to minimize vigilance decrements and were not allowed access to their cell phones to prevent video of drivers being released to the public.

Figure 6. Data Reduction at VTTI

Driver variable reduction included an assessment of what behaviors were exhibited at the time of the event, including non-driving-task engagement, evidence of drowsiness/impairment, and other aspects that might help characterize driver interaction with the automation. For example, reductionists identified instances of improper use, such as using the system in adverse weather or circumventing the need to hold the steering wheel. Figure 7 shows the reduction windows for baseline and RTI samples. For baseline samples, the data reduction window used was 15 seconds—this window included the 10 seconds preceding the sampled point and the 5 seconds after.

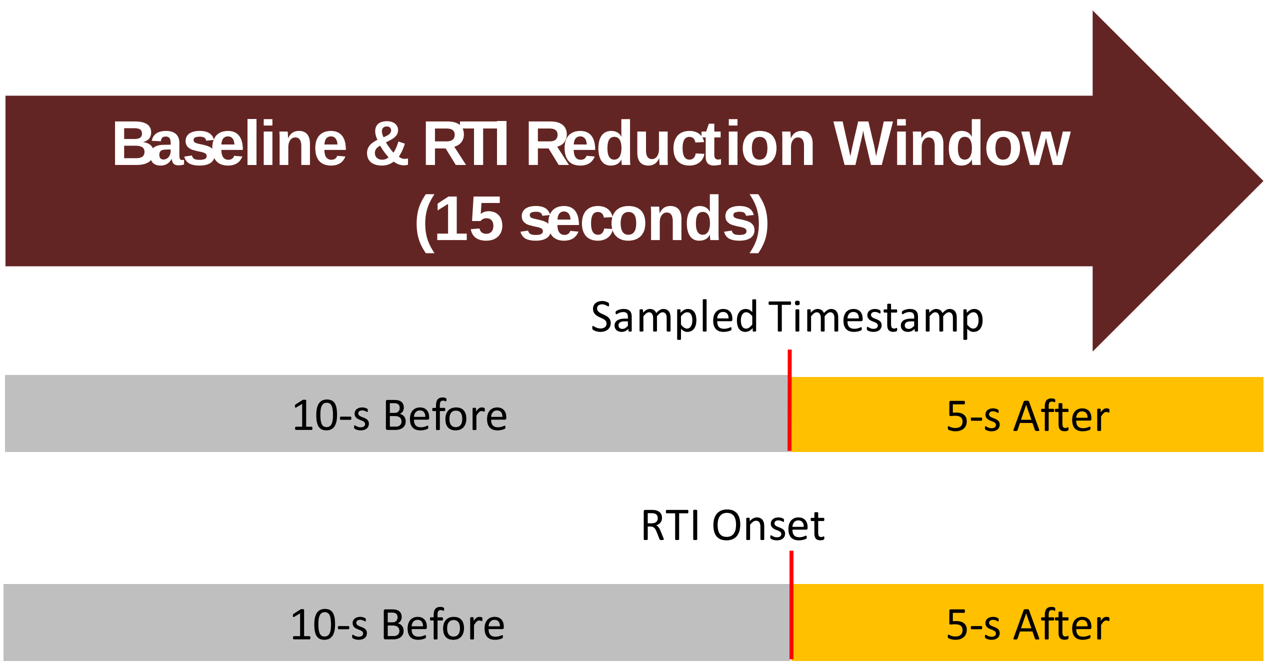

Figure 7. Reduction Windows for Baseline and RTI Epochs

Note that the non-driving task of “monitoring the instrument panel,” included interaction with both the instrument cluster and the center dashboard console display. This task was not based on eye glance, although glances to the display were included as reactions to an RTI (see below). For this task, a driver was observed interacting with the display directly (e.g., pressing a button or touching a screen), or in some other context that indicated interaction (e.g., navigation directions were heard during the epoch). Where possible, specific tasks involving the center dashboard console were included separately (e.g., interacting with the climate controls, radio, navigation, other vehicle setting); however, it was often not possible to discern one center dashboard console task from another.

As shown in Figure 8, the reduction window for SCEs was 10 seconds prior to the precipitating event and 5 seconds after the event resolved. Definitions for precipitating events and event resolutions can be reviewed in the most recent data dictionary (VTTI, 2015).

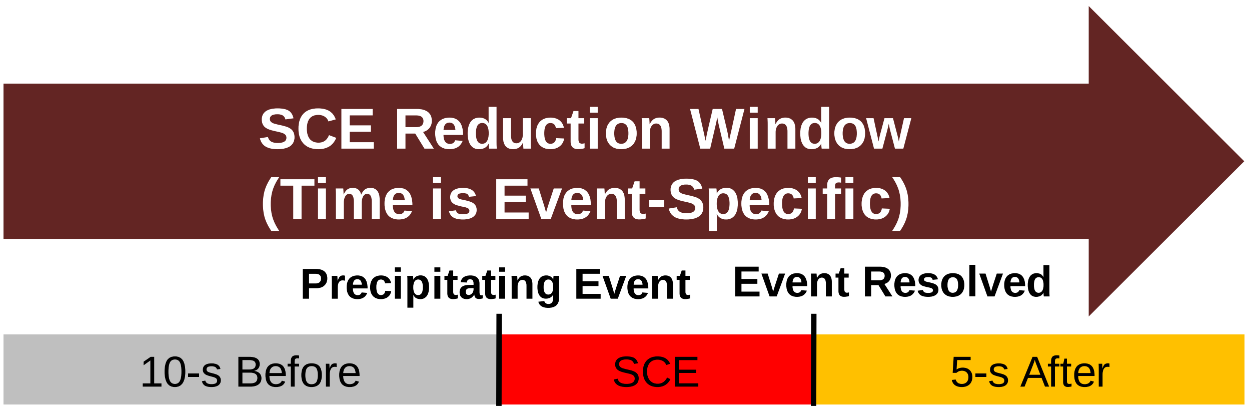

Figure 8. SCE Reduction Window

Data reduction also included environmental variables that were identified from the video, such as roadway type, roadway markings, traffic density, relation to junction, weather conditions, and lighting conditions, in order to define the driving context. Although not specific to reduction, the DAS also recorded vehicle variables such as vehicle speed and lane position, which allowed further description of the driving context for each sample.

In addition to the question reduction, a 15-second eye glance analysis was performed on all sampled driving automation system activations and RTIs. Eye glance reduction for SCEs was for the duration of the epoch. Eye glances were coded using methods previously standardized as part of SHRP 2 data analysis. Table 3 includes eye glance locations and on-road classification as coded across the data set.

Table 3. Coded Eye Glance Locations Classification

Eye Glance Location	On Road Classification
Center Dashboard Console	No
Interior Object	No
Cell Phone	No
Passenger	No
Over-the-Shoulder (left or right)	No
Eyes Closed	No
Instrument Panel	No
Other	No
No Eyes Visible - Glance Location Unknown	Unknown
Forward	Yes
Right Windshield	Yes
Rearview Mirror	Yes
Left Windshield	Yes
Left Window/Mirror	Yes
Right Window/Mirror	Yes

Data Analysis

This section describes both the variables that were used in the analyses and the methods of analysis that were performed for each RQ. The approach to analyzing the current NDS data was exploratory (as compared to an explicitly hypothesis-driven field operation test; FESTA Consortium, 2014). Two general types of analysis were conducted: descriptive and inferential. For the descriptive analysis, sample values of various metrics—such as means, standard deviations, medians, minimums and maximums—are provided. For the inferential analysis, statistical models of various types were built to assess whether any sample findings could be generalized to the population of drivers using lateral and longitudinal automation features. Answers to questionnaires on the usefulness, annoyance level, and ability to understand the driving automation system were tallied and analyzed using descriptive measures. The frequency of prompts (if applicable) 60 seconds prior to an RTI are reported. The time to react was reported for these prompts using descriptive statistics.

Independent Variables

For this study, an independent variable was any variable that may be associated with changes in the distribution of a dependent variable. Independent variables used in different RQs are listed in Table 4.

Table 4. Summary of Independent Variables

Variable	Category	Definition
Environmental Factors	Categorical	Various factors that affect driving scenarios (e.g., weather, locality, traffic density, traffic flow)
Week in Study	Numeric	Numeric week for a particular driver (1, 2, 3, 4)
Vehicle Specifications	Categorical	Vehicle type
Age Group	Categorical, Binary	25–39 or 40–54 years old
Gender	Categorical, Binary	Male, female
Driving Automation Activation Level	Ordinal	Whether both features are engaged, one feature is engaged, or neither feature is engaged
Improper use	Categorical, Binary	Whether the driver was observed using the driving automation system improperly

Dependent Variables

For this study, a dependent variable was any variable for which it was of interest to study changes based on an independent variable listed above. Dependent variables used in the different RQs are listed in Table 5.

Table 5. Summary of Dependent Variables

Variable	Category	Definition
Time to React to RTI	Numeric	Time in seconds from onset of RTI to first instance of a reaction
Time to Intervene After RTI	Numeric	Time in seconds from onset of RTI or prompt to first instance in which the driver intervenes
Method of First Response	Categorical	How driver first reacts to RTI or prompt
Subjective Ratings	Numeric	Likert-type scale ratings from drivers of study vehicles in terms of trust, expectations, usefulness, annoyance, and ease of understanding
Non-Driving Task Engagement	Categorical, Binary	Whether driver was engaged in a non-driving-related task
Non-Driving Task Type	Categorical	Type of non-driving-related task being performed, if any
Driving Automation Improper Use	Categorical, Binary	Whether driver was observed using driving automation system improperly
SCE Rate	Numeric	Rate of SCEs per hour of driving

Time to React and Time to Intervene

In all cases encountered in this effort, the desired intervention from the driver was focused on the vehicle's lateral control. This intervention requires the driver's hands to be on the wheel. Per RQ 1, the reaction and intervention to an RTI were calculated from the RTI onset. This calculation was only performed if the driver did not have their hands on the wheel at the RTI onset. Figure 9 shows an example approach to analyzing both time to react and time to intervene. Reaction time was assessed based on the first reaction to the RTI, which was either a glance to the instrument panel, a hand beginning to return to the wheel, or a foot beginning to brake (these encompass all reaction types observed; see Table 6 in Chapter 4 for percentages). Regardless of the first reaction, intervention time was computed based on when the participant returned a hand to the wheel. Based on these definitions, a participant had to first exhibit a reaction in order to intervene.

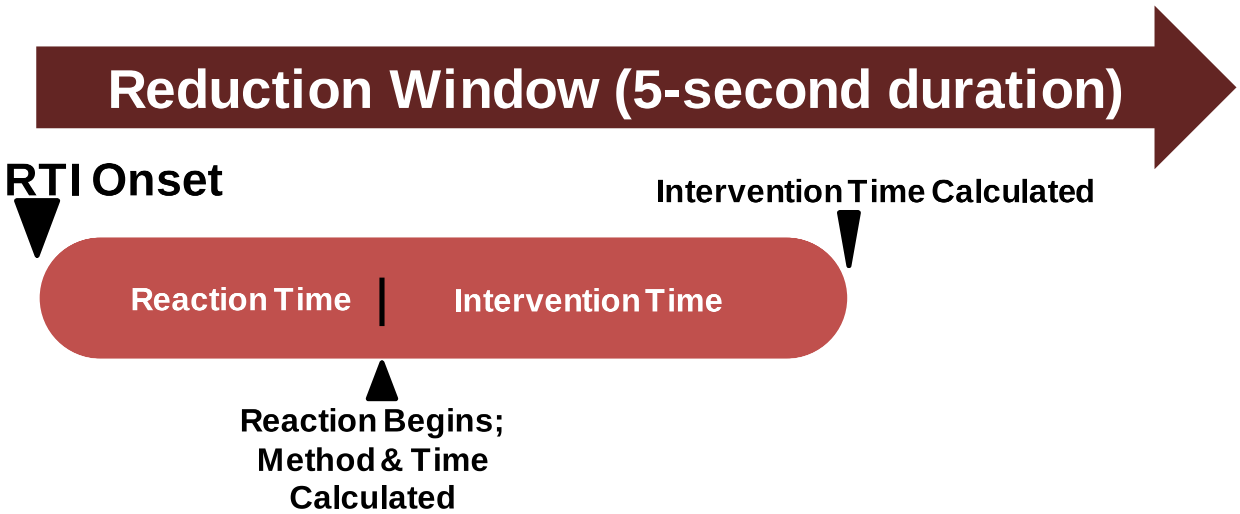

Figure 9. Sequence of Dependent Variables Pertaining to Driver Behavior Adapted from Previous Test Track Studies

If a participant did not react within the 5-second reduction window, even if the RTI state ended, or if the RTI state persisted through the entire reduction window (5 seconds), the participant was considered not to have reacted or intervened to the alert. A participant may also have reacted to an RTI, but not performed an intervention, particularly if a driver's hands were already on the wheel at the onset of the RTI. The reaction and intervention time results presented in the following chapter are specific to RTIs in which reactions and interventions were observed; however, a subset of RTIs without reactions or interventions are included as exemplars of this behavior.

Chapter 4. L2 NDS Results

In this section, the individual tests and the results of the analyses for the NDS are described for each RQ. Each RQ was examined via individual tests, either descriptive or inferential. For each RQ, the general approach is included, followed by individual tests.

System Performance

Focus area 3 investigated *System Performance*. An overview of the driving automation system characteristics for each vehicle is included in Chapter 2. Sampled and reduced data was used to provide insight into the overall performance and usage of the driving automation systems.

RQ 1.1: How does the combined lateral and longitudinal control system operate?

Approach: The system operation was investigated during the vehicle characterization effort, and differences between how study drivers operate the system vs. how the system was characterized were noted.

RQ 1.1.1: What are the total number of miles driven with both features engaged, one feature engaged, or no features engaged?

Overall, the systems performed in the manner expected based on the results of the characterization (see vehicle section in Chapter 2 for an overview of vehicle characterization for each vehicle; details of characterization are provided in Appendix D). Figure 10 shows a map of driving routes observed in the study. Across all 120 participants, 216,585 miles were driven (1,805 average per participant), with 53,359 miles driven below 40 mph. The remaining 163,226 miles were driven above 40 mph. Of these, 70,384 miles were driven with both lateral and longitudinal driving automation active, 50,454 with one feature active, and 42,388 with no features active. Figure 11 shows a breakdown of driving automation use as a function of distance driven each week. Miles driven without any features active are differentiated as available or not available by vehicle speed, and should be considered estimates. The mileage estimates are calculated across the entire data set. Note that it was not feasible for the entire data set to have the presence of lane markings verified by data reductionists.

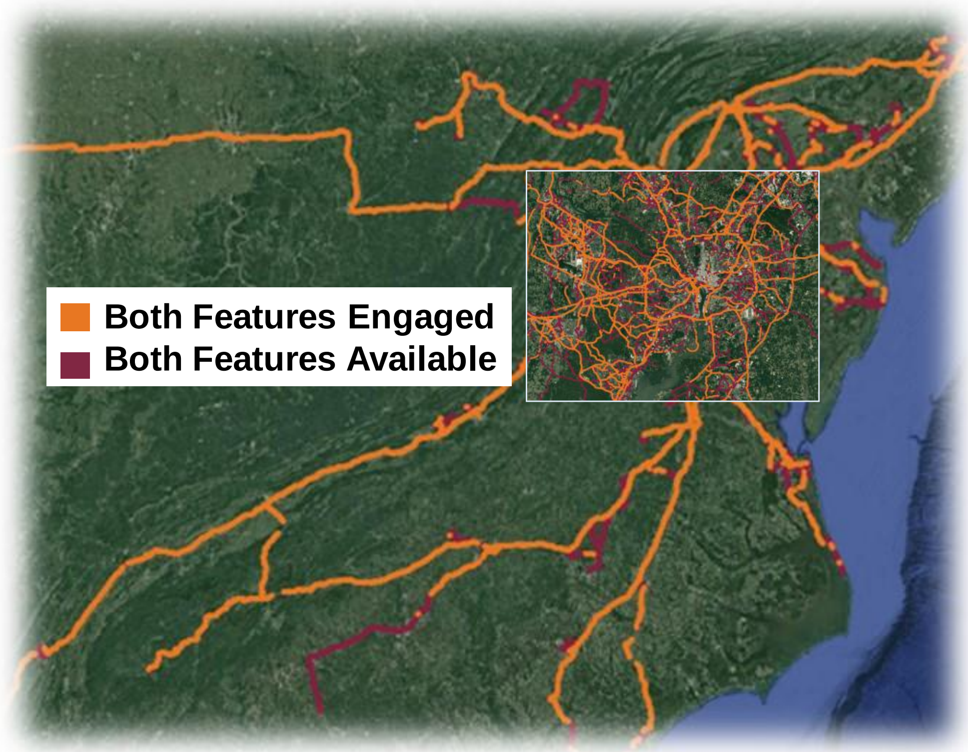

Figure 10. Map of Roads Driven in L2 NDS With Both Features Engaged (Orange) and No Features Engaged but Above 40 mph (Maroon)

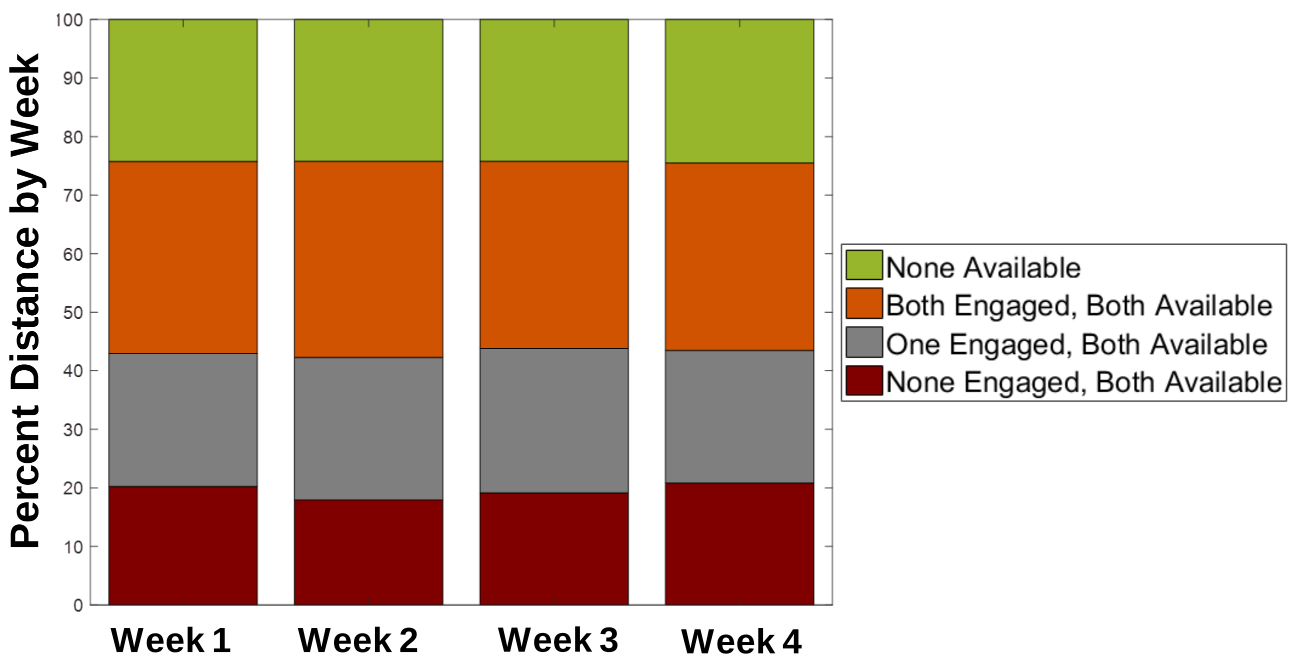

Figure 11. Breakdown of Driving Automation Activation for All Participants by Week

<u>**RQ 1.2:**</u> Are there environmental factors that reduce the use of the driving automation features?

Approach: The impact of traffic density, locality, and weather on driving automation system use were investigated per the individual tests below.

RQ 1.2.1: Are roadway scenarios in which driving automation is active different from roadway scenarios in which driving automation is available but is not engaged or only one feature is engaged?

This section compares differences in environments and traffic scenarios between instances where the features were engaged to instances in which they were not engaged. Environmental factors compared include locality, traffic density, weather, lighting, and traffic flow. Operational definitions of these variables are available in the most recent SHRP 2 data dictionary (VTTI, 2015). More information about the specific categories of these variables are available in Appendix J.

An ordinal logistic regression model was fit with the response variable: the ordered activation level (no features active, one feature active, and two features active).

Traffic density (F value = 12.65, p value <0.0001), locality (F value = 10.49, p value < 0.0001), weather (F value = 4.81 p value = 0.0002) and traffic flow (F value = 38.15, p value <0.0001) were all significant predictors of whether or not features were active at the time. Specific results for each of these variables are described below.

Traffic Density: Figure 12 shows the percentage of activations across traffic density types. Compared to free or stable maneuvering, participants were less likely to activate features in situations where traffic maneuvering was restricted (odds ratio = 0.82, 95-percent confidence interval 0.70 to 0.96).

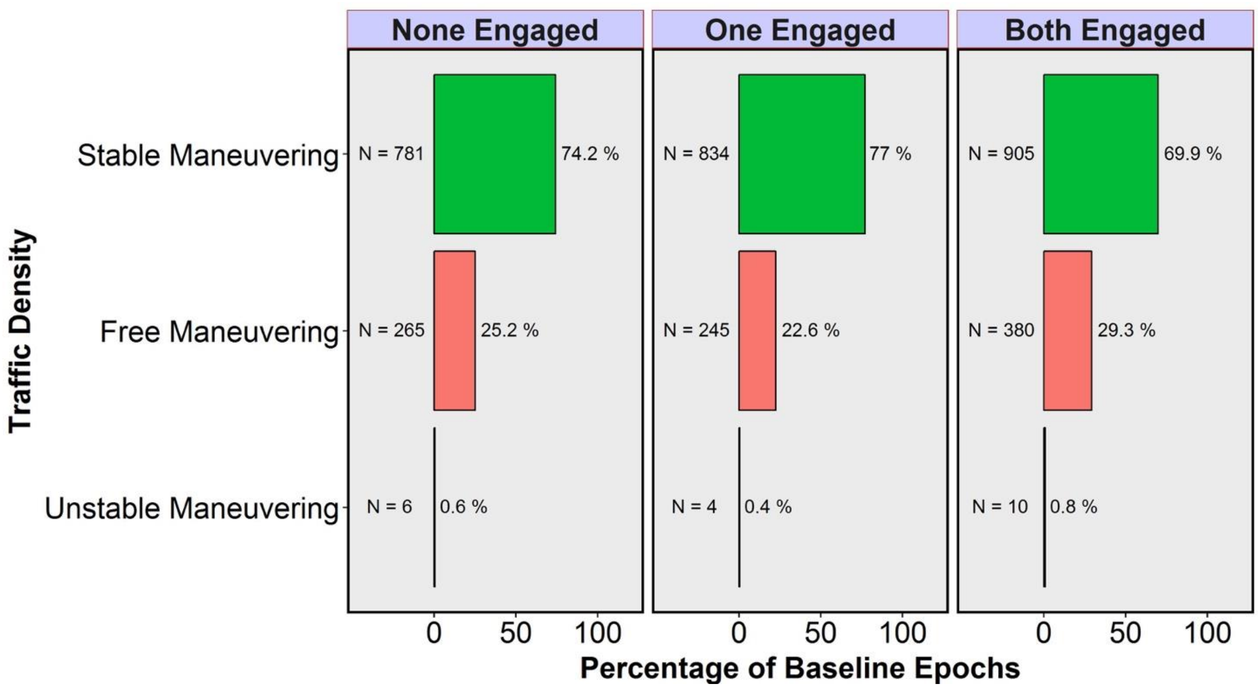

Figure 12. Feature Activation Level by Traffic Flow

Locality: Participants were more likely to activate features on interstate roads compared to business/industrial roads, whether the interstate was controlled access (odds ratio = 2.14, 95-percent confidence interval 1.66 to 2.76) or uncontrolled access (odds ratio = 1.45, 95-percent confidence interval = 1.03 to 2.05). Figure 13 shows percentage of activations across locality types.

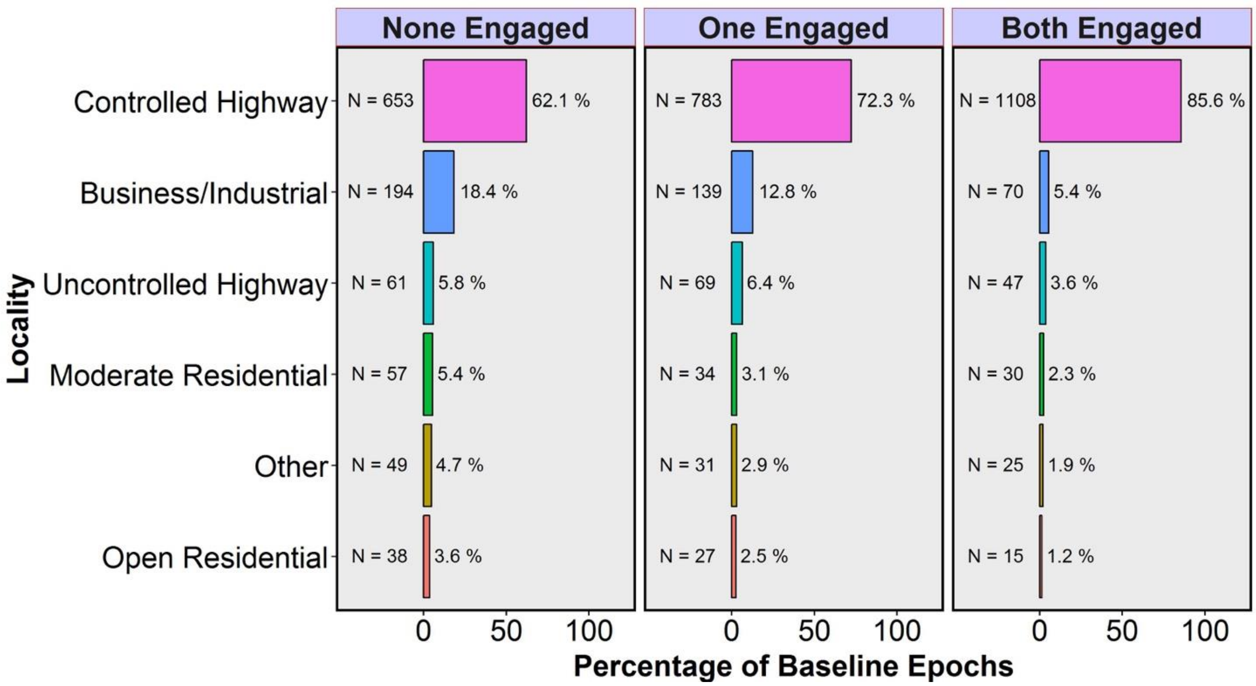

Figure 13. Locality Usage Across Activation Levels for Speeds Above 40 mph

Weather: Participants were less likely to activate the features during rain compared to clear weather (odds ratio = 0.53, 95-percent confidence interval = 0.39 to 0.70). Figure 14 shows percentage of activations across weather types.

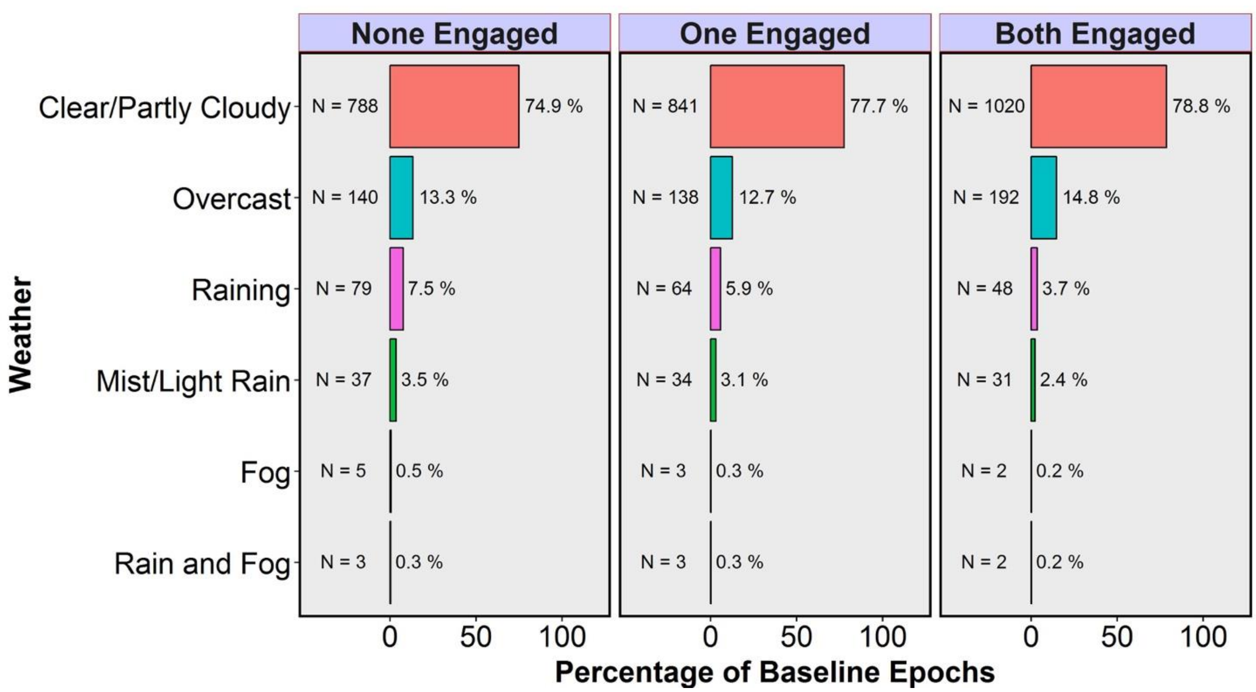

Figure 14. Weather Usage Across Activation Levels for Speeds Above 40 mph

Traffic Flow: Participants were less likely to activate features on roads in which traffic was one-way compared to roads in which traffic was two-way (odds ratio = 0.25, 95-percent confidence interval = 0.16 to 0.39). Figure 15 shows percentage of activations across traffic flow levels.

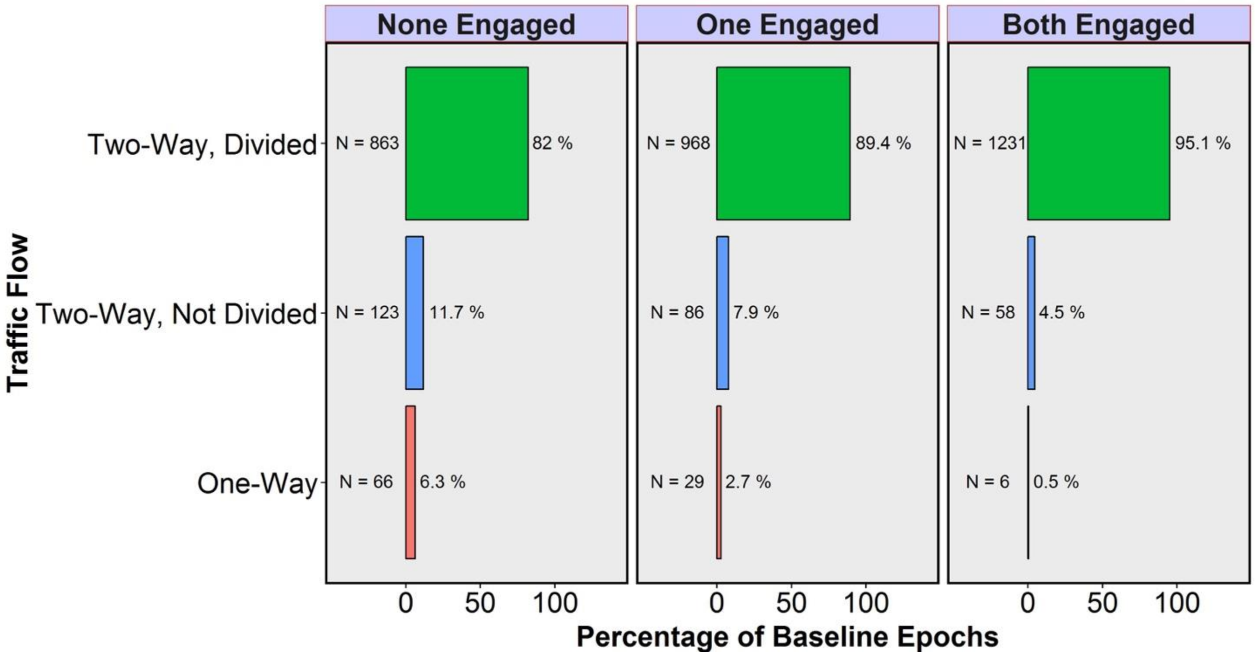

Figure 15. Traffic Flow Usage Across Activation Level for Speeds Above 40 mph

RQ 1.3 Were there additional system limitations observed during the study?

Approach: RQ 1 (see below) specifically investigates response time to RTIs. RTIs were sub-divided for analysis based on whether or not drivers had their hands on the wheel. This designation was based on the design intention of the RTI as adapted from previous work (Grove et al., 2016). Also of interest were SCEs, such as unintended lane departures, which may have occurred while the driving automation system was active, but for which no RTI was issued by the system.

SQ 1.3.1: What percentage of RTIs were observed where a driver did not have hands on the wheel, or in the context of an SCE?

No RTIs were observed in the context of an SCE. The diagram in Figure 16 shows how RTIs were divided based on whether or not a driver had a hand on the wheel at the onset of the RTI. In a total of 26.2 percent (118 total) of RTIs, drivers were observed to have no hands on the wheel, and in 73.8 percent (331 total) of RTI epochs, drivers were observed to have at least one hand on the wheel. Additional analysis of RTI times are included as part of the driver performance focus area.

Cases in which a driver's hands were off the wheel and there was no observed reaction (four cases) or no intervention (two cases) during the reduction window (red block in Figure 16) were reviewed individually; exemplars for these cases are reviewed in the driver performance section.

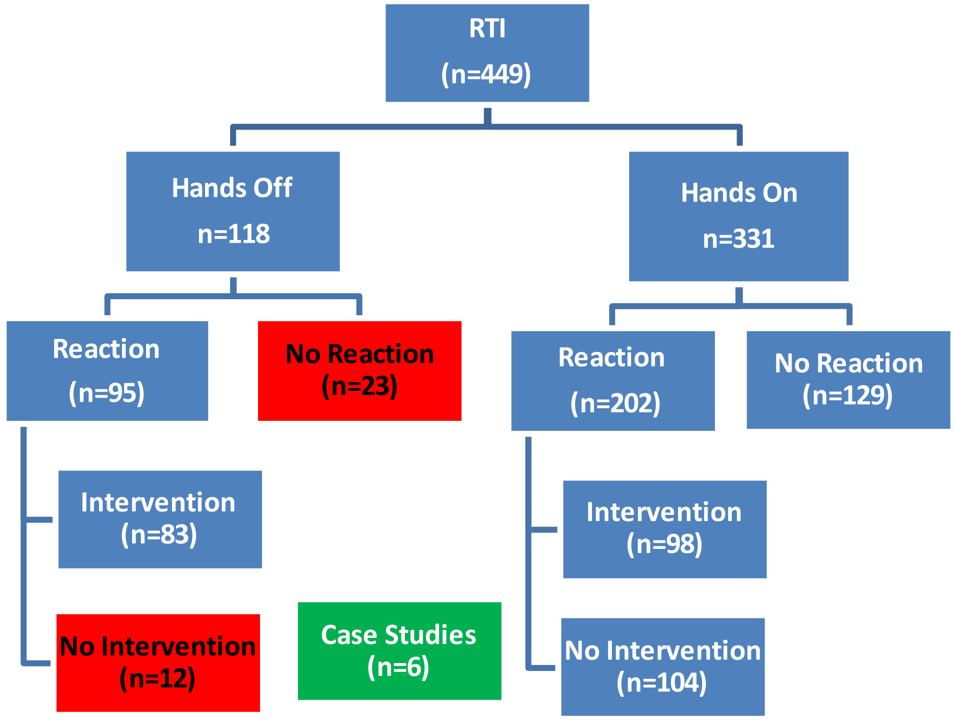

Figure 16. Diagram of RTI Classification With Count for Each Type

SQ 1.3.2: What is the frequency of situations in which the driving automation fails and does not give an RTI?

Participants did report on limitations of the lateral control features during weekly interviews (subjective responses are included in the Driver Engagement focus area). These limitations reported by participants were consistent with system performance observed during the characterization effort (e.g., system performance on curves) and were not associated with RTIs.

Driver System Interaction

This focus area was investigated using non-driving tasks prevalence and eye glance behaviors assessed during baseline epochs.

RQ 2.1: What driver behaviors were observed while the driving automation systems were engaged?

Approach: Prevalence and types of non-driving tasks performed by drivers when both lateral and longitudinal control features were engaged, when one feature was engaged, and when no features were engaged was investigated.

RQ 2.1.1: How likely were participants to perform a non-driving task while the driving automation systems were active?

The initial approach to addressing non-driving task prevalence was assessing the overall presence of any non-driving task. As shown in Figure 17, participants were observed to be just driving (absence of non-driving tasks) during 34.0 percent of events when none of the features were active, during about 38.0 percent of events when one feature was active, and during about 40.1 percent of events when both features were active.

In order to test this relationship, a mixed logistic regression model was fit with the performance of a secondary task vs. just driving as the binary response variable. The condition of L2 use (no features active, one feature active, and both features active) was the independent variable of interest. The model adjusted for environmental differences by including locality, weather, traffic density, and traffic flow, all of which have a significant relationship with the probability of activating the features, as indicated in RQ 3.2.1. The model also included participant variables such as age group, gender, and vehicle. Two models were fit: one testing the main effect of activation level, and one testing the interaction between activation level and week in study.

Activation level did not have a statistically significant relationship with the odds of performing secondary tasks (*F* value = 3.03, *p* value = 0.0506). There was no significant change over time in the relationship between activation level and the odds of performing a non-driving task (*F* value = 0.70, *p* value = 0.7065).

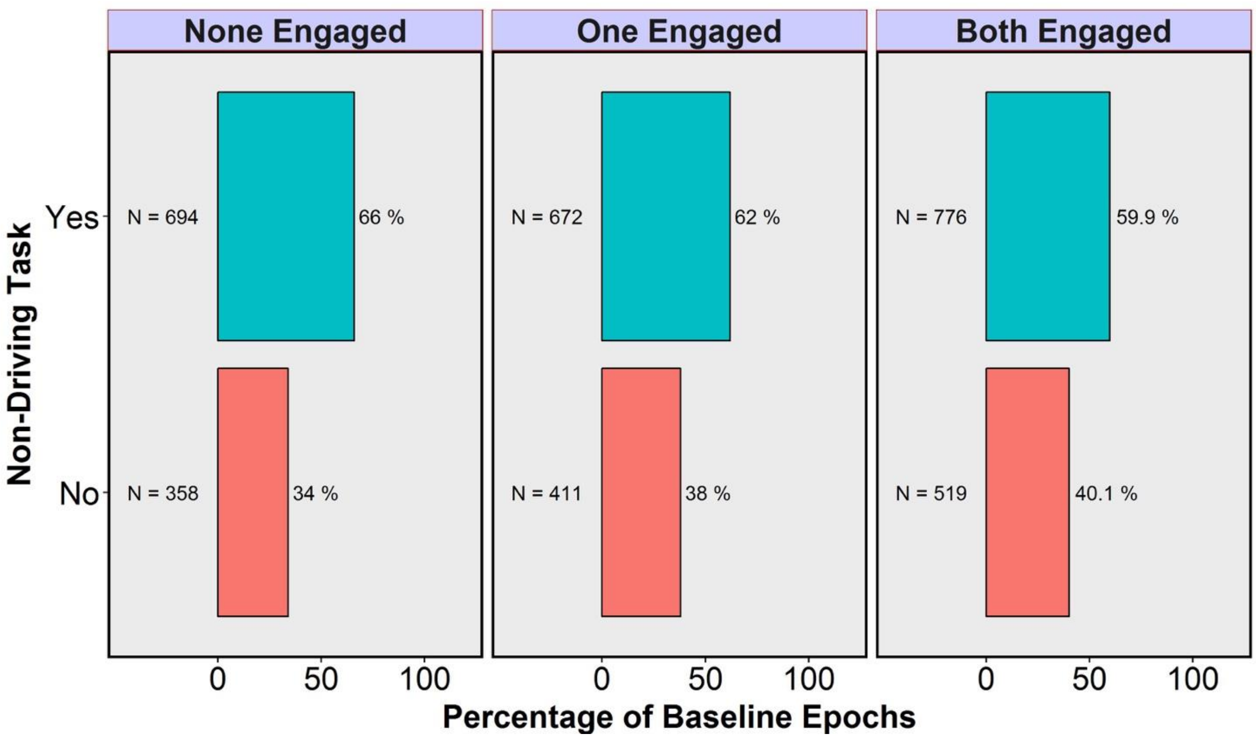

Figure 17. Secondary Task Prevalence by Feature Activation

The inferential results suggest that secondary task prevalence may not be significantly related to feature activation within the epochs sampled. However, even if prevalence is the same, the severity of tasks may be different. Eye glance metrics provide a method to address severity, as they are known surrogates for distraction. Eye glance reduction was used to compute percentage of eyes-off-road time (EORT), percentage of off road glances greater than 2 seconds, and average off road glance duration for each epoch. Figure 18 shows the results for EORT and the percentage of glances greater than 2 seconds by feature activation level for epochs where drivers were observed just driving vs. when a secondary task was present.

When participants were engaged in a non-driving task and both features were engaged, they had eyes off the road 13.2 percent of the time, compared to about 11.7 percent of the time when no features were engaged and about 11.2 percent of the time when one feature was engaged. This difference was not statistically significant (*F* value = 2.21, *p* value = 0.1101) after accounting for environmental factors (traffic density, traffic flow, weather, and locality) and demographic factors (age group, gender, and vehicle). Note that the higher observed percentage of off-road glances greater than 2 seconds when no task was performed was due to eight glances at the instrument cluster greater than 2 seconds when both features were engaged (there was one such glance when one feature was engaged and an additional one when no features were engaged).

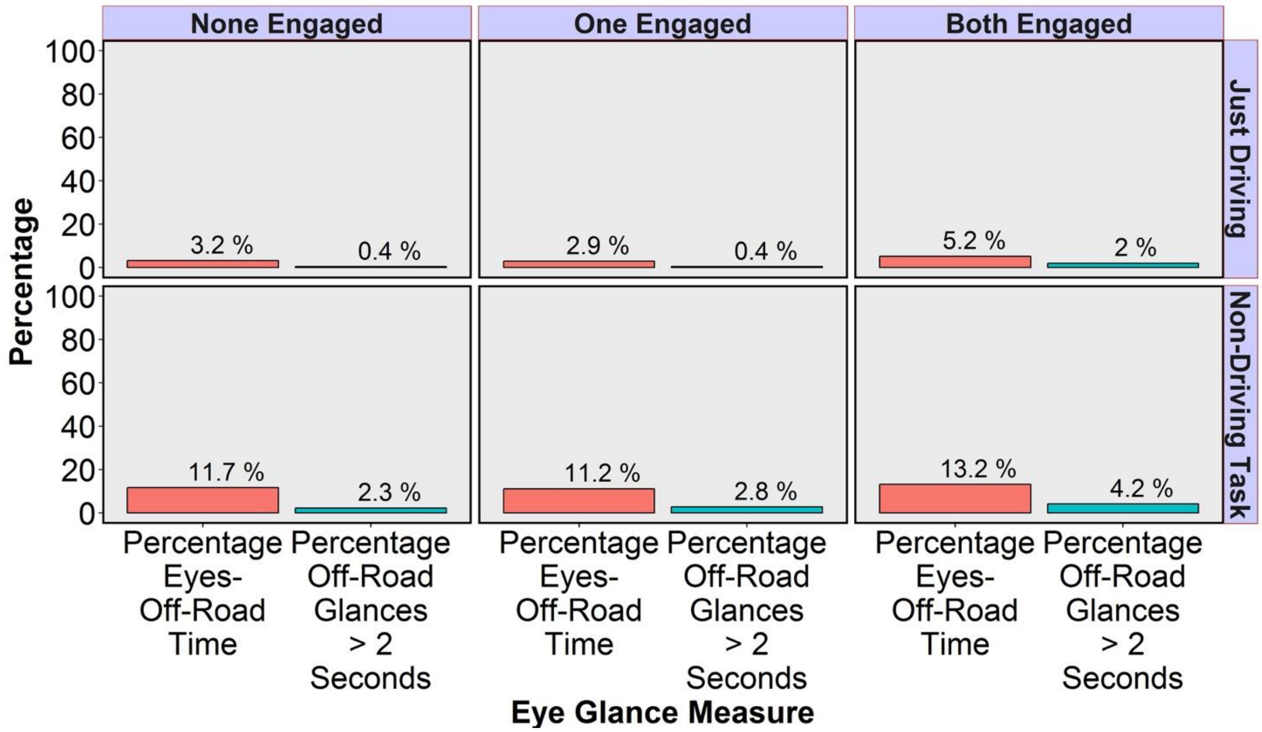

Figure 18. EORT Percentage and Off-Road Glances Greater than 2 Seconds for Epochs with and Without a Non-Driving Task Observed

RQ 2.1.2: What types of non-driving tasks did participants perform while the driving automation systems were active?

Figure 19 shows the most commonly observed non-driving tasks at the three different activation levels. Tasks that were observed less than 2 percent of the time are grouped together in the "Other" category. Note that participants may have engaged in more than one type of non-driving task during the event, so a particular event may be represented in more than one category. Therefore, the total percentages within each activation level will add up to more than 100 percent. A full list of non-driving tasks observed is included in Appendix J. The most common non-driving task was interacting with a passenger, followed by adjusting/monitoring the instrument panel. In about 17.7 percent of cases with both features active, participants were observed to be adjusting/monitoring the instrument panel (referring to items in either the instrument cluster or unspecified features of the center dashboard console). Where possible, items in the center dashboard console were differentiated (e.g., adjusting radio).

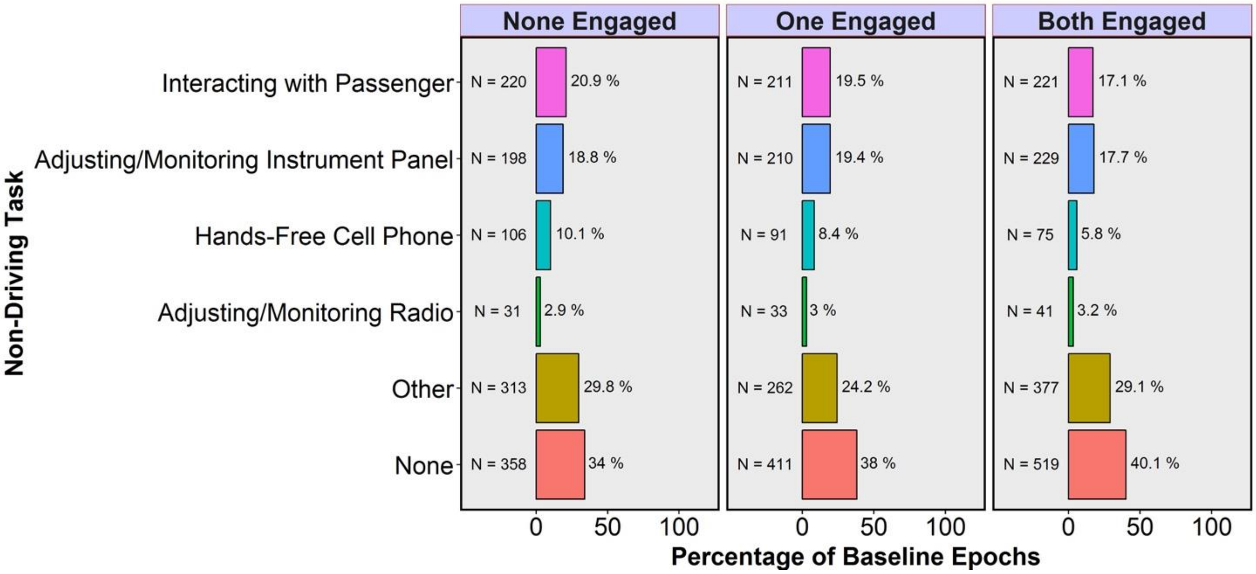

Figure 19. Percentage of Non-Driving Task Performance by Activation Level

As a further investigation on the types of non-driving tasks performed, non-driving tasks were categorized as Visual-Manual, Visual, Manual, or Cognitive based on NHTSA distraction guidelines (2016; definitions included in Appendix B). Figure 20 shows the prevalence for each category. Note that participants may have engaged in more than one type of non-driving task during the event, so one type of event may be represented in more than one category. Therefore, the total percentages within each activation level will add up to more than 100 percent. When participants performed a task, it was most often a cognitive task, performed in 39.0 percent of cases when neither feature was active, compared with 35.9 percent when one feature was active and 31.7 percent when both features were active.

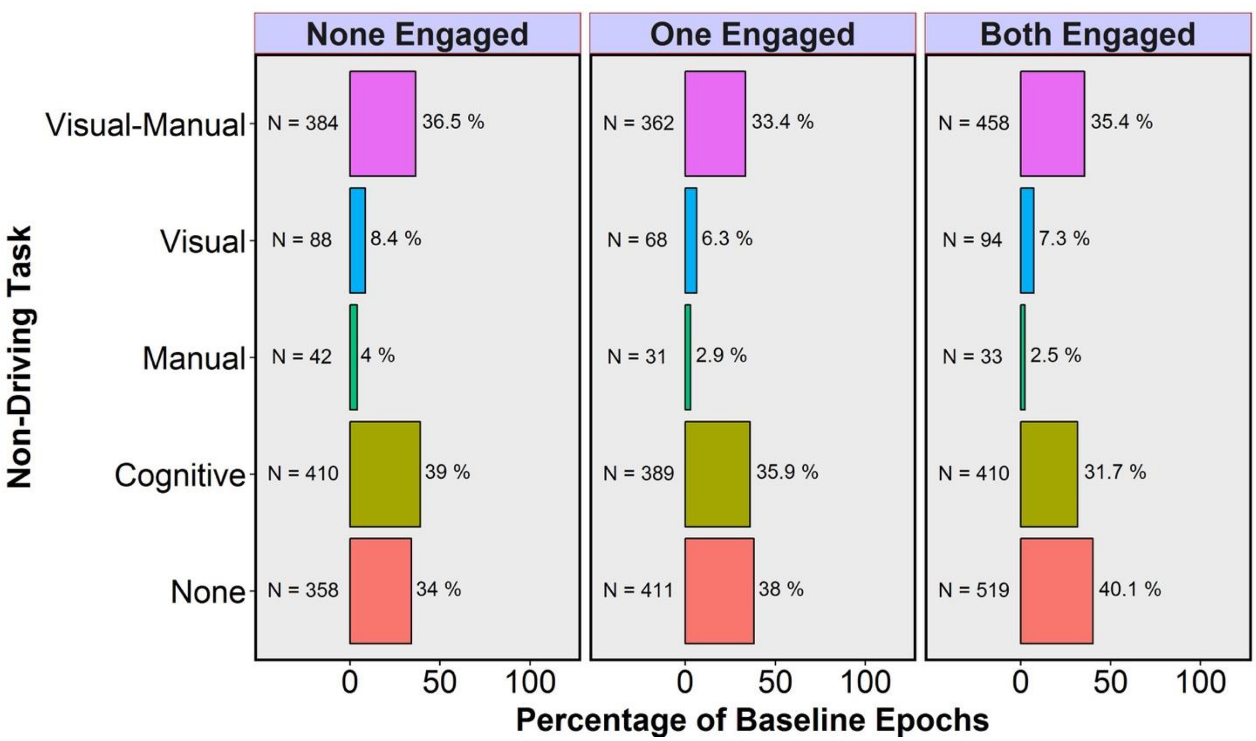

Figure 20. Task Type by Activation Level

Driver Performance

Driver performance was analyzed using drivers' responses to RTIs generated by the lateral driving automation systems, including analyses investigating changes to reaction and intervention times over the course of the study. Also included in this area are investigations of unintended use of the driving automation systems and unintended consequences associated with the driving automation systems.

RQ 3.1: How do drivers react to RTIs that are generated by the driving automation systems?

RQ 3.1.1. What is the manner of first reaction participants had to the RTI?

The analyses presented in this section include RTIs during which participants did not have hands on the wheel at the RTI onset. The percentages of first-response methods for the sampled RTIs are displayed in Table 6. When participants did respond to the RTI, the most common response was to reach for the steering wheel, or to look at the instrument panel while reaching for the steering wheel.

Table 6. Percentage of Reactions to RTIs

Steering Wheel	Reach for Wheel and Look at Instrument Panel	Instrument Panel Glance	Brake	No Response
40.68% (N = 48)	26.27% (N = 31)	11.86% (N = 14)	1.69% (N = 2)	19.49% (N = 23)

The sequence and timing of driver responses immediately prior to and then following an RTI until the driver intervened were investigated via the individual tests outlined below. Reaction and intervention times to the sampled RTIs were examined within the 5-second reduction window.

RQ 3.1.2 & **3.1.3:** How quickly did participants react to the RTI? If there was a reaction, how quickly did participants intervene after the RTI?

As noted previously, of the 449 sampled RTIs, 26.28 percent (N = 118) occurred when a driver did not have hands on the wheel, with hands on the wheel observed during the remaining 331 epochs.

For RTIs with hands off wheel, participants either glanced at the instrument cluster, reached for the wheel, did a combination of both, or pressed the brake pedal in response to the RTI within 5 seconds of its onset 80.51 percent (N = 95) of the time. In 19.49 percent (N = 23) of the cases, participants did not appear to react within the 5-second reduction window.

Figure 21 shows the reaction times across each week in the study for all reaction types. For the 95 cases where a reaction was observed, the mean time to react was 0.94 seconds (S.E. = 0.09 seconds, min = 0.03 seconds, max = 4.50 seconds).

Figure 22 shows the intervention times for each week in the study. Participants put at least one hand back on the wheel within 5 seconds 70.34 percent (N = 83) of the time, and did not do so 29.66 percent (N = 35) of the time. In cases where the participant intervened in response to the RTI, the mean time to intervene was 1.79 seconds (S.E. = 0.11 seconds, min = 0.32 seconds, max = 4.60 seconds).

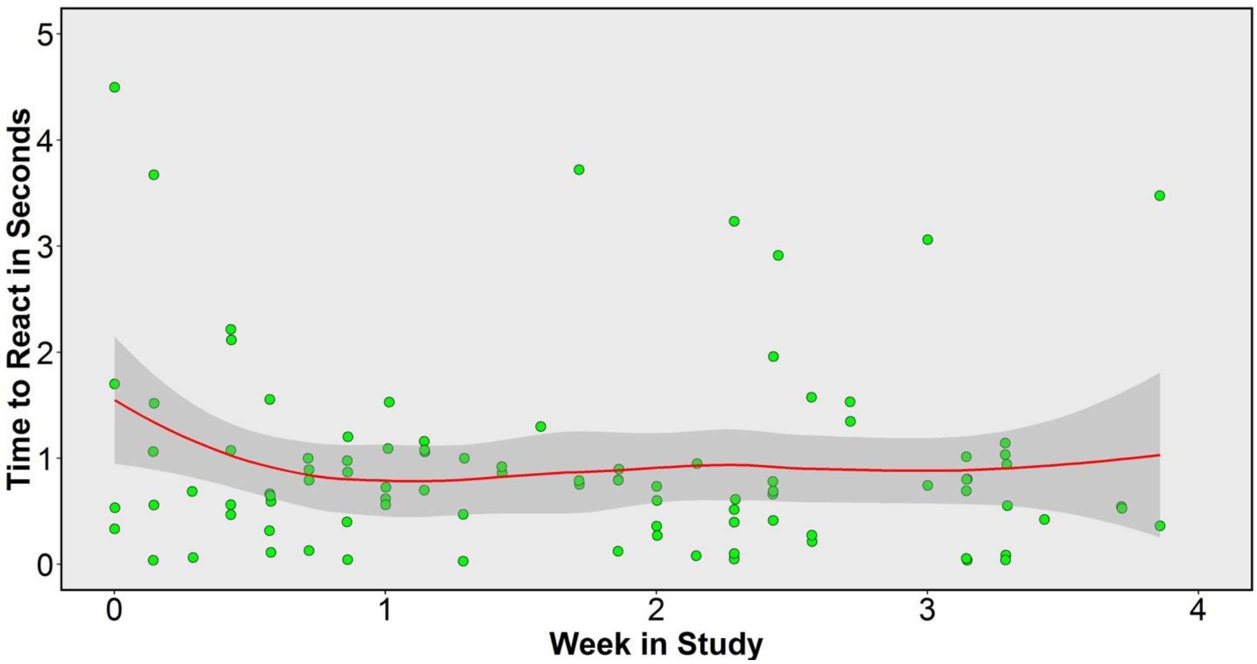

Figure 21. Reaction Time in Seconds for Each Week in Study for the 118 RTIs Without Hands on the Wheel at Onset

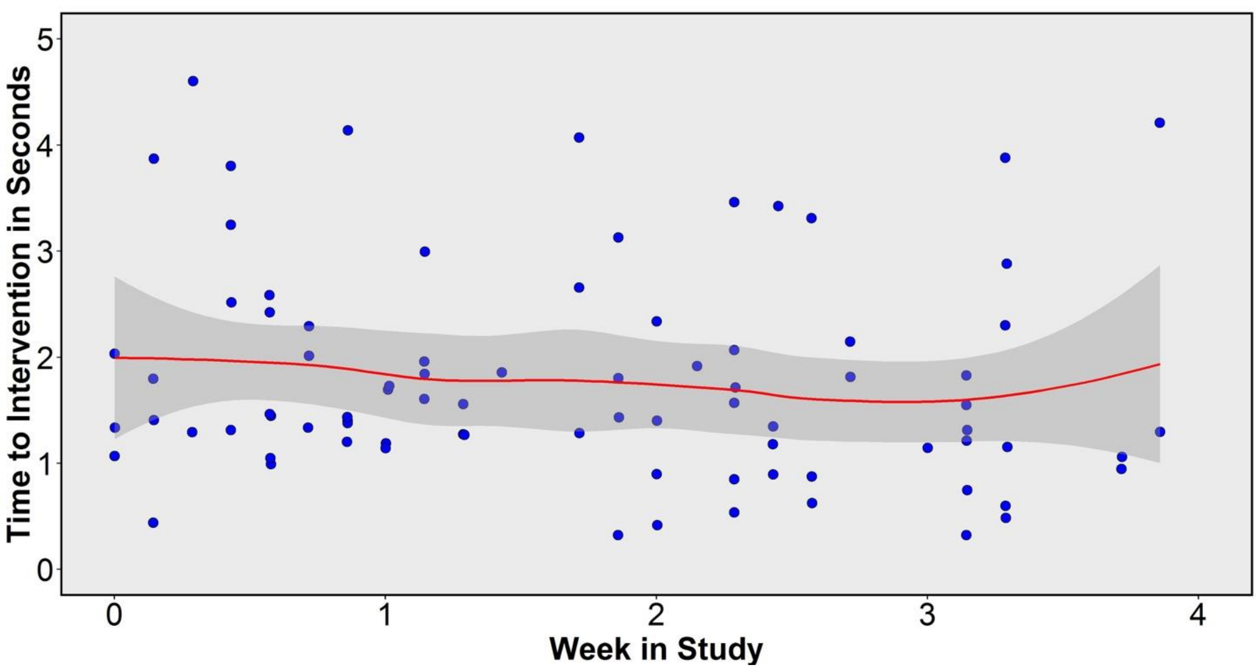

Figure 22. Intervention Time in Seconds for Each Week in Study for the 118 RTIs Without Hands on Wheel at Onset

RQ 3.1.4: Was the reaction and intervention time in response to the RTI different across different scenario severities?

Time to react and time to hands on wheel were both modeled to determine if there was a change across traffic scenarios. An accelerated failure time model with a random intercept for each participant was used to model changes in time to react and time to hands on wheel. The scenarios investigated included locality (highway vs.

non-highway) and traffic density (free flow vs. not free flow). Locality was not significantly associated with reaction time (*t* value = -0.03, *p* value = 0.9737) or time to hands on wheel (*t* value = -0.55, *p* value = 0.5844). Traffic density was also not associated with either time to react (*t* value = -1.19, *p* value = 0.2400) or time to hands on wheel (*t* value = -0.34, *p* value = 0.7326).

RQ 3.2: How do drivers change their behavior over time?

The differences in driver responses to RTIs between the first week of driving automation system use and the final week of driving automation system use were investigated.

RQ 3.2.1: Did participants' time to react or time to intervene after an RTI change significantly over time?

The models fit for time to react and time to hands on wheel shown in Figure 21 and Figure 22 also included the week in study to determine if there were significant changes in these response times over the course of the study. Reaction time (*t* value = -0.96 *p* value = 0.3437) did not significantly change over time in the study. Time to intervene (*t* value = -2.23, *p* value = 0.0314) did change significantly over the course of the study. Specifically, the estimated relative change in time to hands on wheel was a decrease of 10.34 percent (95-percent confidence interval 10.2 percent to 18.80 percent). However, this significant change was due to four RTIs (from four different participants) in the first week when drivers were intentionally keeping their hands off the wheel in order to test the system. When these cases are removed, time to hands on wheel no longer changes significantly over time (*t* value = -0.45, *p* value = 0.6549). More detail on these four cases is included in RQ 1.1.5.

RQ 3.2.2: Was the manner of first reaction to the RTI different across different driving scenarios?

There was no difference in the manner of first response based on driving scenario. However, as noted in RQ 1.2.1, a specific type of non-response was exhibited by participants. In these instances, the participant was intentionally not responding to the RTI; it is inferred that this behavior was intended to explore the boundaries of the system. While participants' hands are not on the wheel, they can be observed hovering over or otherwise placed very near the wheel. These types of behavior occurred most often during the first week of participation, although there were instances throughout participation. There were few secondary tasks present during these scenarios, other than the driver describing the lateral driving automation system to a passenger. Exploratory behaviors occurred in situations where scenario severity was low (e.g., typically free flowing traffic, clear weather, daytime, eyes on road).

Table 7 summarizes the four cases where no reaction was observed within 5 seconds (the aforementioned four cases excluded from the reaction over time analyses), along with two cases where there was a reaction but no intervention within the reduction window.

Table 7. Summary of Six Example Cases of Participants Exploring Lateral System Boundaries.

Epoch Type	Day in Study	Hand Position at Epoch Start	Eye Glance at Epoch Start	Road Type	Traffic	Weather	Time of Day	Speed at Epoch Start
Did not Intervene	6	Lap	Forward	Interstate	Free Flow	Clear/Partly Cloudy	Day	75 mph
Did not Intervene	7	Hovering	Forward	Interstate	Free Flow	Clear/Partly Cloudy	Day	60 mph
Did not React	3	Hovering	Forward	Interstate	Free Flow	Clear/Partly Cloudy	Day	75 mph
Did not React	1	Hovering	Forward	Interstate	Free Flow	Clear/Partly Cloudy	Day	77 mph
Did not React	1	Hovering	Forward	Interstate	Stable Flow	Clear/Partly Cloudy	Day	58 mph
Did not React	5	Lap	Forward	Residential	Free Flow	Clear/Partly Cloudy	Day	30 mph

RQ 3.2.3: Did the probability of performing a non-driving task while driving automation was active change significantly over time?

The probability of performing a non-driving task before the RTI onset was investigated to determine if there was a change over time in the study. For this model, the binary response variable was whether or not the participant was performing any sort of non-driving task at least 1 second prior to the RTI onset, with the aforementioned demographic, environmental, vehicle, and time in the study as independent variables. There was no significant change over time (F value = 0.00, p value = 0.9440).

RQ 3.3: Does using driving automation systems for long durations change any driving performance measures or otherwise impact driver behavior?

The average trip length for baseline epochs was 52.99 minutes (S.E. = 0.69 minutes, min = 2.02 minutes, max = 186.71 minutes). For this analysis, a k-means cluster algorithm with three clusters was used to divide the trips into groups based on trip length. The shorter-trip cluster contained 1,447 trips, with a mean trip length of 32.78 minutes (S.E. = 0.32 minutes, min = 2.02 minutes, max = 51.03 minutes). The middle-trip cluster contained 867 observations, with a mean trip length of 71.00 minutes (S.E. = 0.59 minutes, min = 51.14 minutes, max = 121.48 minutes). Finally, the longer-trip cluster contained 128 trips, with a mean trip length of 159.42 minutes (S.E. = 2.09 minutes, min = 122.19 minutes, max = 186.71 minutes).

For baseline epochs, participants were more likely to activate at least one feature during longer trips than during medium or shorter trips. Participants activated at least one feature in about 84.98 percent (N = 215) of baseline epochs from longer trips, compared to about 77.31 percent (N = 1,002) of baseline epochs from medium trips, and 70.87 percent (N = 1,333) of baseline epochs from shorter trips. This result was statistically significant (*F* value = 9.55, *p* value <0.0001).

Participants were more likely to perform a non-driving task on longer trips than on medium trips or shorter trips. A non-driving task was identified in 77.87 percent (N = 197) of baseline epochs from longer trips, compared to about 61.27 percent (N = 794) of epochs from medium trips and 60.62 percent (N = 1,151) of epochs from shorter trips. This difference was statistically significant (*F* value = 10.88, *p* value <0.0001). The specific task that contributed the most to this difference was talking with a passenger in the adjacent seat, which occurred in about 32.02 percent (N = 81) of epochs from longer trips, compared to about 14.81 percent (N = 192) of epochs from medium trips and 12.81 percent (N = 241) of epochs from shorter trips.

Additional analyses of trips with durations of 2 hours are included as part of the LD Sub-Study reviewed in Chapter 5.

RQ 3.4: Unintended Use: Hands-on-wheel behavior for the previous analyses in the Driver Performance focus area was specific to hands-on-wheel at the onset of an RTI. However, also of interest was the number of cases where improper use of the systems was observed in other baseline epochs. There were no clear instances of drivers defeating the lateral or longitudinal driving automation systems. However, other types of improper use were observed. Drivers were observed with hands off the wheel during baseline epochs (e.g., not associated with an RTI) and driving automation systems were observed to be active on improper roads as well as in improper weather conditions.

RQ 3.4.1: What proportion of driving automation use is improper use?

Improper use of automated features was investigated in the 1,295 epochs when both features were active. A participant was defined as improperly using the features if at least one of the following three conditions was true during the baseline epoch:

- There was visual evidence that both hands and all fingers were off the wheel during the epoch.
- It was raining during the epoch (no instances of snow or dense fog were observed in the samples taken).
- The participant was not driving on an interstate road or divided highway.

In total, there were 247 instances (19.07 percent) where both features were active that were indicative of improper use. Of this total, in 45 instances, the participant did not have hands on the wheel; in 81 instances, the participant was using both features while it was raining; and in 140 instances, the participant was using the driving automation features on an improper roadway. In 19 of the improper use cases, participants were observed with more than one condition for improper use. In 13 of these instances of multiple improper use conditions, the participant was using the features on an improper road type while it was raining. In the remaining six instances of multiple improper use conditions, the participant did not have hands on the wheel while driving on an improper road type.

In addition to these types of improper use, reductionists were trained to note any extreme or obvious instances of drivers abusing the driving automation, for example attaching a foreign object to the wheel to suppress RTI alerts. No instances of this type of behavior were observed in any of the sampled epochs.

RQ 3.4.2: Does the likelihood of driving automation improper use, compared to driving automation use that is not improper, change over time?

A mixed logistic regression model was fit to model the probability of misusing the features when both features were active, with week in study as the independent variable of interest, and age group, gender and lateral/longitudinal trust as covariates. Week in study was not significantly associated with the probability of misusing the features (*F* value = 0.04, *p* value = 0.9887).

RQ 3.5 Unintended Consequences: The primary method for exploring unintended consequences was categorization and count of SCEs that were observed when driving automation was active. Table 8 shows the breakdown of SCEs observed in the data set by feature activation level and event severity. Similar to the sampling strategy outlined above, when no features were active, the availability of driving automation was estimated using vehicle speed. The majority of SCEs occurred with no features active and below 40 mph.

Table 8. Total SCEs Observed in Data Set by Feature Availability Level

SCE Type	Both Features Active	One Feature Active	No Features Active, speed above 40 mph	No Features Active, speed below 40 mph	Study Total
Crash	1	0	0	4	5
Near-Crash	12	11	7	36	66
Combined	13	11	7	40	71
Miles	70,340	50,454	42,431	53,360	216,585
Rate of Combined SCEs per 1,000 Miles	0.18	0.22	0.16	0.75	0.33

In total, there were five crashes observed in the data set. All crashes were low severity, rated as level 3 or level 4 based on previously adapted SHRP 2 definitions (VTTI, 2015). The single crash with both features active was a single vehicle crash in which the driver struck a toll lane access gate at low speed (the driver attempted to enter a “buses only” entrance). Although both features were active at some point during the reduction window, the driver pressed the brake prior to impact, overriding the driving automation features. The driver was not distracted and had at least one hand on the wheel throughout the event. No damage to the gate or vehicle was observed in this instance. Of the four remaining crashes, three were curb strikes in which the driver struck a sidewalk, curb, or median divider. The remaining crash occurred during a low speed parking maneuver.

For the near-crash events with both features active, the most common type was a rear end-striking event (n = 9), in which the driver performed a hard-braking event in response to a lead vehicle. In one of these events, the driver did not have either hand on the wheel. For three of these events, there was a secondary near-crash event with a following vehicle. In all other cases, there was visual evidence that the driver had a hand on the wheel.

The second most common event was a sideswipe conflict with a vehicle in an adjacent lane or merging vehicle (n = 3), in which the participant braked hard in reaction to another vehicle merging or drifting into their lane. In one of these near-crash events, there was evidence of distraction but the driver had at least one hand on the wheel.

RQ 3.5.1: How does the SCE rate per mile of driving differ between both features engaged, one feature engaged, and no features engaged?

One crash and 30 near-crashes occurred during about 163,225 miles of driving when the automated features were either active or available. The crash was listed as a level 3, or “minor” crash. Table 8 displays SCE counts and mileage within different activation levels.

A mixed Poisson regression model was fit to compare the SCE rate per mile driven at different activation levels, with age group and gender as covariates, and the log of total miles driven as an offset. Different activation levels were not found to have significantly different SCE rates (F value = 0.38, p value = 0.6841).

Driver Engagement

Focus area 4 investigates *Driver Engagement*, which includes analyses of driver responses to prompts. Prompts are early, visual-only stages leading to multi-modal RTIs observed while the driving automation systems were active. Also included in this section are results from subjective questionnaires administered each week of the study, which include facets of driver engagement, comfort, and trust.

RQ 4.1 If available, how do drivers respond to system prompts?

Some study vehicles included visual-only stages of an alert before a multi-modal RTI in order to keep the driver engaged or aware when the driving automation systems were active. Responses to prompts were investigated during the window of time prior to an RTI. Given the timing and sequence of the various RTI stages, it was only possible for a participant to receive one pre-RTI prompt within the time window.

RQ 4.1.1: What was the manner of reaction to the prompt?

When participants responded to the prompt, they always did so by reaching for the steering wheel.

RQ 4.1.2: How quickly did participants react to a prompt?

There were three vehicles that provided prompts just prior to the RTIs. Drivers of these vehicles did not respond to 83.73 percent (N = 108) of the prompts; the prompt response rate was only 16.27 percent (N = 21). All of the prompts evolved into RTIs.

Given that the prompts were early stages of an RTI (i.e., if a driver did not respond to a prompt, it would evolve into an RTI), responses to prompts may be reflected in overall RTI response times, rather than as specific reaction to a prompt itself. It is possible that the presence of early stage visual alerts decreased reaction times or otherwise influenced reaction times to RTIs.

An exploratory analysis of reaction and intervention times between vehicles with and without prompts was conducted. Of the 118 RTIs without hands on wheel, slightly more than half were observed in vehicles with a visual prompt (58 percent, N = 68), with the remaining RTIs occurring in a vehicle without a prompting system (42 percent, N = 50).

For these 95 RTIs with a reaction, 61 occurred in vehicles with a prompting system, compared to about 34 for vehicles without a prompting system. The mean reaction time when participants did react was 0.83 seconds (S.E. = 0.09 seconds, min = 0.04 seconds, max =3.67 seconds) for vehicles with a prompting system, compared to a mean of about 1.12 seconds (S.E. = 0.20 seconds, min = 0.03 seconds, max = 4.50 seconds) for vehicles without a prompting system.

When a reaction was observed, participants intervened within the 5-second window about 67 percent of the time (N = 56) in vehicles with a prompting system, compared to about 33 percent of the time (N = 27) in vehicles without a prompting system. The mean intervention time when participants did intervene was 1.81 seconds (S.E. = 0.14 seconds, min = 0.32 seconds, max =4.60 seconds) for vehicles with a prompting system, compared to a mean of about 1.74 seconds (S.E. = 0.19 seconds, min = 0.32 seconds, max = 4.07 seconds) for vehicles without a prompting system.

RQ 4.2: Do drivers report that the driving automation systems function as they would expect?

Drivers were asked about their opinions of the driving automation features throughout their participation, in addition to overall level of trust. Analyses specific to trust ratings are addressed in RQ 4.4.

Overall, changes in driver expectations about the driving automation systems were noted. Specific comments about aspects of the driving automation features (e.g., RTIs, displays) that drivers found more useful, or conversely, difficult to understand, misleading, or annoying are summarized here. Drivers were asked to respond to subjective questionnaires on a weekly basis. Open-ended comment results reported here are summarized based on common themes.

For longitudinal control features, Figure 23 includes total comments received for the following themes. Responses were collapsed across all study questionnaires; however, a comment was only counted once, even if the participant mentioned the same thing multiple times.

- Hard braking to slowed traffic: Longitudinal system brakes in an abrupt or hard fashion.
- Delay in System Reaction: Participants observed slowed traffic before the system started to respond.
- Limited Sensor Range: Sensor-related comments, including not detecting adjacent or merging vehicles.
- Delayed Acceleration After Stopping: Longitudinal systems are slow to resume a set speed after coming to a stop in traffic.
- Safety Concerns: Safety concerns with longitudinal control features.
- Following Distance Too Far: Following distance/headway settings in the vehicle allowed for traffic to cut in front.
- Problems With Activation Method: Comments about how the systems were activated.
- Function Was Inconsistent Overall: Descriptions of the general function of the longitudinal system.

For lateral control feature feedback, the following themes are summarized in Figure 24.

- Lane Centering Problems: System did not “center” the vehicle in the lane or other lane keeping problem.
- Overall System Improvement: General overall lateral system improvement suggestion not captured by another category.
- RTIs Confusing or Annoying: RTIs confused or annoyed the driver.
- Curve Performance: Vehicle performance related to road curvature.
- Problems With Activation Method: How the systems were activated.
- Safety Concerns: Safety concerns with lateral control features.

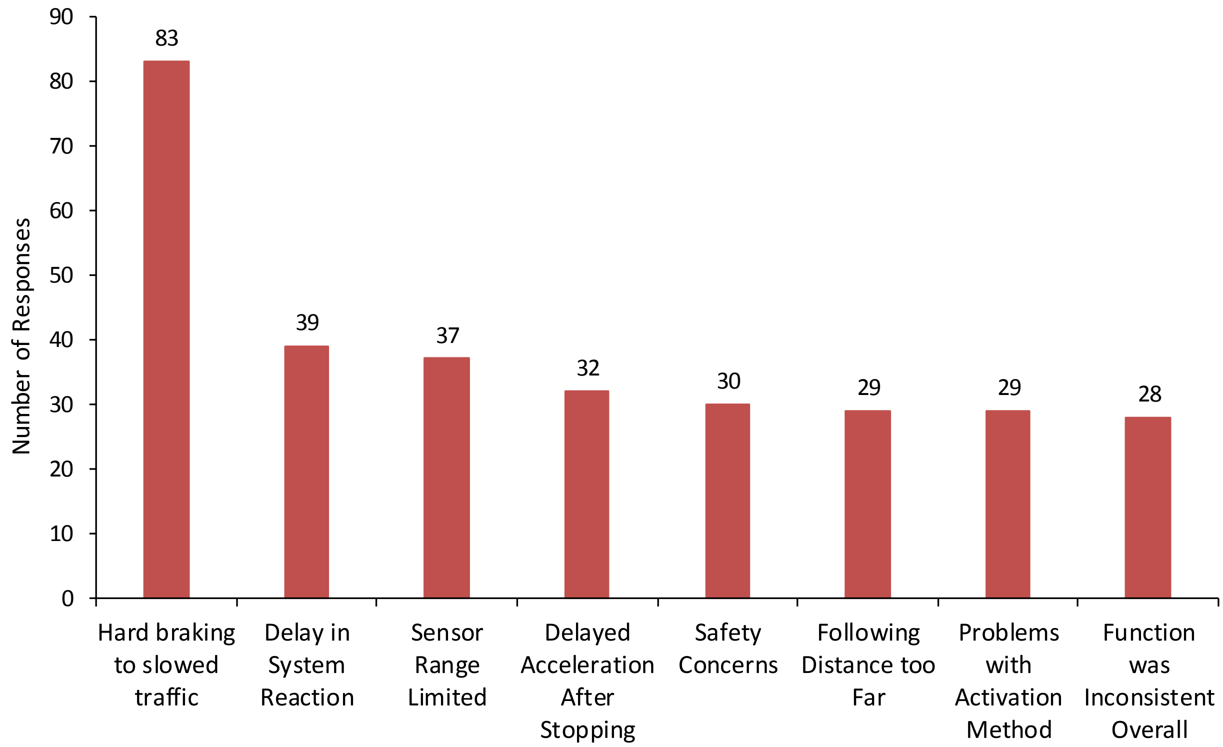

Figure 23. Summarized Feedback on Longitudinal Control Features

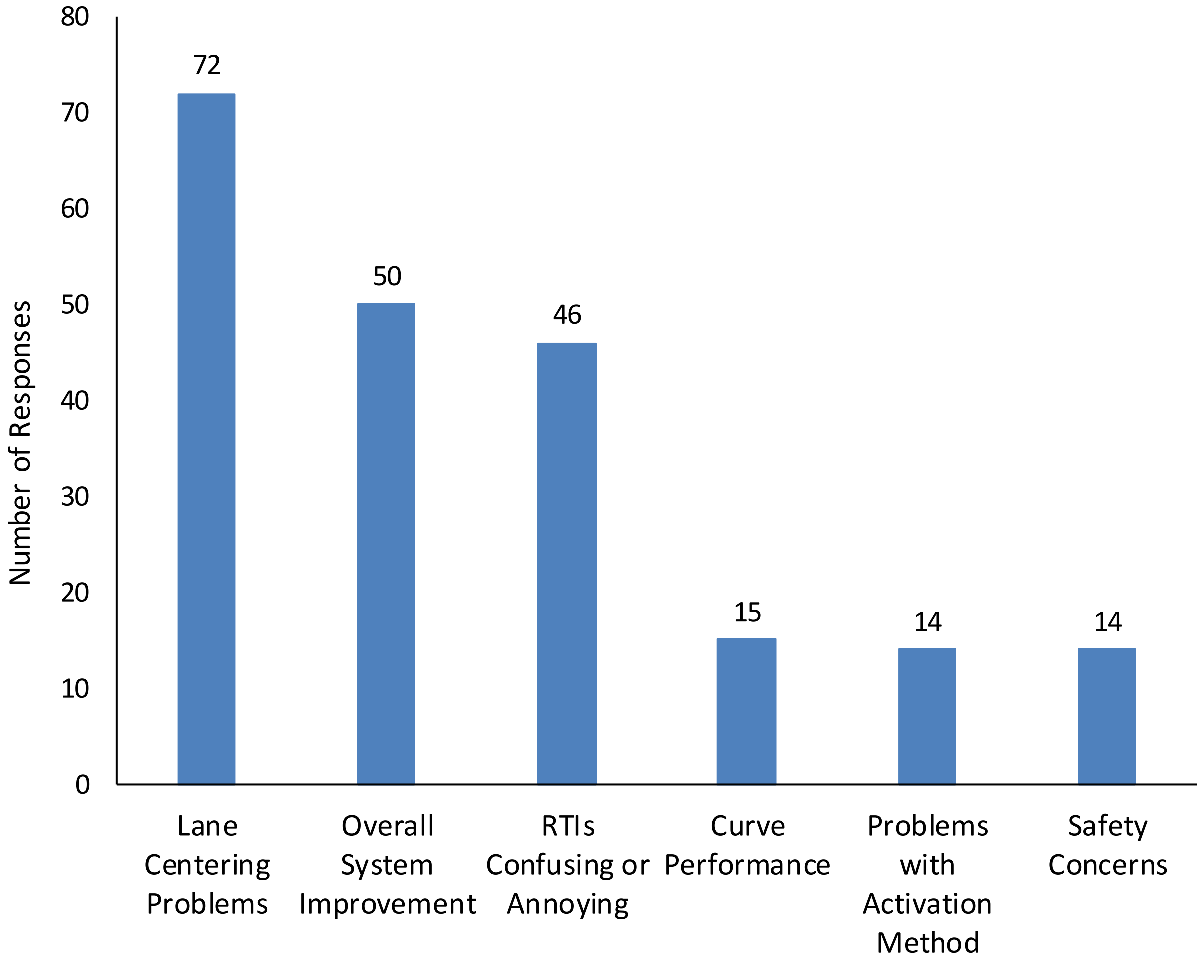

Figure 24. Summarized Feedback on Lateral Control Features

RQ 4.2.1: Do participants rate the driving automation functioning as close to expectations, above expectations, or below expectations?

The most common comment received for longitudinal functions (Figure 23) was that participants expected the system to brake sooner than it did. When the longitudinal system did slow the vehicle, participants described the system response as a hard-braking event. With the lateral system (Figure 24), participants expected the system to actively center the vehicle in the lane, which was outside of the capability of the majority of the systems.

RQ 4.3: Do drivers report different expectations across various types of roadways, driving conditions, speeds, etc.? That is to say, when asked for their opinions, do drivers recognize the limitations of the driving automation systems?

Drivers did not comment on specific road types, although the results for system activations show participants were most likely to activate the systems where they were designed to be used (closed access highways).

In limited cases, participants may not have understood the full limitations of the lateral systems on curves. In 15 instances, drivers did comment that the lateral system did not function well on curves, which is a noted limitation of the systems and was covered during vehicle training.

RQs 4.3.1: Which aspects of the driving automation system did participants rate as useful or, inversely, annoying? Which aspects of the driving automation system did participants rate as easy or, inversely, difficult to understand?

As discussed, participants were asked to provide responses on a scale of 1–7 with 1 as "Strongly Disagree" and 7 as "Strongly Agree" during each week of the study (see Appendix F for questionnaires). For this research question, responses averaged across all participants at the end of participation are presented. Figure 25 shows average scores for the Post Experiment Questionnaire. Overall, both lateral and longitudinal systems were rated highly. Additionally, drivers reported that they were overall very familiar with the features and that features were dependable. At the end of the study, participants reported an average score between "Slightly Agree" and "Moderately Agree" (5.6) that the lateral system functioned well enough that they could perform a secondary task; however, there was no difference in non-driving task engagement and feature activation.

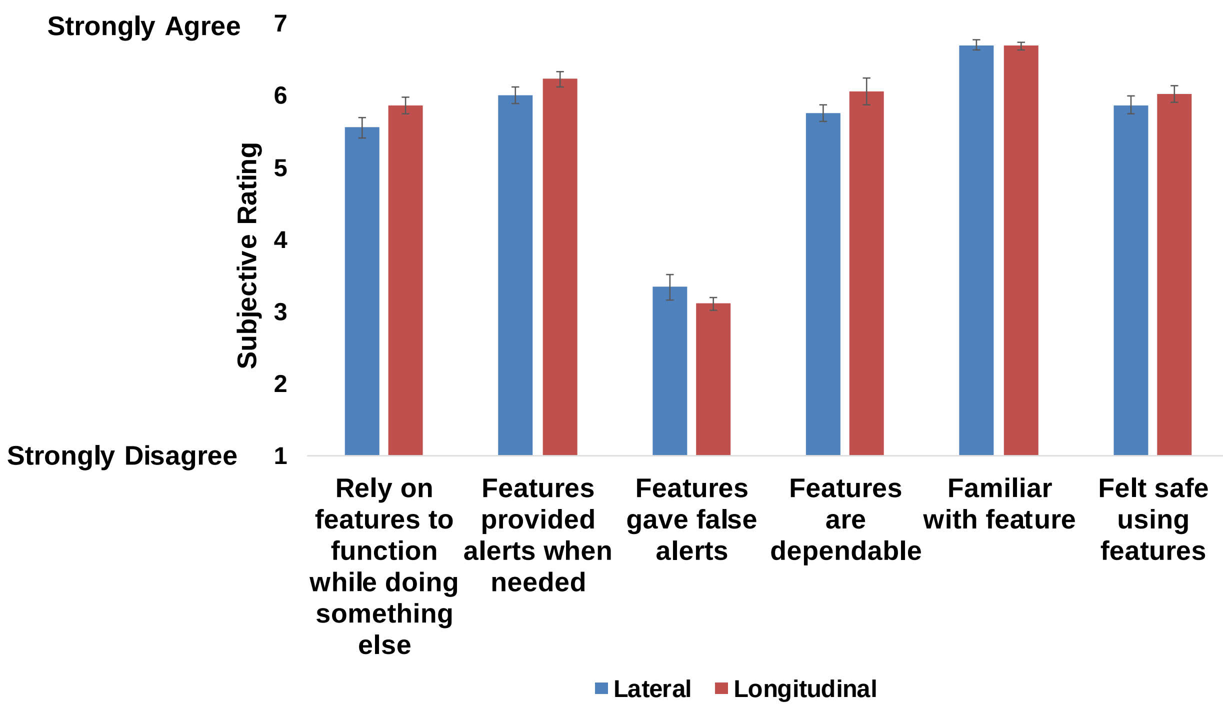

Figure 25. Final Average Subjective Ratings for Lateral and Longitudinal Control Features

Participants reported RTIs as being confusing or annoying (see above). This is likely related to the number of RTIs that occurred when participants already had their hands on the wheel at the RTI onset.

RQ4.4: Do drivers trust the lateral and longitudinal features? In addition, do drivers have any other safety concerns with the features?

Approach: Drivers were asked about their opinions of the lateral and longitudinal control features throughout their participation, including overall level of trust.

Questions specific to safety and security are shown in Figure 25. Drivers reported that they felt safe using both features, although they did make some comments regarding safety and security in open-ended questions. Additional questions specifically asked participants about their level of trust in both lateral and longitudinal control features. Specific analyses of the trust responses are included below.

RQ 4.4.1: What level of trust do drivers give the driving automation system?

Participants rated their subjective levels of trust in the longitudinal control features and lateral control features once at the beginning of the study, at the end of the study, and after every subsequent week in the study, for a total of five ratings. The ratings were each on a 7-point Likert scale, where participants rated the extent to which they trusted each system from "Strongly Disagree" (1) to "Strongly Agree" (7).

Longitudinal and lateral trust both averaged around 5.59, midway between "Slightly Agree" and "Moderately Agree," at the start of the study. By the end of the study, longitudinal trust increased to 5.92, while lateral trust increased to 5.67. Means and standard errors of longitudinal and lateral trust for each week are displayed in Table 9.

Table 9. Feature Mean Trust Over Time

Feature	Study Start	Week 1	Week 2	Week 3	Study End
Longitudinal	5.59 (S.E. = 0.12)	5.45 (S.E. = 0.12)	5.79 (S.E. = 0.99)	6.03 (S.E. = 0.10)	5.92 (S.E. = 0.12)
Lateral	5.59 (S.E. = 0.12)	5.36 (S.E. = 0.12)	5.69 (S.E. = 0.12)	5.88 (S.E. = 0.11)	5.67 (S.E. = 0.17)

RQ 4.4.2: Do participants' subjective trust ratings change significantly over time?

Figure 26 shows participants' average self-reported trust for lateral and longitudinal control features, as assessed on a Likert scale as described above. A longitudinal statistical model was fit investigating the change in average reported longitudinal trust over the course of the study. In order to model this, the responses were transformed such that Strongly Disagree= "1," Moderately Disagree= "2," etc., up to Strongly Agree= "7"; The weeks in the study were transformed such that the first survey = "0," the survey a week into the study = "1," etc. Thus, week in study was fit as a continuous variable linearly related to average trust. The inference is on the slope of trust over time, where a positive slope implies an overall average increase in trust and a negative slope implies an overall decrease in trust. Age group, gender, and vehicle were fit as covariates. A random intercept and a random slope term were added for each participant, accounting for the correlation of observations within a participant, as well as the degree to which those correlations changed over time.

A statistically significant linear increase in trust over time was found for longitudinal trust (t value = 20.07, p value < 0.0001). Specifically, the linear increase of trust from week to week was estimated to be 0.14 (95-percent confidence interval of 0.08 to 0.20), which means that from one week to the next, the average trust in the longitudinal control features increased by about 0.14 points. This implies an average increase in trust of 0.56 points from the beginning to the end of the study.

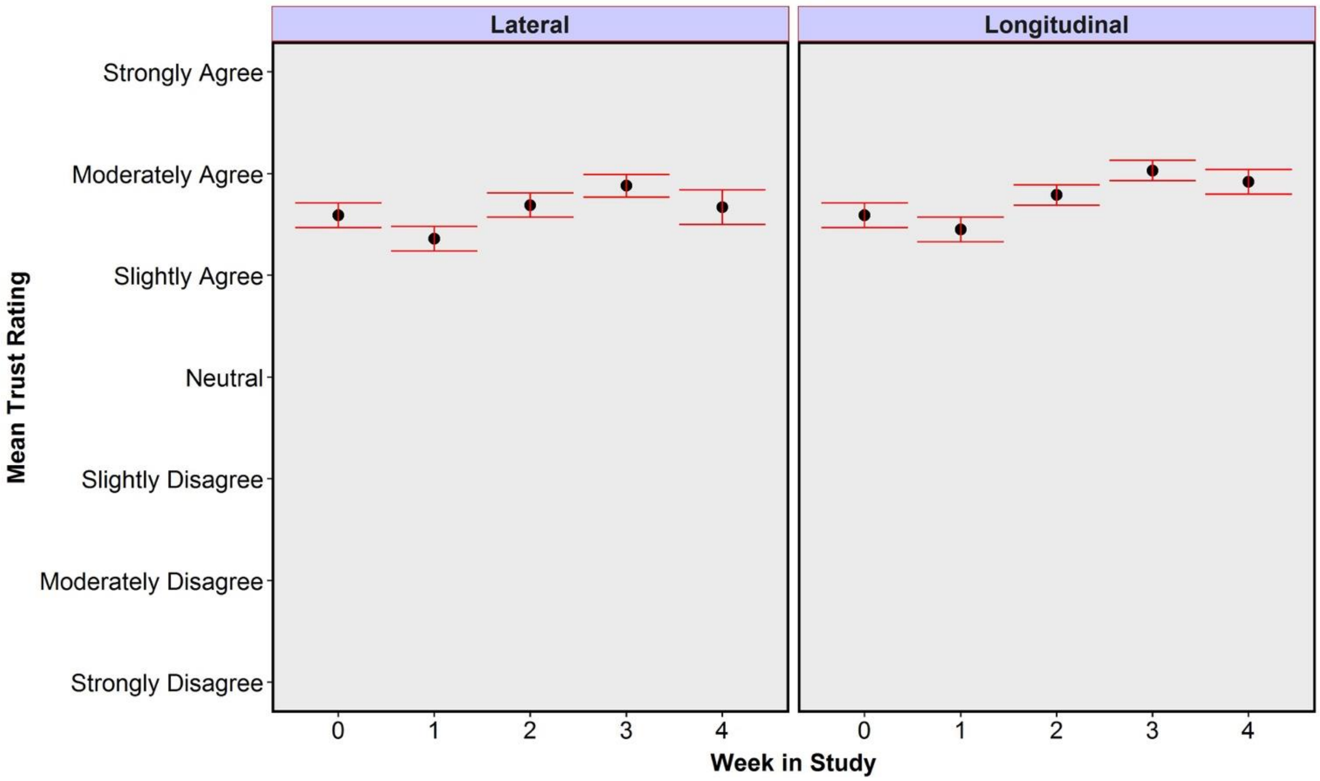

Figure 26. Average Subjective Trust for Both Lateral and Longitudinal Control Features for Each Week in Study

A longitudinal statistical model was fit investigating the change in average reported lateral trust over the course of the study, using a method similar to that used to model longitudinal trust.

A statistically significant linear increase in trust over time was found for lateral trust (*t* value = 4.02, *p* value = 0.0472). Specifically, the linear increase of trust from week to week was estimated to be 0.07 (95-percent confidence interval of 0.0009 to 0.14), indicating that from one week to the next, the average trust in the lateral control features increased by about 0.07 points. This implies an average increase in trust of 0.28 points from the beginning of the study to the end of the study.

RQ 4.4.3: Is there a relationship between trust and rate of driving automation improper use?

A mixed logistic regression model was fit modelling the probability of misusing the features when both features were active, with lateral and longitudinal trust at the end of a given week (week 1, week 2, week 3, or week 4) as the independent variables of interest, and age group and gender as covariates. Neither lateral trust (*F* value = 1.75, *p* value = 0.1863) nor longitudinal trust (*F* value = 0.35, *p* value = 0.5566) were significantly associated with the probability of misusing the features.

Results Summary

The overall results of the analyses described above suggest that participants were operating the driving automation system-equipped vehicles in a manner consistent with intended use and within the observed envelope of operation that was determined during the characterization effort. When operating the vehicles above 40 mph, drivers typically drove with both features active. Drivers were less likely to activate the systems in heavy traffic, on non-interstate roads, and in rainy weather conditions.

Non-driving task prevalence was observed to be similar across all activation levels. Furthermore, the types of tasks performed and EORT were also similar across activation levels. The observed prevalence of non-driving tasks was high compared to previous NDS results (SHRP 2), but it should be noted that the current study used a 15-second reduction window to assess non-driving tasks. Previous estimates of secondary tasks performed as part of SHRP 2 were based on a 6-second reduction window (see the General Discussion Chapter for a more direct comparison of the two rates).

Driver reaction times were within an expected range (average of 1 second) based on the results of previous research (e.g., Blanco et al., 2015) A few cases where there were long/no observed reactions were clustered in the first week of participation and are associated with drivers explaining system functionality to passengers and/or exploring the operating envelope of the systems for themselves. This is not altogether surprising, and even potentially beneficial, behavior, as drivers are able to understand firsthand the limits of system performance. Intervention times follow a similar pattern (intervention within 2 seconds); lack of intervention was mostly observed in response to RTIs where drivers already had hands on the wheel. In these cases, the driver had already "intervened" per the design intent of the RTI.

Overall, drivers appeared to trust the driving automation systems, and were comfortable using them. Driver interviews and trust ratings suggest that there was no real change in trust in the lateral systems, although summarized comments suggest that there were situations reported where the lateral systems did not function as expected. Again, these limitations are consistent with how the vehicles were characterized, and it is likely that even after the features were demonstrated, participants still had a higher that realistic expectation of function. Trust in the longitudinal system did increase over time; subjective feedback suggests that drivers learned the limitations of the longitudinal system and were able to use it more effectively after understanding its limitations.

Training is a topic often discussed in conjunction with driving automation systems, and this was included as **RQ4.6** in the current project. Given the results presented in this report, there does not appear to be an explicit need for additional training for features similar to those tested. Each of the systems required driver intervention, and the data support the idea that participants were effectively monitoring the systems and intervening properly in most cases. However, it should be noted that VTTI worked with stakeholders to develop a minimum training module similar to information that drivers would have received at a dealership. The VTTI-developed training was not overly in-depth but was intended to provide a basic understanding of the systems' features. Also, as noted in Chapter 2, training was kept as similar as possible across vehicles to avoid any potential bias from training differences. While not a causal link in and of itself, the results observed must take into context the basic training provided.

Chapter 5. Longer Drive Sub-Study

A driver's engagement in the driving task and their ability to intervene at a moment's notice may be mediated by the effects of the driver's condition during longer drives, as longer driving durations can lead to factors such as fatigue or drowsiness (e.g., Blanco et al., 2009; Rau et al., 2009). In order to investigate scenarios specific to longer drives, the L2 NDS Sub-Study focused on collecting naturalistic data during prolonged one-time exposures. Where possible, results from the LD Sub-Study are discussed in relation to those of the L2 NDS. Given the differences in location and exposure, comparisons to the NDS are descriptive rather than statistical in some cases. The following research questions are specific to the LD Sub-Study.

RQ 2.1 (LD): What driver behaviors are observed when the driving automation systems are engaged during long-duration drives?

Approach: Prevalence and types of non-driving tasks performed by drivers during the LD Sub-Study were investigated. Comparisons are made to the NDS portion of the study

RQ 3.3(LD): Do samples observed in naturalistic settings show differences in driving behavior compared to driving automation system use during long durations on a single trip?

Approach: Samples for the LD Sub-Study were taken from a single 4-hour trip. Samples from early instances of driving automation system use and RTIs were compared to instances of driving automation system use and RTIs at the end of the drive. Data observed from the Sub-Study were also compared to corresponding drives observed during the NDS portion of the research effort.

Vehicles

There were two vehicles used for the LD Sub-Study. Because the Sub-Study commenced before the conclusion of the L2 NDS data collection period, a 2016 Tesla Model S P90D AWD with Autopilot Convenience and Range Upgrade accessible to the research team was the first vehicle used for LD participants. Upon conclusion of the L2 NDS data collection period and the return of the study vehicles, the research team added a second Tesla to the LD Sub-Study in order to collect more participant data each day. This second vehicle was a 2015 Tesla Model S P90D AWD with Autopilot Convenience, Insane Speed, and Range Upgrade previously used in the NDS portion of the study.

Participants

A total of 48 participants were recruited to complete the LD Sub-Study design. Participants were recruited from the New River Valley area of Virginia. An equal number of males and females were recruited from two age groups: 25–39 and 40–54 years old (same age groups as in the NDS). Drivers were screened for several criteria, with the intention of finding participants as similar as possible to those used in the NDS portion of the study (Appendix E). VTTI leased the test vehicles, which means they were considered to be state vehicles. As such, participants were required to meet the same criteria as state employees in order to be allowed to drive the vehicle. Accordingly, the research team was required to verify driving histories in collaboration with Virginia Tech Human Resources. Participants also completed a pre-drive questionnaire used to assess their frequency and perception of risky driving behaviors (Appendix F). This questionnaire has been used in previous NDSs (Dingus et al., 2015) and was the same questionnaire used for participants in the L2 NDS study.

All study screening, recruitment, training, and data collection activities were approved by the Virginia Tech IRB prior to study execution. Drivers were compensated $210 for their participation.

Procedures

Screening requirements were as close as possible to those used in the L2 NDS. The 60-mile commute requirement was not included for the LD Sub-Study, as the Sub-Study driving session was a one-time event. Potential participants were contacted by the recruitment group at VTTI and screened for their eligibility to participate. Eligible drivers then completed the pre-drive questionnaire and underwent a driving history check. Due to IRB requirements, data was not collected if heavy rain or any snow was forecasted along the data collection route.

Each driver's participation time was approximately 7 hours, around 4.5 hours of which were spent on the road and/or charging the vehicle. After reviewing and signing the Informed Consent Form, participants underwent basic hearing and vision tests and filled out a demographic survey. They then received orientation and training on the Tesla Model S, using the same training method as the NDS (Appendix G). While participants in the main NDS described above were not told how often they were expected to activate these systems during their 4-week participation, in the LD Sub-Study, participants were instructed to activate the lateral and longitudinal control features whenever they felt comfortable doing so. As with the main NDS, the training portion included a test drive in which the experimenter first demonstrated the driving automation, followed by a session in which the participant drove while the experimenter observed and answered any questions posed by the participant. After this test drive portion, the experimenters verified with each Sub-Study participant that they felt comfortable with and capable of utilizing the systems during their 4-hour drive.

Before beginning the drive, but after completing the training and the vehicle test drive, participants completed a questionnaire (Initial Questionnaire in Appendix F), which was based on questionnaires used in previous test track research (Blanco et al., 2015), regarding their initial opinions of the vehicles and the driving automation systems. After completing all training, questionnaires, and verifying the vehicle's condition, participants were then instructed to drive a pre-set route from VTTI on Rte. 460E and I-81S to the Tesla Supercharger station located at 416 Pinnacle Parkway in Bristol, TN (Figure 27). Participants were instructed to transmit two photographs to the research team—one which showed that the vehicle was being charged, and one of the instrument panel to indicate the current odometer reading. This route was 125 miles and took approximately 2 hours of driving. Participants were instructed to charge the vehicle for approximately 30 minutes, and then to retrace the route by driving on I-81N and 460W to return to the VTTI campus in Blacksburg.

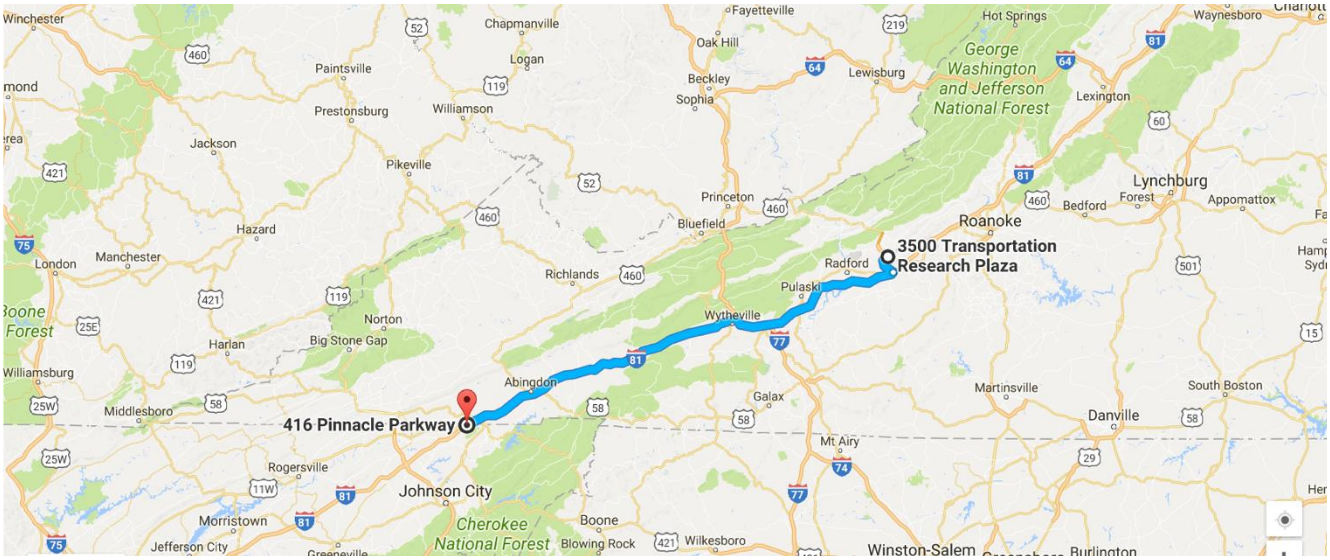

Figure 27. Map of route along US-460 and I-81 between VTTI and the Tesla Supercharger in Bristol, TN (Source: Google Maps)

The 48 participants were split into two groups of 24. Half completed the drive during daytime hours, and the other half completed the drive during nighttime hours. The participation times for day and night were set in order to gather data during the two periods of circadian lows in the 24-hour period. The driving automation system capabilities were available to all participants at the time the vehicle was assigned to them and they were instructed to use the driving automation systems whenever they felt comfortable doing so. After the completion of the drive, a post-participation questionnaire was administered.

Data Sampling

Similar to the L2 NDS, in the LD Sub-Study, the research team sampled instances in which both features were engaged, instances in which one feature was engaged (in the Tesla's case, only the longitudinal system could be active individually), and instances in which none of the features were engaged. These samples were collected at times when both features were available for use. The samples were stratified by blocks of driving, with the first block serving as the drive from VTTI to the end destination in Bristol, TN, and the second block serving as the drive from the end destination back to VTTI. Each block was divided into two segments (the first and second half of driving within that block; approximately 60 minutes and 62.5 miles per block), and one epoch of each type was sampled randomly from each segment, for a total of two samples of each type per block.

Additionally, VTTI analyzed all RTIs and all SCEs that occurred during the LD Sub-Study. Table 10 displays the total sampling frequency for each epoch type.

Table 10. Total Epochs for the LD Sub-Study

Epoch Type	Total Samples	Average Samples per Driver	Miles Driven
Two Features Engaged	190	4	9,143
One Feature Engaged	77	2	667
No Features Engaged	66	1	591
RTIs	45	1	
SCEs	3	0	

Data Reduction

Using the same reduction protocol used for the NDS portion of the study, trained data reductionists used the recorded video, audio, and parametric data to reduce the driver, vehicle, and environmental factors that existed during each of the sampled driving automation system activations, RTIs, and valid SCEs. The reduced and annotated data were used to describe the circumstances within each epoch. As described in Chapter 3 above, all reduction took place in a secure data reduction lab at VTTI; reductionists were limited to shifts of 6 hours or less to minimize vigilance decrements and were not allowed access to their cell phones to prevent video of drivers being released to the public.

Data Analysis

This section describes both the variables that were used in the analyses and the methods of analysis that were performed for each RQ. The methods of analysis used during the LD Sub-Study were similar to those used during the NDS. Two general types of analysis were made: descriptive and inferential. For the descriptive analysis, sample values of various metrics—such as means, standard deviations, medians, minimums, and maximums—are provided. For the inferential analysis, statistical models were built to assess whether any sample findings could be generalized to the population of drivers of vehicles equipped with driving automation systems. Table 11 and Table 12 show the independent and dependent variables relevant to the research questions in the LD Sub-Study.

Table 11. Summary of Independent Variables for the LD Sub-Study

Variable	Category	Definition
Environmental Factors	Categorical	Various factors that affect driving scenarios (e.g., weather, roadway markings, traffic density,)
Minute of Drive	Numeric	Numeric minute in the drive
Age Group	Categorical, Binary	25–39 or 40–54 years of age
Gender	Categorical, Binary	Male, female
Driving Automation Activation Level	Ordinal	Whether both features were engaged, one feature engaged, or neither feature was engaged
Driving Automation Improper Use	Categorical, Binary	Whether the driver was observed using the driving automation system improperly

Table 12. Summary of Dependent Variables for the LD Sub-Study

Variable	Category	Definition
Time to React to RTI	Numeric	The length of time (in seconds) from the onset of the RTI (or prompt) to the first instance of a reaction
Time to Intervene After RTI	Numeric	The length of time (in seconds) from the onset of the RTI (or prompt) to the first instance in which the driver intervenes
Method of First Response	Categorical	Manner in which the driver first reacts to the RTI (or prompt)
Non-driving Task Engagement	Categorical, Binary	Whether or not a driver was engaged in a non-driving-related task
Non-driving Task Type	Categorical	Type of non-driving-related task being performed, if any
Driving Automation Improper Use	Categorical, Binary	Whether the driver was observed using the driving automation system improperly

Results

In a similar fashion to the NDS portion of the study, the research questions for the LD Sub-Study were analyzed by individual tests. Summary statistics were computed (the variables in the Sub-Study are categorical, so frequencies are reported). Inferential statistics were also computed by using statistical models that relate each of the dependent variables in Table 12 to the independent variables in Table 11. The specific inferential models chosen are described below.

The following research questions are specific to the LD Sub-Study. Note that there were no differences between the day and night cohorts for the following research questions; analyses are reported for the full cohort of 48 participants.

RQ 2.1 (LD): Do samples observed in naturalistic settings show differences in driving behavior compared to driving automation system use during long durations on a single trip?

Based on the study design, in all sampled cases, the participant was driving on an interstate. Therefore, only traffic density and weather were included in this analysis (note that only seven instances had any level of rain). An ordinal logistic regression model was used to investigate the relationship between feature activation and traffic density/weather. Weather (F value = 0.09, p value = 0.9663) was not significantly associated with the probability of activating the features in this study. However, traffic density (*F* value = 4.00, *p* value = 0.0466) was significantly associated with the probability of activating features. Specifically, participants were more likely to activate features in free maneuvering than when maneuvering was stable but restricted (odds ratio = 1.63, 95-percent confidence interval 1.01 to 2.65). This result is similar to the NDS result. Figure 28 and Figure 29 show the distributions of weather and traffic density, respectively, by activation level.

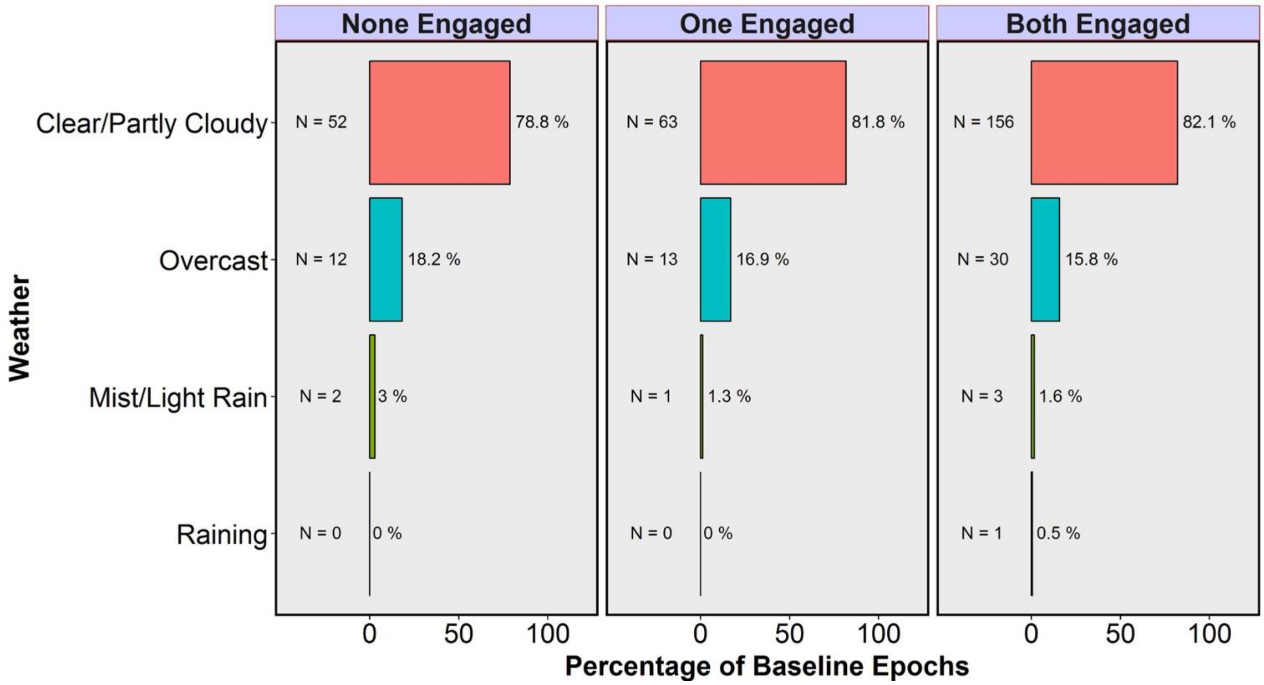

Figure 28. Weather by Feature Activation for the LD Sub-Study

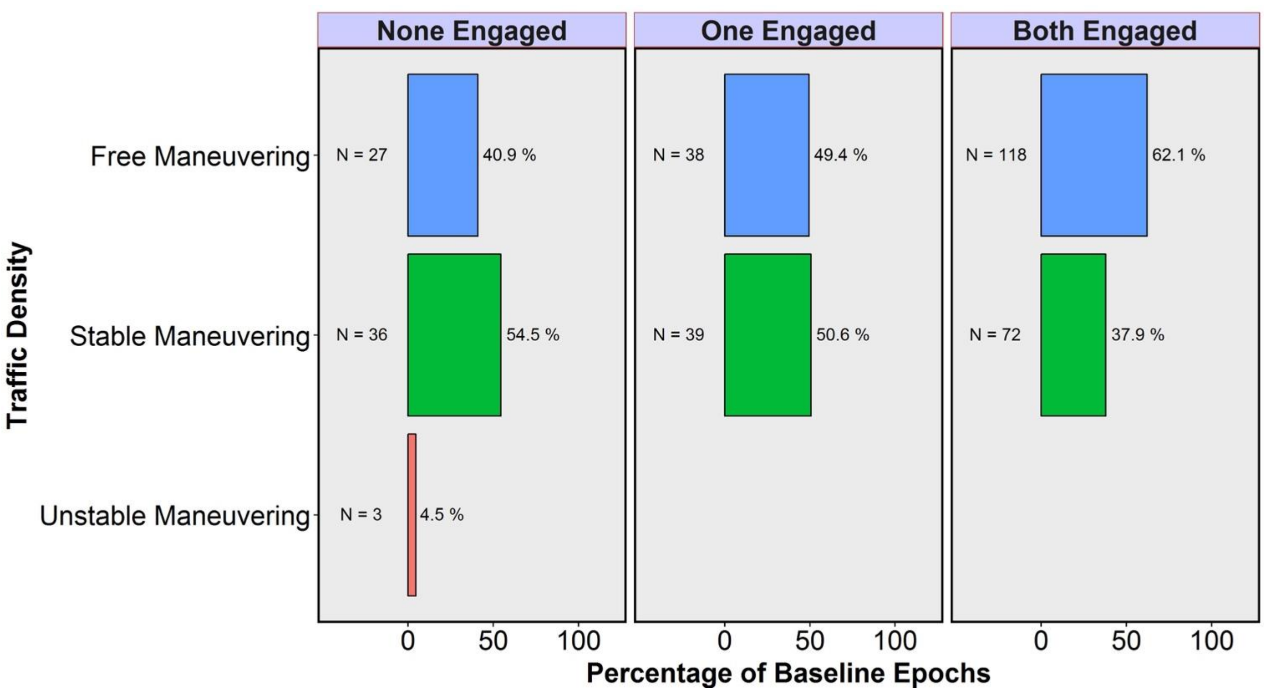

Figure 29. Traffic Density by Feature Activation for the LD Sub-Study

RQ 4.4 (LD): What driver behaviors are observed while the driving automation systems are active during long duration drives?

RQ 4.4.1: How likely were participants to perform a non-driving task while the driving automation is active?

Participants were observed to have performed a non-driving task during about 64.7 percent (N = 123) of epochs where both features were active, compared to about 76.6 percent (N = 59) of epochs where one feature was active and about 72.7 percent (N = 48) of epochs where none of the features were active. A mixed logistic regression model was used to investigate the relationship between feature activation and non-driving task performance. There was no statistically significant difference between activation levels in terms of the probability of performing a non-driving task (*F* value = 3.12, *p* value = 0.0512). Figure 30 displays the probability of performing a non-driving task by activation level.

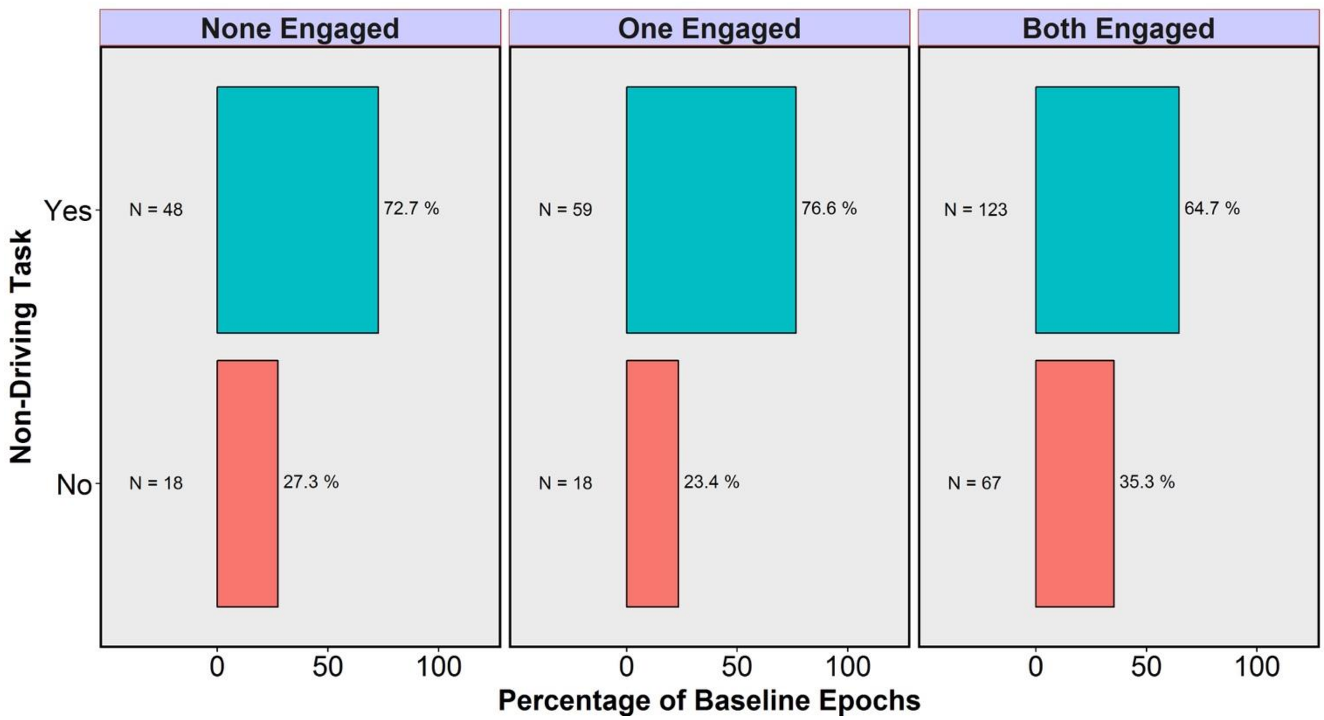

Figure 30. Non-Driving Task Prevalence for LD Sub-Study Baseline Epochs

Participants performed non-driving tasks about 67.06 percent (N = 114) of the time during daytime sessions and about 71.07 percent (N = 113) of the time during nighttime sessions. There was not a significant difference in the probability of performing a non-driving task between nighttime and daytime sessions (*F* value = 1.28, *p* value = 0.2631).

RQ 4.4.2: What types of non-driving tasks do participants perform while driving automation is active? Are participants more likely to perform a non-driving task while driving automation is active compared to other event types?

The most common non-driving task that participants performed was monitoring the instrument panel, which they did 29.5 percent (N = 56) of the time when both features were active, about 37.7 percent (N = 29) of the time when one feature was active, and about 37.9 percent (N = 25) of the time when no features were active. The second most common non-driving task was talking/singing to an unknown audience, which was performed about 14.2 percent (N = 27) of the time when both features were active, about 24.7 percent (N = 19) of the time when one feature was active, and about 15.2 percent (N = 10) of the time when no features were active. Figure

31 displays more commonly performed non-driving tasks in this study. Note that participants may have engaged in more than one type of non-driving task during the event, so one event may be represented in more than one category. Therefore, the total percentages within each activation level will add up to more than 100 percent.

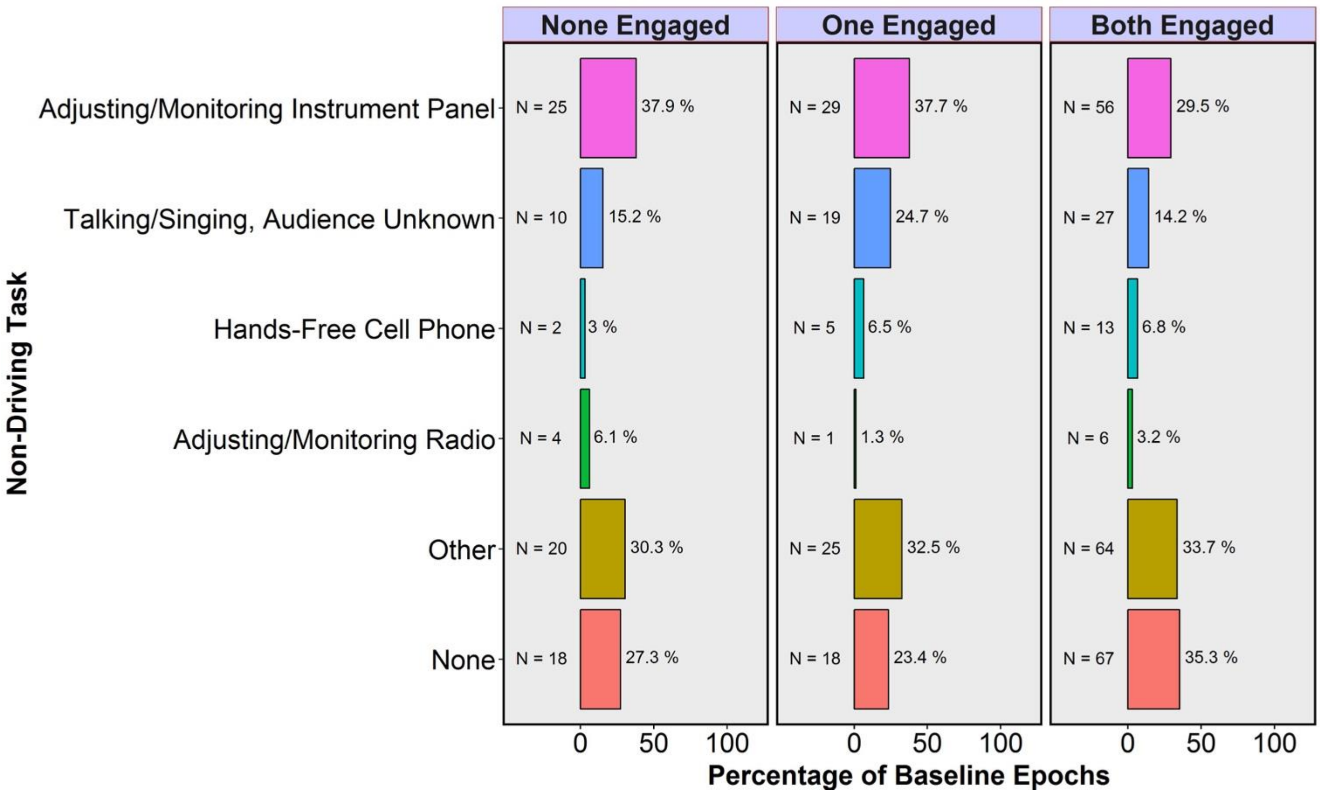

Figure 31. Non-driving Tasks Observed During the LD Sub-Study

During the LD Sub-Study, when participants were not engaged in a non-driving task, they made very few glances off road (Figure 32). None of the epochs in which one or zero features were engaged include any eyes-off-road time. In about 0.3 percent of time with both features engaged, participants had their eyes off road. When participants were engaged in a non-driving task and both features were engaged, they had eyes off the road 20.8 percent of the time, compared to about 15.6 percent of the time when no features were engaged and about 15.2 percent of the time when one feature was engaged. This difference was not statistically significant (F value = 1.40, p value = 0.2492).

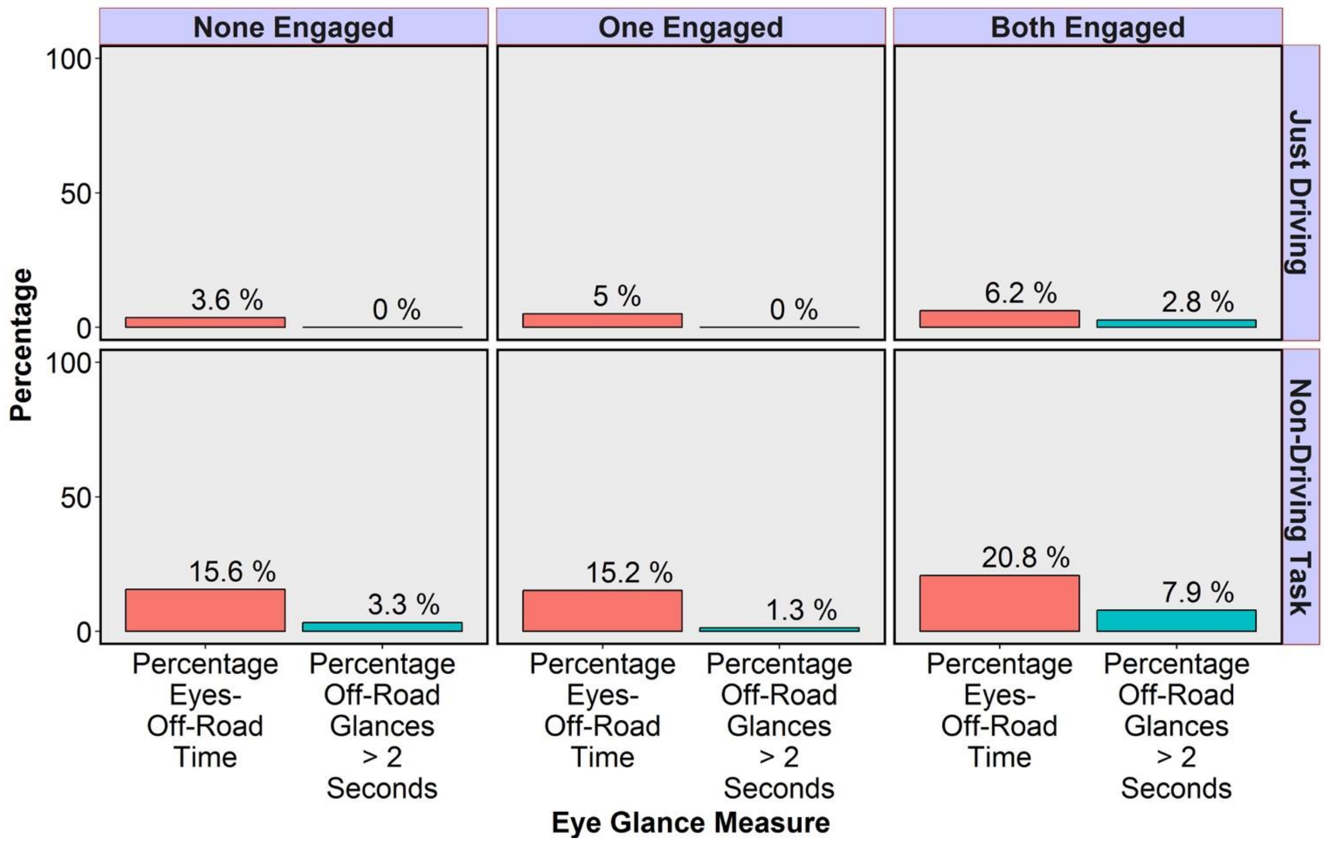

Figure 32. Eye Glance Behavior by Non-Driving Task and Feature Activation During the LD Sub-Study

RQ 4.4.3: Does the likelihood of driving automation improper use, compared to driving automation use that is not improper, change over time?

Participants improperly used the automation features about 4.74 percent (N = 9) of the time. During five of these instances of improper use, the participant did not have hands on the wheel at the sampled time. During the remaining four instances of improper use, the participant was using the features during some level of rain. The probability of improperly using the features did not change significantly over time (*F* value = 0.32, *p* value = 0.8117). During about 7.61 percent (N = 7) of the time during daytime sessions, the participants improperly used the features, compared to about 2.04 percent (N = 2) of the time during nighttime sessions. However, the likelihood of improperly using the features was not statistically significant (*F* value = 0.10, *p* value = 0.7523).

RQ 4.4.4: How quickly did participants react and intervene to RTIs?

An RTI without hands on the wheel was observed in 15.56 percent (N = 7) of the 45 sampled RTIs. Participants reacted within the 5-second window during all seven of these RTIs, and the mean reaction time was 0.82 seconds (S.E. = 0.04 seconds, min = 0.66 seconds, max = 0.94 seconds). Participants intervened within the 5-second window during six of the seven RTIs, and the mean intervention time in those instances was 2.06 seconds (S.E. = 0.33 seconds, min = 1.27 seconds, max = 3.47 seconds). The remaining RTIs were observed to have occurred when the driver's hands were already on the wheel (N = 38). The low number of RTIs did not allow for meaningful statistical inference across time.

Longer Drive Sub-Study Results Summary

The LD Sub-Study was designed to provide a data set to complement the larger NDS data set. The analyses show similar trends to the larger NDS, in that drivers were observed to be actively supervising the lateral and longitudinal control features. Although not included in the above analyses, trust was assessed via the same 1-7 Likert scale used in the NDS; average score for the lateral control features was 5.7 (S.E. = .19) and 6.6 (S.E. = .07) for the longitudinal control features. Participants engaged in non-driving tasks at a slightly higher rate than in the NDS, but in the LD Sub-Study, participants were less likely to perform a non-driving task when both features were engaged as opposed to when no features were engaged. The most common non-driving task was monitoring the instrument panel, which again is consistent with actively supervising the system. Similar to the NDS, drivers had a low number of RTIs; response times were within a similar range as those observed in the larger study. Epochs that showed instances of improper use were fewer in the LD Sub-Study compared to the NDS, which is not surprising given the pre-determined interstate-only route and other restrictions (e.g., no heavy rain or snow). Additional comparison between the NDS and LD results are included in Chapter 6.

Chapter 6. General Discussion

Overview

The L2 naturalistic study was intended to produce an initial understanding of market-ready driving automation systems. This project is the first study sponsored by NHTSA to review the interaction of drivers with market-ready vehicles that include lateral and longitudinal automated features. This research effort was intended to provide insight into four focus areas: System Performance, Driver System Interaction, Driver Performance, and Driver Engagement. The research questions and sampling were designed to be an initial approach to exploring the data set. Key findings are summarized in Table 13.

Overall percentages of non-driving task prevalence are shown in Table 14. The driving automation systems were not observed to increase the likelihood of performing the most distracting or riskiest driving behaviors in the present samples. Although instances of drivers engaging in distracting behaviors (e.g., cell phone browsing, texting) were still observed, these behaviors were just as prevalent during baseline periods with no features engaged or only one feature engaged. Overall percentages of non-driving task engagement were, however, higher than estimates from previous NDSs. Non-driving tasks were observed in the SHRP 2 baseline driving periods about 52 percent of the time, compared to 62 percent here. A key distinction between the two is the longer reduction window used in this study (15 seconds) vs SHRP 2 (6 seconds). If the window is shortened to only 6 seconds, the rate in the present study (53 percent) approximates that observed in SHRP 2.

Table 13. Summary Results for NDS and LD for Each Focus Area

Focus Area	Variable	NDS Result	LD Result
System Performance			
	Hands On RTI	26.2%	15.56%
	Hands Off RTI	73.8%	84.44%
Driver System Interaction			
	Mean Non-Driving Task Prevalence	62.27%	71.3%
	Improper Use Overall	19.24%	4.74%
	Improper Use with Hands Off Wheel	3.8%	2.6%
Driver Performance			
	Mean Reaction Time	.94 seconds	.82 seconds
	Mean Intervention Time	1.79 seconds	2.06 seconds
Driver Engagement			
	Mean Lateral Trust (end of study range of 1-7)	5.92	5.7
	Mean Longitudinal Trust (end of study range of 1-7)	5.67	6.6

Table 14. Overall Non-Driving Task Prevalence for Both NDS and LD

	No Features Engaged	One Feature Engaged	Both Features Engaged
NDS	65.4%	61.9%	59.5%
Monitoring Instrument Panel	9.8%	11.6%	10.1%
LD	72.6%	76.6%	64.7%
Monitoring Instrument Panel	28.8%	23.4%	20.0%

During the longest drives observed in the NDS, drivers were more likely to engage at least one feature (either lateral or longitudinal) and were more likely to perform a non-driving task (76.52 percent) (As presented in Chapter 4, RQ 3.3). The LD Sub-Study yielded similar results (71.3 percent of baseline epochs include non-driving tasks) (As presented in Chapter 5, RQ 4.4). It is noted that the increase observed in the NDS was due to interaction with a passenger; this task was not possible in the Sub-Study, as no passengers were present. Still, it is a key finding that in neither case were longer drives associated with an increase in more distracting tasks, such as those involving a cell phone.

As shown in Table 14, one non-driving task in particular that was highly prevalent during both the NDS and the LD Sub-Study was adjusting/monitoring the instrument panel. Again, this category includes interaction with both the instrument cluster and the center dashboard console. For these tasks, a driver was observed interacting with the display directly (e.g., pressing a button or touching a screen), or some other context indicating interaction (e.g., navigation directions are heard during the epoch). Where possible, tasks in the center dashboard console were included separately; however, it was often not possible to discern one center dashboard console task from another (e.g., interacting with the climate controls, radio, navigation, other vehicle setting). This task is somewhat expected if participants are actively monitoring the driving automation systems, as the systems' status and other adjustable settings are present in the instrument cluster.

Participants in both the NDS and the LD Sub-Study reported high levels of trust in the lateral and longitudinal control features, but this was not related to over-reliance or improper use. Drivers tended to actively supervise/drive with the lateral and longitudinal control features engaged. Overall RTI occurrences were low. Furthermore, for the majority of the sampled RTIs, participants already had their hands on the wheel at the onset of the RTI. For alerts where the driver did not already have hands on the wheel, participants were observed to react within 1 second and return their hands to the wheel within 2 seconds on average. This is within the "shut-off" time for the lateral systems that include this feature. The sequence and timing of responses observed is consistent with the findings of previous test track studies, specifically those in Blanco et al., (2015), which reported a 1-second reaction time as the 90th percentile for multi-modal RTI alerts when participants were using L2 driving automation.

Improper Use

The primary factor in determining improper use is the design intent of the system. In all cases, the lateral control feature required drivers to keep their hands on the wheel, to use the features only in clear weather, and to use the features on interstate roads. The NDS showed an overall improper use rate of 19 percent (234 cases). The majority of these cases involved participants using the features on an improper road type or in improper weather conditions. However, in 3.8 percent of epochs (50 of 1,299), hands off wheel behaviors were observed (alone or combined with other improper use cases). In the LD results, observations of improper use on improper road types and during improper weather conditions was limited due to study design. A total of 2.6 percent of cases of hands off wheel behavior were observed in the LD Sub-Study. In the typical improper use case, for both the NDS and the LD Sub-Study, the driver was looking forward, even if their hands were off the wheel. Additionally, the number of RTI epochs was low, suggesting that hands off wheel behavior was limited. Taken together, this suggests that drivers were generally attentive and engaged in the driving task even if the systems afforded some level of hands off wheel behavior. In the most extreme cases of hands off wheel, it can be inferred that the driver was intentionally testing the limits of the driving automation system. These were typically isolated incidents at the beginning of NDS participation, and occurred on straight sections of roadway with light traffic present. Furthermore, these cases did not lead to more instances of improper use or distraction.

Unintended Consequences

There were low numbers of SCEs over the course of data collection and no change in SCE (crashes and near-crashes combined) rate across activation levels. There was only one crash event that occurred when both features were active during the reduction window. This was a minor crash where the driver entered an express lane that was restricted to buses only and had to intervene prior to impact with the express lane entry gate.

The majority of the SCEs observed were conflicts in the longitudinal path. The most common SCE type for both features active was a conflict with a lead vehicle, followed by a conflict with a merging vehicle. Participants commented on the “delayed” response of longitudinal automation, and in these cases, they overtook the system aggressively. It is possible that the near-crash events observed would have been resolved by the longitudinal systems alone without the driver’s intervention. SCEs were not observed to be the result of lateral system failures.

While not observed in the present study, the characterization effort identified an edge case where neither the driver nor the system was actively steering the vehicle. In four of the five vehicle models tested, lack of response to an RTI results in the lateral system disengaging. In three of these four vehicles, the system disengages abruptly. If the driver is unresponsive for any reason, self-induced or not, neither the system nor driver is in control. This is not any different than if a driver were unresponsive in a vehicle without lateral automation; however, it is an instance where lateral automation could lead to this type of unintended consequence.

Existing Research

Test track research (Blanco et al., 2015; Llaneras, et al., 2013; Llaneras, Cannon, & Green, 2017) suggested that drivers would be more likely to glance away from the road and more likely to engage in non-driving tasks when “imperfect” automated lateral control features were available to the driver. This result was not observed in the current study; although drivers engaged in non-driving tasks, there was no difference between activation levels. Test track research often includes conditions designed to test the “worst case” scenarios, which may include asking drivers to perform non-driving tasks as part of the experiment (Blanco, et al., 2015). Furthermore, the need to monitor the system may act as a task in and of itself, as evidenced by increased glances to the instrument panel observed in this study.

It is an often-reported conclusion that humans are poor at extended monitoring tasks (e.g., vigilance decrement; Warm, et al., 2008). As such, a continuing concern in the literature is the degree to which the driver is performing an extended monitoring task while driving automation is active (e.g., Banks et al., 2017) as opposed to actively driving. This also relates to length of “take over time” (e.g., Gold et al., 2013, Eriksson & Stanton, 2017) in the event that a driver has to resume the driving task as the fallback driver. In the present study, it would not be accurate to say that drivers were “taking over;” the data suggests that drivers were actively supervising (e.g., in the loop and receptive to alerts) and not ceding and subsequently resuming control. This behavior is consistent with L2 function and design intent. In the present study, reactions to RTIs were used as a driver performance measure, with the majority of RTIs issued when a driver already had hands on the wheel. Still, it is acknowledged that this issue is highly debated, and this result could change as capabilities of driving automated systems increase.

At the outset of this project, little on-road research had been conducted in the area of partial driving automation. No other naturalistic studies with similar vehicles have published results at the time of this report. However, at least one additional naturalistic driving project is underway (Fridman et al., 2017). Of great interest will be the degree to which the results match those observed here.

Limitations

As with any research study, the current project had limitations. Participant selection and vehicle types are the primary caveats to generalizing the results observed.

First, it is noted that the participant cohort used is likely representative of safer drivers, which may have reduced the occurrence of risky behaviors. The driving history check performed excluded participants with certain driving violations (such as driving while intoxicated), and drivers with more than three driving violations in the past 5 years. This check was required due to University policy in order to insure the vehicles for the duration of the study. Still, clear cases of distraction were observed along with improper use of the driving automation systems.

In addition to a “safe” cohort of participants, the vehicles selected could be considered quite “safe” as well. All of the study vehicles had passive safety systems, such as blind spot warning and forward collision warning systems, in addition to the driving automation systems of interest. These additional features were not investigated as part of this research effort but could have also reduced the occurrence of safety-critical events. However, these vehicles are likely representative of new vehicle technology; lateral and longitudinal automation are unlikely to be available without additional safety features. Although driving data was not used to investigate these features, participants did experience them while driving the vehicle. Participants reported positive experiences with these additional safety features, particularly blind spot warning systems. Instances of forward collision warnings were limited.

In terms of generalization to current driving automation systems, all of the vehicle models tested here have undergone additional developments as part of new model year changes. It is possible that lateral and longitudinal capabilities, RTI design, and other HMI strategies may be different in the next generation of vehicles.

A final limitation was the 4-week participation time in the NDS. There were no observed differences over time in this study but 4 weeks is not a long duration compared to previous NDSs where the participation period was months or years. Furthermore, driving time in the LD Sub-Study was around 4 hours, with sampling limited to that time. Participants in the LD Sub-Study may not have reached the same overall comfort level with the driving automation features in that time, as compared to the exposure time in the NDS portion of the study.

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Appendix A. Award Language for Research Questions

The language of the research questions in the award document is as follows:

- Driver Engagement: How did drivers respond to transitions in automation states and with functions designed to keep them engaged and aware? Which elements did the driver find useful, difficult to understand, misleading, or annoying? Were the observed transition times and sequences consistent with findings from track studies such as those conducted within (e.g., NHTSA's 2015 Human Factors Evaluation of level 2 and level 3 Automated Driving Concepts study [Blanco et al., 2015])?
- Driver Performance: What driver behaviors were observed in the operation of the automation (tendencies, errors, learning, etc.)? How did drivers recover and/or change their behavior over time? Did the automation impact driver performance over longer periods of driving in an automated state?
- System Performance: How did the combined lateral and longitudinal control system operate? What operational conditions influenced the availability of the automated functions?
- Driver-System Interaction: Were combined braking and steering controls functionally compatible with driver expectations for the automation? Were expectations consistent across various types of roadways, driving conditions, speeds, etc.?

Additionally, inferred observations from this study may include:

- Driver Interface Design: Were the tested automation concepts consistent with the draft Automated Vehicle-Human Factors Design Principles that are being developed within the *Human Factors Evaluation of level 2 and level 3 Automated Driving Concepts* study (Blanco et al., 2015)? Were there any data or observations from this study that could help support these design principles?
- Unintended Use: Did drivers find and implement means for defeating the intended use or monitoring mechanisms of the automation? What means for defeating the automation were discovered after a functional review by the experimenters?
- Unintended Consequences: Were there any unintended consequences regarding the driver from their daily use of the vehicle with automated control systems such as from complacency, indifference, errors of omission/commission, etc.?
- Safety and Security: In what ways were drivers satisfied with using the automated vehicle in daily driving? Did drivers feel safe and secure? Did the automation produce a false sense of safety and security?
- System Failures: How did drivers recover from degradations or failures in the design, including false alarms, nuisance warnings, loss of sensors/data for sustaining the automation, etc.?
- Licensing and Training: What are the automation training/licensing considerations observed or inferred from experimental observations, potentially including teens, older drivers, new drivers, infrequent drivers, handicapped drivers, and other populations?

Appendix B. List of Acronyms

ACC	adaptive cruise control
DAS	data acquisition system
DDT	dynamic driving task
EORT	eyes-off-road time
HMI	human-machine interface
IRB	Institutional Review Board
L2	Level 2
LD	Longer Drive Sub-Study
NDS	naturalistic driving study
RTI	request to intervene
RQ	research question
SCE	Safety-critical event
SHRP 2	Second Strategic Highway Research Program
SQ	sub-question
VTTI	Virginia Tech Transportation Institute

Appendix C. Operational Definitions

Based on previous test bed research (Blanco et al., 2015) the following operational definitions are included.

Abuse of automation: *intentional* incorrect use of the driving automation system. An example would be a driver that actively defeats safety systems by using an object to hold down a button on the steering wheel, allowing them to keep their hands off the wheel for longer than the system would otherwise allow.

Cognitive task: tasks that require the driver to avert their mental attention away from the driving task.

Feature activation level: the number of features engaged: both features, one feature (either lateral or longitudinal), or no features active.

Feature engaged: the "On" state of the lateral and longitudinal control features. Used synonymously with a feature being active.

Hands on wheel: visual evidence that a driver has at least one hand on the wheel as verified by video analysis. Having fingers alone on the wheel satisfies this case.

Improper use: either misuse or abuse of the driving automation system.

Instrument panel: a non-driving task where the driver was observed interacting with either the instrument cluster OR the center dashboard console (e.g., pressing a button or touching a screen), or there was some other context indicating interaction (e.g., navigation directions are heard during the epoch).

Manual task: any task that requires the driver to take one or both hands off the steering wheel to manipulate a control, device, or other non-driving-related item

Misuse of automation: an *unknowing or unintentional* incorrect use of the driving automation. An example would be an uninformed driver who activates driving automation features on roadways for which they are not intended (e.g., non-interstate roads).

Non-driving task: any task not directly related to driving. Sometimes termed a Secondary Task. Examples include, but are not limited to, cell phone use, texting, eating, drinking, etc.

Prompt: a visual only early stage of an RTI; the notification to the driver is to return hands to the steering wheel. During the prompt, the lateral control feature remains engaged even if the driver does not respond. Lack of response leads to an RTI.

Request to intervene: a notification to the driver that the lateral control feature requires driver intervention to remain engaged. Typically, the required intervention is for the driver to return hands to the wheel

System limitation: unexpected failure of the driving automation system. This includes alerts presented when conditions do not require driver intervention, or a situation where an alert is presented too late for driver intervention. Note that this includes an alert not being generated at all, such as a lane drift with no alert.

Time to react to RTI: the time, after the RTI is first presented, at which point the driver performs an action that could be considered a reaction to the RTI (looking forward, moving hand, or moving foot).

Time to intervene: the time, after the RTI is first presented, until the driver puts a hand back on the steering wheel.

Visual task: any task that requires the driver to look away from the roadway to visually obtain information.

Visual-manual task: a task with a combination of Visual and Manual distraction. Any task that requires the driver to take one or both hands off the steering wheel to manipulate a control, device, or other non-driving-related item AND to look away from the roadway to visually obtain information.

Appendix D. Characterization Approach and Driver Interface Design

The purpose of vehicle characterization tests was threefold. The effort was primarily to understand the driving automation systems: how to activate, operate, and what restrictions are indicated by the manufacturer in order to guide data analysis. Second, the characterization allowed for development of the training modules in Appendix G. Finally, this effort allowed researchers to confirm DAS operation in order to validate data integrity. Characterization allowed for installation of DASs and associated cameras in a way that did not change the function of any of the driving automation systems. The characterization tests were conducted in three phases: static testing, public road testing, longer drive testing. Each driving phase included multiple drives with each of the study vehicles.

Phase 1: Static Characterization

The first phase of characterization involved static testing. Static testing comprised reviewing the vehicle owner's manual, reviewing controls and menus, and documenting the vehicle interior. This included reviewing how the entertainment systems operated, how seat adjustments were performed, how climate controls were operated, and how to pair a smartphone with the vehicle.

Researchers reviewed how the lateral and longitudinal control features were activated and deactivated (e.g., button, lever, menu setting, brake press) for each vehicle, as well as if they could be activated separately. Characterization also included reviewing manuals to determine what speed ranges and environments were recommended by the manufacturer.

Although not part of the current research effort, other alerts that were part of the vehicle HMI (e.g., Forward Collision Warning, blind spot warning) were noted so they could be included as part of participant training.

Phase 2: Public Road Testing

The next phase of testing was a series of controlled driving scenarios on pre-determined routes around the Blacksburg area. The routes comprised different road types (interstate, divided highway, city, rural). When possible, routes were different in different traffic densities. Characterization was performed during both day and night conditions.

During this phase, researchers intentionally used the systems improperly. When possible, vehicles were driven in rain, fog, or other adverse weather conditions. Researchers ascertained RTI timing and duration by intentionally removing hands from the wheel to generate RTIs.

Video of each vehicle HMI (feature activation and RTI icons) was collected in order to train VTTI machine vision algorithms to detect feature activation and RTI state.

The following questions were developed to guide the characterization effort; these are not all inclusive but provide an insight into how the operational envelopes of the driving automation systems were ascertained.

Questions specific to the lateral control features:

- Does the lateral control feature operate at the speed ranges specified in the owner's manual?
- Can you take your hands off the wheel when the lateral control feature is active? If so how long before you receive an RTI and/or system becomes unavailable?
- Does the system provide a request to intervene?
- Does the RTI escalate in any way?
- Are there prompts that notify you to keep your hands on the wheel while the system is on?
- Does the alert mode change (e.g., visual to visual + auditory, to visual + auditory + haptic)?
- What happens if the driver does not respond to the RTI?
- Does the lateral control feature track surrounding vehicles?

Questions specific to longitudinal control features:

- Does the longitudinal control feature operate at the speed ranges specified in the owner's manual?
- Does the lateral control feature track surrounding vehicles?

Additional questions:

- Are there other alerts that the vehicles provide (e.g., Forward Collision Warning)?
- Can these be turned on/off individually?
- Are any a required component of either the lateral or longitudinal control feature?

Phase 3: Longer Drive Testing

The next phase of the characterization testing was a series of longer duration trips (2+ hours). The final test routes were primarily highway driving, and allowed for longer duration use of both lateral and longitudinal control features. This phase of characterization also served to verify DAS performance over longer duration trips as well as to provide an overall review of feature performance in a variety of driving scenarios.

Driver Interface Design

In addition to the general characterization, driver interfaces used in each vehicle were compared to draft guidelines published by NHTSA (Campbell et al., 2018). This evaluation was conducted per SQ5, which is as follows:

- SQ 5: Driver Interface Design: Were the tested automation concepts consistent with the Human Factors Design Guidance document that were developed within the *Human Factors Evaluation of level 2 and level 3 Automated Driving Concepts* study? Any data or observations from this study that could help support these design principles will be noted.

There are many facets of HMI guidance provided in the report, many of which were not directly studied in the current research effort. Most relevant to the present work are the following guidance principles:

- The HMI should provide continuous display of activation status of the driving automation features
- When alerting the driver the following guidelines are provided for messages
    - Visual only messages should be used for more complex and lower priority information
        - Simplest icons or text with the fewest lines possible
    - Messages should include an auditory component for high priority info
        - Simple salient tones to gain attention of the driver
    - Haptic should be included for messages with highest priority information, in combination with other modes
    - Some combination of multi-modal alerts should be used for safety-critical information

As noted above, for each vehicle used in this study, the characterization also determined what features the HMI included, and in what manner these features are presented. Characteristics included whether the system contained an audio, visual, or some combination (no RTIs included a haptic component). The characterization also included the timing of these various components (whether they occurred at the same time or in a sequence, and in what sequence they occurred), the length of time the various components lasted, whether or not the components increased in intensity over time, and what action on the part of the driver is required to relieve the RTI.

Images of the displays used to indicate lateral and longitudinal control feature activation as well as the RTIs sampled for each vehicle are included below. Only images and timing information relevant to sampled data in the present study are included. Image size and location varies based on vehicle type.

Audi Q7

Audi Q7 icons are displayed in the instrument cluster for all features in standby (Figure 33) Lateral active (Figure 34) Longitudinal active (Figure 35) and both active (Figure 36) are included. Figure 37 shows the image displayed for the RTI. When in standby, icons are white, and are displayed in green while active. The RTI is accompanied by an audible tone, but does not include a haptic component. The RTI is temporary, and is displayed after the system detects a lack of steering input. The RTI state can persist for around 2 seconds before the lateral system deactivates; the tone does not intensify over time.

Figure 33. Instrument Cluster in the Audi Q7 Showing the Location of the Lateral and Longitudinal Icons (Yellow Circle)

Figure 34. Lateral Automation Icon for Audi Q7

Figure 35. Longitudinal Automation Icon for Audi Q7

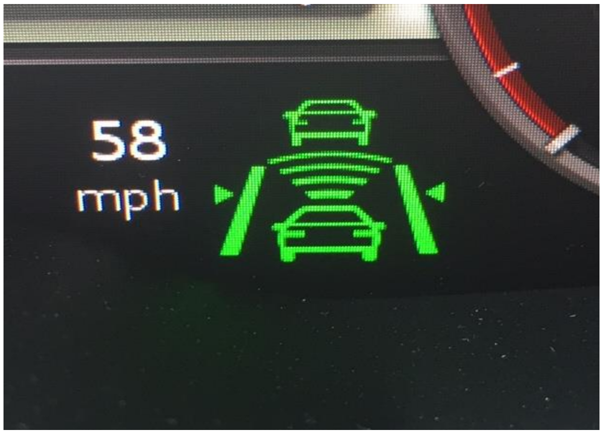

Figure 36. Lateral and Longitudinal Both Active for Audi Q7

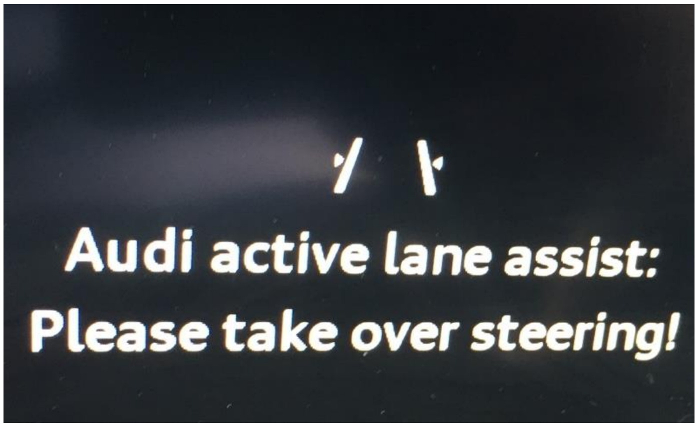

Figure 37. RTI for Audi Q7

Infiniti Q50

The display for the Infiniti Q50 is shown in Figure 38 with all systems in standby (left) and the lateral system active (right). When active, the HMI displays active features in green, as opposed to white while in standby.

Figure 39 shows the image of an RTI, which shows up in the larger display as well as the small icon in the top left (both are circled in yellow).

Figure 39 also shows the longitudinal system active, circled in green. The RTI for this vehicle is a lane departure warning, and alerts the driver when the vehicle is about to cross a lane marking (either left or right), notifying the driver to steer the vehicle appropriately. The RTI includes an auditory component, but not a haptic component. The RTI state persists for 1–2 seconds, but does not shut off lateral function; the tone does not intensify over time.

Figure 38. Display for Infiniti Q50 With All Features Off (left) and Lateral Only Active (right)

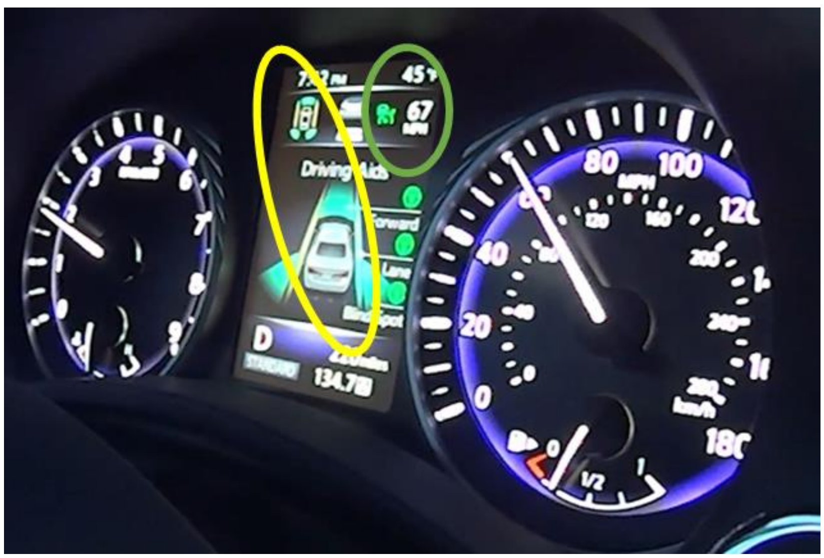

Figure 39. RTI Image (Yellow Circle) With Longitudinal Active (Green Circle) in the Infiniti Q50

Mercedes E350

Figure 40 shows an image of the lateral (circled in yellow) and longitudinal (circled in blue) systems active in the Mercedes E350. The lateral activation is noted by the green steering wheel icon (as shown in Figure 41, turns grey if disengaged). The longitudinal activation is noted by the white dots below the set speed. Figure 42 shows the HMI icon used for both the visual prompt and the RTI. The prompt state can persist for 5 seconds, at which point the RTI time begins, accompanied by an auditory tone. The RTI state can persist for 5 seconds before the lateral system will suspend operation. The RTI tone does not escalate while the alert state persists.

Figure 40. Lateral (Yellow Circle) and Longitudinal (Blue Circle) Systems Active in the Mercedes E350

Figure 41. Both Lateral and Longitudinal Sytems Deactivated in the Mercedes E350

Figure 42. Visual Prompt and RTI Image in the Mercedes E350

Tesla Model S

Figure 43 shows both lateral and longitudinal active for the Tesla Model S. Icons are grey when available but not active, and not present if not available. As pictured, they are highlighted in blue when active. Figure 44 shows the icon for both the prompt and RTI. The RTI responds to the detection of hands on the wheel. During the prompt state (persists for 10 seconds), the outer edge of the cluster will flash at an increasing rate until the RTI state, which includes an auditory component, is reached. The RTI state persists for 2 seconds before it escalates to the next stage, and will finally reach a “lockout” (not pictured) if the driver does not place hands on the wheel or if hands are not otherwise detected. As each stage escalates, the volume of the tone increases.

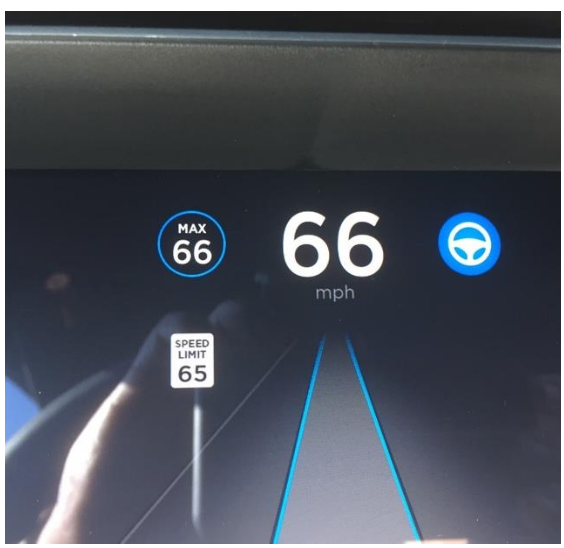

Figure 43. Lateral and Longitudinal Control Systems Both Active in the Tesla Model S

Figure 44. Prompt and RTI Icon in the Tesla Model S

Volvo XC90

Figure 45 shows the lateral control feature active (left) and in standby (right) for the Volvo XC90. The icon is grey when in standby and white when active. Figure 46 shows the longitudinal system active in the XC90; a vehicle icon is present in the speedometer along with the set speed. Figure 47 shows the prompt (left) and RTI (right) icons. The RTI responds to the detection of steering inputs from the driver. The prompt state will persist for 15 seconds before escalating to the sampled RTI, which includes an auditory component, and then the lateral control feature will deactivate. The alert state persists indefinitely, although the lateral system is suspended while the RTI state is active.

Figure 45. Lateral Control Features Active (Left) and in Standby (Right) in the Volvo XC90

Figure 46. Longitudinal Active in the Volvo XC 90

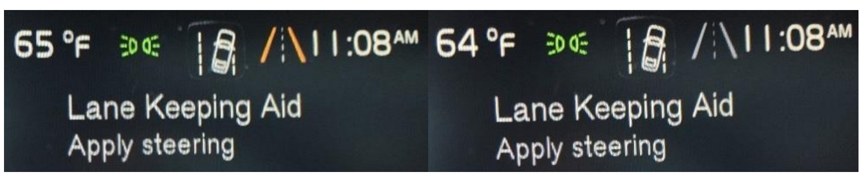

Figure 47. Prompt (Left) and RTI (Right) in the Volvo XC90

Appendix E. Participant Screening Criteria

This appendix contains the screening criteria for both the NDS and LD Sub-Study, including the script used to contact participants. Please note that the code name for recruitment for the NDS was “Deluxe,” and that name will occur throughout this appendix. Also note the code name for the LD Sub-Study was “Bristol,” and that name will also occur throughout this appendix.

Deluxe Study Screening Questionnaire

Note:

Initial contact between participants and researchers may take place over the phone. If this is the case, read the following Introductory Statement, followed by the questionnaire. Regardless of how contact is made, this questionnaire must be administered verbally before a decision is made regarding suitability for this study.

Introductory Statement:

After prospective participant calls or you call them, use the following script as a guideline in the screening interview.

Hello. My name is _____ and I am calling from the Virginia Tech Transportation Institute, in Blacksburg, VA. We are collaborating with the National Highway Traffic Safety Administration on a research project and are recruiting people to participate in the Northern VA area. Once eligibility is determined, your name will be added to the list of potential participants. The purpose of this research is to learn more about how people typically use some of the features found in today’s newer vehicles.

Participation in this study involves driving one of our instrumented test vehicles instead of your own vehicle for a 4-week period. If you choose to participate, full details of what is required of you as a participant will be provided to you, for your review, before any appointments would occur. The vehicle provided to you is instrumented with data collection equipment, including cameras, which will collect digital video of your image, and audio recording, anytime the vehicle is turned on. The monitoring system will be unobtrusive; it won’t affect your ability to drive safely and you won’t have to interact with it at all. Due to the cameras involved, this study is not suitable for people who frequent areas where video recordings are not allowed, for example military installations, high security facilities, or border crossings. No one is allowed to drive the vehicle except the enrolled participant and no smoking will be allowed inside the research vehicle. Also, you must agree that no hazardous materials, flammable materials, or illegal materials will be hauled using the research vehicle.

The data collected is kept secure. The data will be encrypted and can only be decrypted by authorized technicians. Your name will never be associated with the recorded data. For example, all participants are assigned a participant number, such as #10. There will be some questionnaires to complete before you begin driving the vehicle, periodically during the study, and at the end of your participation.

If you participate, you will receive payments with a MasterCard; payments will be electronically loaded on to the MasterCard throughout the study. If you complete the initial meeting session for this study, have signed your informed consent, but choose not to participate further or are ineligible to participate in the study, you will be paid $30.00 for your time. If you are eligible and able to participate, payment will occur in the following increments: 1. $20 for each of the weekly questionnaires 2. $0.25 per mile when the vehicle is returned, up to 1,200 miles. For those who participate fully, the maximum payment for the entire study would be $500.

Any questions yet?

If you are interested in possibly participating, I need to go over some screening questions to see if you meet all the eligibility requirements. Any information given to us will be kept secure and confidential.

Do I have your consent to ask the screening questions? [If yes, continue with the questions. If no, then politely thank him/her for his/her time and end the phone call.]

Participant Eligibility Questions:

Do you currently hold, a valid U.S. driver's license, which you can present at the time of the study? YES _____ NO _____ If yes, how long have you held a U.S. license? __________________ Criterion: they are ineligible to participate if unable to present a VALID U.S. driver's license at their appointment and they must be an experienced driver (at least 2 years). Can't include time with a Learner's Permit during the 2 years of experience. (Must be fully licensed for at least 2 years). NOTE: They will be reminded that they must present a driver's license at their appointment if scheduled.
What is your current age? ________________ YOB__________ Criterion: Must be 25-54 years old to participate.
What is your gender? Male ______ Female __________ Criterion: the total number of participants will be gender balanced if possible.
Does your current U.S. Driver's License have any restrictions? YES _____ NO _____ Criterion: Must present a driver's license with NO restrictions at their appointment if scheduled. For example, can't be restricted to only driving to and from work.
Are you willing to have your driving history verified by us? YES _____ NO _____ If yes, do you have a personal email and Internet access to complete the driving history survey? YES _____ NO _____ Note: Virginia Tech Human Resources dept. will send you a link to click on, via email, and you will be asked to put in personal information they need in order to complete the driving history background check. If you are eligible, we will go into more details about this process, after we complete all the screening questions.

Criterion: Must be willing to submit to driving history verification using a personal email and have Internet access to complete the process.
On average, how many miles do you drive per day? _________________ Criterion: Must drive an equivalent of at least 60 miles per day, 5 days or more per week on average.
Do you have a smartphone with Bluetooth capability? YES _____ NO _____ Comments: ____ Criterion: Must own a smart phone with Bluetooth capability. Preference given to those who use Bluetooth regularly.
As a part of this study, the research team will send you a link to a survey each week by email. If necessary, the experimenter may conduct this survey by telephone instead. In either case, the survey is expected to take less than 5 minutes. Are you willing to complete this survey each week, using a personal email address or over the phone? Yes______ No_____ Criterion: Must agree to complete weekly questionnaires/survey by email or phone.
Do you have a garage where you can keep the research vehicle parked securely while at home? YES _____ NO _____ Does your garage have an electrical outlet? YES ___NO ____ Do you know if the outlet is 110 or 240? _____________________________________ Would you be able to plug in an electric vehicle inside the garage to recharge the batteries each night? YES ___NO ____ Criterion: Must park in a secure area, preferably a garage. NOTE: Must have appropriate electrical outlet(s) and be able to charge an electric vehicle in order to be assigned one of the electric research vehicles. (Not all of the study vehicles are electric; they could participate while driving one of the other types of research vehicles.)
Where would you park the research vehicle while at work? ____ Criterion: Must park in a secure area.

Do you (or the vehicle owner) have liability insurance on the vehicle you normally drive?

YES _____ NO _____

If yes, are you willing to provide proof of insurance to the research team prior to or at the time of participation? You must be covered by the policy if the vehicle is not in your name.

YES _____ NO _____

Criterion: In order to participate, an individual must have liability insurance on their primary vehicle and be willing to provide proof of insurance at time of participation or in advance of their appointment. (Insured drivers will help to screen out high-risk individuals.)

Do you use your primary vehicle as a vehicle for hire? YES _____ NO _____

Criterion: Must not use their primary vehicle as a “for hire” vehicle, such as Uber driver, or taxi.

Are you a U.S. Citizen or permanent resident with a valid green card?

YES _____NO _____

**Note: participant will need to bring their Social Security Number to the study for W-9 paperwork for payment. (The card is not needed if they have their Social Security Number memorized.)

Criterion: Must be a U.S. citizen or permanent resident (green card holder). Student visas do not apply.

If selected to participate in this study, will you provide your SSN and complete a W-9 at the time of participation? YES _____ NO _____

Criterion: Must be willing to provide SSN number and complete a W-9 at their first appointment; this is for payment purposes as required by Virginia Tech.

Do you understand and agree that no one other than you will be allowed to drive the research vehicle? YES_______ NO________

Criterion: Must agree to not allow anyone to drive the vehicle at any time during the study.

Do you live in the Northern Virginia area? YES _____ NO _____

If yes, Where do you live (city/state)? ______________________________________

Comments: ____

Criterion: Must live or work in the Northern Virginia/Washington DC area.

Do you plan to stay in this area over the next 3 to 4 months? YES______ NO________ Criterion: Must plan to reside in study area for duration of the study.
Do you agree to not allow any smoking inside the research vehicle? YES______ NO________ Criterion: Must agree to not allow any smoking inside the research vehicle.
Do you regularly drive in areas where videotaping or audio recording is not allowed, for example, military installations, high-security facilities, etc.? YES _____ NO _____ Notes:____ Criterion: Cannot drive in areas where videotaping/audio recording is not allowed.
You will be asked to drive without sunglasses when safe to do so. Will this present a problem should you be eligible to participate? Yes _______ No ______ Do you wear eyeglasses that tint or darken in the sunlight while sitting inside a vehicle? Yes _______ No _______ Criterion: Must be able to drive without sunglasses or without lenses that darken while inside a vehicle.
We need to ask a few questions about your medical history… Do you have a history of any of the following medical conditions? If yes, please explain.
Any history of neck or back conditions, or injury to those areas, which still limit your ability to participate in certain activities? YES _____ NO _____ If yes, please explain:____ Cannot have a history of neck or back conditions which still limit their ability to participate in certain activities.

Any head injury, stroke, or illness or disease affecting the brain? YES _____ NO _____ If yes, please explain:____ Cannot have a history of brain damage from stroke, tumor, head injury, recent concussion, or disease or infection of the brain.
Current heart condition which limits your ability to participate in certain activities? YES _____ NO _____ If yes, please explain:____ Cannot have a current heart condition which limits their ability to participate in certain activities.
Current respiratory disorder/disease or any condition which requires oxygen? YES _____ NO _____ Notes:____ Cannot have current respiratory disorder/disease or disorder/disease requiring oxygen.
Any epileptic seizures or lapses of consciousness within the past 12 months? YES _____ NO _____ Notes:____ Cannot have had an epileptic seizure or lapse of consciousness within the past 12 months.
Chronic migraines or tension headaches? YES _____ NO _____ If yes, do they occur more than once a month on average? YES _____ NO _____ Notes: Cannot have, on average, more than one migraine or severe headache per month during the past year.
Current problems with the inner ear, dizziness, vertigo, or balance problems? YES _____ NO _____ Cannot have current problems with inner ear, dizziness, vertigo, or balance problems.

Do you have diabetes which requires insulin? YES _____ NO _____

If yes, please explain:____

Cannot have uncontrolled diabetes (have they been recently diagnosed or have they been hospitalized for this condition, or any changes in their insulin prescription during the past 3 months?).

Have you had any major surgery within the past 6 months, including any eye procedures?

YES _____ NO _____

Must not have had any major surgery within the past 6 months (including eye procedures).

Do you currently suffer from motion sickness while driving a motor vehicle; are you comfortable with glancing at, say a personal device, a map, or GPS and back to the road several times, without getting motion sickness?

YES _____ NO _____

Cannot suffer from moderate to severe motion sickness while driving a vehicle and glancing at a device or map while driving.

Are you currently taking any medicines or substances that may cause drowsiness or impair your driving ability?

YES _____ NO _____

Cannot currently be taking any substances that may interfere with driving ability (cause drowsiness or impair motor abilities).

(*Females only*) Are you currently pregnant? (*if "yes," politely inform the participant:* while being pregnant does not disqualify you from participating in this study, you are encouraged to talk to your physician about your participation to make sure that you both feel it is safe. If you like, **<u>we can send you a copy of the consent form to discuss with your physician</u>**. *Answer any questions*)

YES _____ NO _____

(Can still participate, but encourage them to speak with their doctor first.)

Do you have normal, or corrected to normal, vision in both eyes?

YES _____ NO _____

Criterion: Must have normal or corrected to normal vision in both eyes.

Do you have normal, or corrected to normal, hearing? YES _____ NO _____ Criterion: Must have normal or corrected to normal hearing.
Are you able to drive an automatic transmission without assistive devices or special equipment? Yes _____No________ Criterion: Must be able to drive an automatic transmission without assistive devices/special equipment.
Have you had any moving violations in the past 3 years? If so, please explain. YES _____ NO _____ Comments ____ Criterion: Must not have been convicted of more than two driving violations in the past 3 years. Must not have been convicted of driving while under the influence (DUI), DWI, etc. in the past 3 years.
Have you been involved in any automobile accidents in the past 3 years? YES _____ NO _____ If so, please explain ____ Criterion: Must not have been convicted of an injurious accident in the past 3 years (driving violation, where they were found 'at fault'; the accident involved another person).
There are five different high-end, luxury vehicles being used in this project. Would you be comfortable driving the following vehicle type for the 4-week duration of the study? Please note that these vehicles require premium fuel (with one exception). (Circle the models, they reply 'Yes' for.) 2016 Mercedes-Benz, E350 sedan 2015 Infiniti, Q50 sedan 2015 Tesla Model S (electric, not gasoline powered) 2017 Audi Q7 (light/small SUV), does have AWD 2016 Volvo XC90 (light/small SUV), does have AWD Comments:____

Criterion: Must be comfortable with driving one of the types of vehicles being used in the study and be willing to use only premium fuel (if that applies to their assigned vehicle). If participant owns one of these vehicles then they need to be assigned to a different make of vehicle.

If you participate, you will not be allowed to drive the vehicle off road on unpaved roads, dirt access roads, or long unpaved driveways. Are you okay with this?

YES _____ NO _____

Criterion: Must agree they will not drive a research vehicle off road.

If you participate, you will not be allowed to tow with the research vehicle or to put any type of bike rack, ski rack, storage rack, and/or container onto the vehicle. Are you okay with this?

YES _____ NO _____

Criterion: Must agree they will not put any type of bike rack, ski carrier, or storage type of container onto the vehicle. Must agree they will not tow anything with the research vehicle.

If you participate, you will not be allowed to haul any flammable or hazardous materials with the study vehicle. Are you okay with this?

YES _____ NO _____

Criterion: Must agree they will not haul any type of flammable or hazardous material, including gasoline containers.

Do you have experience driving a vehicle with any of the following features? Have you used:

(Circle any they have experience with.)

ACC (Adaptive Cruise Control)

Blind Spot Assist

Lane Keeping Assist

Steering Assist

Rear Camera

Electric Vehicles

This is to ensure that the widest possible levels of driver experience with automated technologies are included.

What type of roads do you typically travel each week? Please indicate a percentage of each type you drive on. Interstate _____________ Highway (average speeds 45–65 mph) _______________ City or urban streets (average speeds are 35 mph or less) ______________________ Rural routes (not a divided highway) ___________________________ Other ____ This is to ensure that the widest possible sample of roadway types are included.
Do you have any events or plans that you know of over the next three to four months, such as birth of a child, planned surgeries, extended vacations, trips, or travel plans, which would impact your normal routine? Notes: ____ This is to ensure that the normal driving for a participant is not altered during their participation. If an event cannot be rescheduled or a participant cannot be scheduled prior to or after an event, that participant should be excluded. Road trips are fine if they are not driving out of the country.

How did you hear about this project? ____

If the individual is eligible up to this point, get additional consent to collect addresses and initiate driving history check:

You are eligible for this project. Do I have your consent to record your contact information and initiate a driving history check? Yes No

[If yes, continue with the questions. If no, then politely thank him/her for his/her time and end the phone call.]

Availability: ____

Name (as appears on driver's license): ____________________________________

E-mail address: ____

Home Phone #: ____________________ Cell#_______________ Work #_____________

Home Address____

City: ____________________ State_______________ Zip_______________

Work Address____

City: _______________________ State_________________ Zip_________________

What is the distance in miles between your home and work? _______________________

How many days a week do you work on average? _______________________

Can you give us an idea of how much and where you drive on a weekly basis?

____

Criteria: Must drive at least 300 miles per week. Preference given to those whose distance between work and home is at least 30 miles, or their job entails they are driving at least 60 miles during the day each day.

If Eligible: Please provide your email address so that we can initiate the driving history check. This check will be performed by personnel at Virginia Tech Human Resources in cooperation with a third-party vendor using the same processes that VTTI personnel undergo upon hiring. The procedure for this check is as follows:

1. Name and primary email address is provided to Human Resources personnel.
2. Human Resources personnel initiate the check with the third-party vendor.
3. The third-party vendor will contact you via email and provide a secure link for you to provide your information.
4. Information that you must provide to the third party includes name as it appears on driver's license, current address, Social Security Number, primary phone number, email address, state from which your driver's license was issued, driver's license number, and expiration date. You will also be asked if they have other current addresses, and any other names or aliases.
5. The third-party vendor will notify VTTI if the driving check is clear.

Once we receive confirmation of your driving history check, we will contact you to schedule an appointment to meet with you and continue your participation. We encourage you to read a copy of the Informed Consent prior to coming in for your scheduled appointment. Please review it ahead of time and contact us with any questions or concerns. You will be asked to read and sign a copy of this document upon meeting with VTTI staff and prior to participating. Do not bring this document with you to the appointment; we simply ask for you to review the document ahead of time and to let us know you received it. Do you prefer we send as an email attachment or by United States Postal Service (USPS)?

Scheduled on (date & time):____

____

Would you like to be contacted for future studies? Yes: ______No: ______

If yes, collect the following:

Last Name: ____________________________ First Name: ____________________Y.O.B. ___________

Home Phone #: _______________________ Cell#_________________ Work #_______________

Town or city: ______________________ State: _______

Specialty Driver's License____

If CDL, endorsements/restrictions____

Make and Model of Primary Vehicle (light) ____

Bristol Screening Questionnaire

Note:

Initial contact between participants and researchers may take place over the phone. If this is the case, read the following Introductory Statement, followed by the questionnaire. Regardless of how contact is made, this questionnaire must be administered verbally before a decision is made regarding suitability for this study.

Introductory Statement:

After prospective participant calls or you call them, use the following script as a guideline in the screening interview.

Hello. My name is _____ and I'm with the Virginia Tech Transportation Institute, here at the Smart Rd, in Blacksburg, VA. We are currently recruiting people to participate in a research study. Your visit will last approximately 7 hours. Half of participants will drive during the day and half at night. Paperwork and training is expected to take around 1-2 hours and the main driving portion of the study will be around 5 hours.

We will ask participants to drive our research vehicle, a Tesla Model S, on Route 460 and I-81 to Bristol, TN and back in order to test new automotive technology. An experimenter will NOT be present in the study vehicle during the main portion of the drive, however, our staff will train you on how to use the features of the Tesla and ensure you are comfortable with driving the vehicle with the experimenter prior to sending you out alone on the planned route. You will be shown how to use the Tesla Autopilot system and other driver assistance features; you will be expected to use the features while driving. You will be required to stop in Bristol, TN at a Tesla charging station to recharge the Tesla for 30 min., which is an electric vehicle.

The vehicle is equipped with data collection equipment which records video and audio data. Prior to the driving portion, you will need to complete paperwork, vision tests and a simple hearing test. No one is allowed to drive the vehicle except the enrolled participant; passengers will be prohibited, and no smoking will be allowed inside the research vehicle. Food and drink will be allowed during the trip.

This project pays $210 if you fully participate. Payment will be with a MasterCard.

Any questions yet?

If you are interested in possibly participating, I need to go over some screening questions to see if you meet all the eligibility requirements of this study. Any information given to us will be kept secure and confidential.

Do I have your consent to ask the screening questions? [If yes, continue with the questions. If no, then thank him/her for their time and end the phone call.]

Participant Eligibility Questions:

Do you currently hold, a valid U.S. driver's license, which you can present at the time of the study? YES _____ NO _____ If yes, how long have you held a U.S. license? _________________ Has your license ever been suspended? YES _____ NO _____ If yes, how many times & when? ____ Is your license valid now? YES _____ NO _____ *Criterion: they are ineligible to participate if unable to present a VALID U.S. driver's license at their appointment and they must be an experienced driver (at least 2 years). Can't include time with a Learner's Permit during the 2 years of experience. (Must be fully licensed for at least 2 years).* *Must not have a history of license suspension during the past 7 years or have a history of multiple suspensions.* *NOTE: They will be reminded that they must present a driver's license at their appointment if scheduled.*
On average, how many days a week do you drive? ______________ *Criterion: Must drive, on average, at least 3 days per week.*
Does your current U.S. Driver's License have any restrictions? YES _____ NO _____ *Criterion: Must present a driver's license with NO restrictions at their appointment if scheduled. For example, can't be restricted to only driving to and from work. Participating in a research project doesn't qualify as 'work'.*
Are you willing to have your driving history verified by us? YES ___ NO ___ If yes, do you have a personal email and Internet access to complete the driving history survey? YES _____ NO _____ *Note: You will receive a link from a 3rd-party that we will identify for you ahead of time, via email, and you will be asked to put in personal information they need in order to complete the driving history background check. If you are eligible, we will go into more details about this process, after we complete all the screening questions.*

Criterion: Must be willing to submit to driving history verification using a personal email and have Internet access to complete the process.
Are you willing to complete an online survey? YES _____ NO _____ If yes, do you have a personal email and Internet access to complete the survey? YES _____ NO _____ *Note: You will receive a link via email, and you will be asked to complete a short survey. If you are eligible, we will go into more details about this process, after we complete all the screening questions.* *Criterion: Must be willing to complete an on-line survey using a personal email and have Internet access to complete the process.*
What is your current age? _______________ YOB_________ *Criterion: Must be 25 - 54 years of age to participate.*
For research purposes, do you identify as Male, Female, [pause] or Other? (Circle one) *Criterion: the total number of participants will be gender-balanced, if possible.*
Are you a U.S. Citizen? YES ____ NO ______ If No, are you a permanent resident with a valid green card to work anywhere in the U.S.? YES ____ NO ______ To clarify, Are you a Visa holder or do you have a *Valid Green Card with permanent resident status*? Visa ____ Green Card ____ If you have a Visa you will not be eligible to participate. Those with a Permanent Resident Green Card are eligible. Notes:____ *Criterion: Must be a U.S. citizen or permanent resident (green card holder able to work anywhere in the U.S. with NO restrictions such as limit on number of hours he or she can work each week or place he or*

she is allowed to work, for example, he or she can't be limited to only working at 1 company or VT only). Visa holders are not applicable.
If selected to participate in this study, you will be asked to provide your SSN or VT ID number. Will you complete a W-9 for payment purposes as required by Virginia Tech at the time of participation? *(for payment documentation and tax recording purposes Va Tech will require them to complete a W-9)* <u>*Please note:*</u> *VA Tech would never require your SS # or any personal banking information during a phone call. If scheduled to participate in any type of study, VT would send instructions whether you need to bring personal information for an appointment, in order to complete required paperwork at a study location.* YES _____ NO _____ *Must be willing to provide SSN or VT ID number for payment purposes.*
Do you have a smartphone with Bluetooth capability, and be willing to pair it with the vehicle during the study? YES _____ NO _____ Is the Bluetooth capability a feature that you typically use? YES _____ NO _____ Does your phone have a camera? YES _____ NO _____ There is a point in the study where you will park the vehicle, would you be willing to use your phone to take two specific photos, while parked, and send them by text or email to the research team from the designated location? Type & Comments: ____ *Criterion: Must own a smartphone with Bluetooth capability and a camera. Preference given to those who use Bluetooth regularly. Must be willing to use their phone's camera and text or email two photos to research staff with the phone while at the designated stopping point during the study. Note: the vehicle will be parked; we will ask them to do this while at the charging station, which is discussed later in this screening.*
Are you available to participate in a session, lasting about 7 hours during the daytime; appointments will likely start at 9 am? YES _____ NO _____

Are you available to participate in a session, lasting about 7 hours during the night-time; appointments will likely start at 8 pm? YES _____ NO _____

Are you comfortable driving the Tesla on Highways and Interstates during

daylight hours from 9 am to 4 pm? YES _____ NO _____

nighttime hours from 8 pm to 3 am? YES ______ NO _______

Comments, if any: ____

Criterion: Volunteers will be scheduled for a visit during a time frame they've indicated as comfortable with, such as day vs night or either. Volunteers are needed for both day and night slots during to meet the requirements of the study. If the volunteer is comfortable with either night or daytime, they will be randomly assigned.

Do you agree to refrain from smoking while inside the research vehicle; this includes no vaping, electronic cigarettes, etc.? YES______ NO________

Criterion: Must agree they will not smoke or vape while in the research vehicle.

Do you understand and agree that no one other than you will be allowed to drive or ride in the research vehicle? YES_______ NO________

Criterion: Must agree to not allow anyone to drive or ride in the vehicle at any time during the study.

Do you (or the vehicle owner) have liability insurance on the vehicle you normally drive? You must be covered by the policy if the vehicle is not in your name. YES _____ NO _____

Criterion: In order to participate, an individual must have liability insurance on their primary vehicle. (Insured drivers will help to screen out high-risk individuals.)

Have you participated in any experiments for Virginia Tech Transportation Institute? YES ___NO ___

If yes, describe the study: ____

Criterion: Ineligible if in a previous related study (Charlotte, Emerald, Driver Expectations, Light Year, APIS, AD (Google car)).
Are you comfortable reading, writing, and speaking English? YES _____ NO _____ *Criterion: Must be comfortable reading, writing, and speaking English.* *NOTE: If the screener finds during the phone interview, the caller is struggling with their ability to communicate fluently in English or has a severe speech impediment (i.e. stuttering) that may affect their ability to participate in the voice command tasks, the screener may determine the caller as ineligible.*
The Tesla being used in this project is equipped with driver assistance features. Would you be comfortable driving on the Interstate and using the following vehicle features during the study? **Note:** You will receive training designed to replicate what you would receive at a dealership if you were to buy or lease this vehicle. An experimenter will demonstrate how to use the car and its features prior to going out alone. (Circle the features, they reply 'Yes' for.) Traffic Aware Cruise Control- A type of cruise control that will adjust the vehicle speed as well as distance from vehicles ahead Autosteer- A type of steering automation that will steer the vehicle within the lane of travel Comments:____ *Criterion: Must be comfortable with driving and using the features of the Tesla while driving on the interstate.*
The Tesla is an electric vehicle. Would you be comfortable stopping in Bristol, TN at the charging station and charging the vehicle for 30 min. halfway through the trip? YES _____ NO _____ **Note:** For daytime participants, the charging time will approximately occur between 12:30 and 1 pm; for nighttime participants, this will approximately be between 11:30 pm and 12 midnight. Experimenters will be available by phone, should they have any questions while at the charging station. There are several restaurants, one of which is open until 12 midnight, a short walk away; that you may visit while the vehicle is charging.

Are you comfortable with stopping and charging the vehicle during the daytime? _____ Nighttime? ___ **Notes: ____** *Criterion: Must be comfortable with stopping and charging the Tesla. Note if comfortable with charging at nighttime.*
Have you ever owned any model of Tesla vehicle? YES _____ NO _____ If No: Have you driven or traveled as a passenger in any model of Tesla before? YES _____ NO _____ If yes, do you know the model? __________ Notes: ____ *Criterion: Must not be a current Tesla owner. Priority will be given to participants that are not familiar with the driver assistance features of a Tesla.*
Do you typically work daytime hours or another schedule? Notes: ____ Do you typically stay up late or have a varied schedule? Notes: ____ *Criterion: This criterion should provide the widest possible range of behaviors.*
Have you ever experienced motion sickness while in a moving vehicle? YES _____ NO _____ Are you okay with driving and looking at a GPS system, then to the road and back, without getting motion sickness? YES _____ NO _____ Notes: ____

Criterion: Cannot easily suffer from motion sickness while in a moving vehicle. If they have had motion sickness while trying to read while riding in the front seat, it is acceptable; but not if they have difficulty riding in the back seat under any circumstance. Cannot have difficulty driving, looking down at a display on the console and back up to the road several times.

We need to ask a few questions about your medical history…

Do you have a history of any of the following medical conditions? If yes, please explain.

Any history of neck or back conditions, or injury to those areas, which still limit your ability to participate in certain activities? YES _____ NO _____

If yes, please explain:____

Criterion: Cannot have a history of neck or back conditions which still limit ability to participate in certain activities.

Do you have any mobility limitations which may cause you to require assistance getting in and out of the motor vehicle or walking to and from the building and out to the research vehicle?

Are you able to drive an automatic transmission without assistive devices or special equipment? Yes_____ No________

Criterion: Must not require assistance to walk out to the vehicle or getting in and out of a motor vehicle – no mobility limitations. No leg braces, ankle/foot in a boot, etc. Must be able to drive an automatic transmission without assistive devices or special equipment.

Any head injury, stroke, or illness or disease affecting the brain? YES _____ NO _____

If yes, please explain:____

Cannot have a history of brain damage from stroke, tumor, head injury, recent concussion, or disease or infection of the brain.

Any current heart conditions that limit your ability to participate in certain activities? YES ___ NO ___ If yes, please explain:____ *Cannot have a heart condition which limits their ability to participate in certain activities.*
Current respiratory disorder/disease or any condition which requires oxygen? YES _____ NO _____ Notes:____ *Cannot have current respiratory disorder/disease or disorder/disease requiring oxygen.*
Any epileptic seizures or lapses of consciousness within the last 12 months? YES _____ NO _____ Notes:____ *Cannot have had seizures or lapses of consciousness in the last 12 months.*
Chronic migraines or tension headaches? YES _____ NO _____ If yes, do they occur more than once a month on average? YES _____ NO _____ Notes:____ *Cannot have, on average, more than one migraine or severe headache per month during the past yr.*
Current problems with the inner ear, dizziness, vertigo, or balance problems? YES ____ NO _____ *Cannot have current problems with inner ear, dizziness, vertigo, or balance problems.*
Do you currently have uncontrolled diabetes? YES _____ NO _____ Notes:____

Cannot have uncontrolled diabetes (frequent low/high blood sugar levels that they are struggling to keep regulated). Cannot have been recently diagnosed or have been hospitalized for this condition or incurred any changes in their insulin prescription during the past 3 months.
Have you had any major surgery within the past six months, including any eye procedures? YES _____ NO _____ *Must not have had any major surgery within the past 6 months (including eye procedures).*
Are you currently taking any medicines or substances that may cause drowsiness or impair your driving ability? YES _____ NO _____ *Cannot currently be taking any substances that may interfere with driving ability (cause drowsiness or impair motor abilities)*
(*Females only*) Are you currently pregnant? (*if "yes," politely inform the participant:* while being pregnant does not disqualify you from participating in this study, you are encouraged to talk to your physician about your participation to make sure that you both feel it is safe. If you like, **we can send you a copy of the Consent Form to discuss with your physician**. *Answer any questions*) YES _____ NO _____ *(Can still participate, but encourage them to speak with their doctor first)*
Do you have normal, or corrected to normal, vision in ***both*** eyes? YES _____ NO _____ *Note: If you need glasses while driving, you will need to wear them during this experiment.* *Criterion: Must have normal or corrected to normal vision in both eyes.*
Do you have normal, or corrected to normal, hearing? YES _____ NO _____ *Criterion: Must be able to hear and follow researcher's verbal directions while participating.* *Must have normal or corrected to normal hearing. Must pass hearing test administered by VTTI.*

You will be asked to drive without sunglasses. Will this present a problem should you be eligible to participate? Yes _______ No ______ Do you wear eyeglasses that tint or darken in the sunlight while sitting inside a vehicle? Yes _______ No _______ *Criterion: Must be able to drive without sunglasses or w/o lenses that darken while inside a vehicle.*
If you participate, you will only be allowed to drive the vehicle on the pre-determined test route, which includes *Route 460 and Interstate 81*. Are you okay with this? YES _____ NO _____ Notes: ____ *Criterion: Must agree they will only drive the study vehicle along the pre-determined test route and must be comfortable with driving on the interstate.*
Have you had any moving violations in the past 3 years? YES ____ NO ____ If so, please explain____ *Criterion: Must not have been convicted of more than two driving violations in the past 3 years.*
Have you been involved in any automobile accidents in the past 3 years? YES _____ NO _____ If so, please explain____ *Criterion: Must not have been convicted of an injurious accident (driving violation) in the past 3 years.*

How did you hear about this project? ____

If the individual is eligible up to this point, get additional consent to collect full name and email in order to initiate the Pre-Drive Questionnaire online survey and the driving history check:

You are eligible for this project. Do I have your consent to record your contact information and initiate the online survey and the driving history check? Yes No

[If yes, continue with the questions. If no, then politely thank him/her for his/her time and end the phone call.]

Recruiting Others:

Do you know anyone else that may be interested in hearing about this study?

If yes, may we send you the information so you can forward it to them? (Or they can provide our phone #, email, website address to others; we will be happy to speak to anyone interested in hearing more)

Do you prefer we send you the info by Email: ________________________ or USPS mail (address):____

If Eligible:

Availability: ____

Name (as appears on driver's license): _____________________________________

Home Phone #: _____________________ Cell#________________ Work #______________

We will need you to complete a driving history check in order to meet eligibility requirements. You will receive notification to initiate the driving history check via email. This check will be performed by personnel at Virginia Tech Human Resources in cooperation with a third-party vendor using the same processes that VTTI personnel undergo upon hiring. The procedure for this check is as follows:

6. Volunteer's Full Name and primary email address is provided to Project personnel.
7. Full Name and primary email address is provided to VT Human Resources personnel.
8. VT Human Resources personnel initiate the check with the third-party vendor.
9. The third-party vendor will contact you via email and provide a secure link for you to provide your information.
10. Information that you must provide to the third party includes name as it appears on driver's license, current address, Social Security Number, primary phone number, email address, state from which your driver's license was issued, driver's license number, and expiration date. You will also be asked if they have other current addresses, and any other names or aliases.
11. The third-party vendor will send the driving history results to VT Human Resources.

Once we receive confirmation of your driving history check and if it meets VT requirements, you will be included in the pool of eligible participants. If selected to participate, we will contact you to complete an on-line survey by email and once we receive confirmation the survey is completed, we will schedule an appointment for you to participate.

We encourage you to read a copy of the Informed Consent prior to coming in for your scheduled appointment. Please review it ahead of time and contact us with any questions or concerns. You will be asked to read and sign a copy of this document upon meeting with VTTI staff and prior to participating. Do not bring this document with you to the appointment; we simply ask for you to review the document ahead of time and to let us know you received it. Do you prefer we send as an email attachment or by United States Postal Service (USPS)?

Scheduled on (date & time):____

E-mail: ____

Town or city you live & approximate travel time to VTTI: ______________________________

Criteria: Must complete a license history check and be deemed eligible to drive a VA state vehicle by the VT human resources department. Also must complete the on-line study survey to be eligible.

Would you like to be contacted for future studies? Yes: ______No: ______

If yes, collect the following:

Last Name: ____________________________ First Name: ____________________________ Y.O.B. ________________________

Home Phone #: _______________________ Cell#________________ Work #______________

Town or city: ______________________ State: _______ Zip: __________

Specialty Driver's License____

if CDL, endorsements ____

restrictions____

Make and Model of Primary Vehicle (light) _______________________________________

Appendix F. Questionnaires

This appendix includes all subjective questionnaires that are part of the research plan. Questionnaires were selected based on previous test track studies using L2 vehicles as well as previous NDS studies.

Deluxe Pre-Drive Questionnaire

*For Crash Risk please rate how much you feel this behavior increases your risk using the following rating scale: 1 = no greater risk, 4 = moderately greater risk, 7 = much greater risk.

	In the past 12 months while driving how often did you…	Never	Rarely	Sometimes	Often	Crash Risk* (1-7)
1	Run a red light?	0	1	2	3	
2	Drive when sleepy and find it hard to keep your eyes open?	0	1	2	3	
3	Take risks while driving because it is fun? For example, driving fast on curves or “getting air?”	0	1	2	3	
4	Change lanes suddenly to get ahead in traffic?	0	1	2	3	
5	Speed for the thrill of it?	0	1	2	3	
6	Not yield the right of way?	0	1	2	3	
7	Make illegal turns?	0	1	2	3	
8	Follow a car very closely or “tailgate?”	0	1	2	3	
9	Follow emergency vehicles when the siren is on?	0	1	2	3	
10	Take more risks because you are in a hurry?	0	1	2	3	
11	Drive at your normal speed during bad driving conditions such as road construction, rain, ice, or snow?	0	1	2	3	
12	Pass other cars on the right side or on the shoulder of the road?	0	1	2	3	
13	Try to be the first off the line when a light turns green?	0	1	2	3	
14	Accelerate when a traffic light turns yellow?	0	1	2	3	
15	Drive shortly after drinking alcohol or using recreational drugs?	0	1	2	3	

	In the past 12 months while driving how often did you…	Never	Rarely	Sometimes	Often	Crash Risk* (1-7)
16	Drink alcohol or use recreational drugs while driving?	0	1	2	3	
17	Cut off, honk, or yell at other drivers who drive too slowly or cut you off?	0	1	2	3	
18	Get very angry at other drivers?	0	1	2	3	
19	Drive to reduce tension?	0	1	2	3	
20	Do other things while driving, like use a cell phone, eat or drink, put on makeup, read things, or smoke cigarettes?	0	1	2	3	
21	Take your eyes off the road to adjust the CD player or pick something up from the floor?	0	1	2	3	
22	Take your eyes off the road to talk to passengers?	0	1	2	3	
23	Race other cars or drivers?	0	1	2	3	
24	Not check the rearview when passing another car or merging onto the highway?	0	1	2	3	
25	Drive 10–20 mph over limit?	0	1	2	3	
26	Drive more than 20 mph over limit?	0	1	2	3	
27	Not yield to pedestrians?	0	1	2	3	
28	Drive too fast for conditions?	0	1	2	3	
29	Drive without wearing a safety belt?	0	1	2	3	
30	Turn without signaling?	0	1	2	3	
31	Drive with badly worn tires?	0	1	2	3	
32	Pass where visibility was obscured?	0	1	2	3	
33	Not make a full stop at stop sign?	0	1	2	3	

Deluxe Initial Questionnaire

Date: ___________

Participant Number: ___________

Circle the number that best describes your feeling or impression.

Lateral Control Features

- I can rely on the lateral control features to function properly while I am doing something else.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- The lateral control features provided alerts when needed.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- The lateral control features gave false alerts.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- The lateral control features are dependable.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- I am familiar with the lateral control features.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- I felt safe using the lateral control features.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- I trust the lateral control features.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

Longitudinal Control Features

- I can rely on the longitudinal control features to function properly while I am doing something else.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- The longitudinal control features provided alerts when needed.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- The longitudinal control features gave false alerts.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- The longitudinal control features are dependable.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- I am familiar with the longitudinal control features

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- I felt safe using the longitudinal control features.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- I trust the longitudinal control features.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- Considering both lateral and longitudinal control features available in the vehicle, please rate your overall level of trust the vehicle.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

Deluxe Weekly Check-in Interview

Date: ___________

Participant Number: ___________

Week of Study: ___________

Inform the participant: I have some questions for you about your experience with the vehicle you have been driving. These questions are open-ended and in asking you these questions we are only interested in your thoughts and opinions. With your permission, I will record your answers during this phone call to transcribe later. These will help us better evaluate the lateral and longitudinal control features of the study vehicles.

Probe Questions:

- Overall, what are your thoughts on the lateral and longitudinal control features?
- Follow-up with questions on the key points the participant makes.
- Can you describe how comfortable you were using the longitudinal control (a.k.a., Adaptive Cruise Control, Intelligent Cruise Control, Distronic Plus, Traffic-Aware Cruise Control) system?
- Follow up with:
- How quickly (specific time or relative time) the participant reached that level of comfort
- Anything that they feel affected their level of comfort
- Can you describe how comfortable you were using the lateral control (a.k.a., Active Lane Assist, Active Lane Control, Steering Assist, Lane Centering, Lane Keep Aid) system?
- Follow up with:
- How quickly (specific time or relative time) the participant reached that level of comfort
- Anything that they feel affected their level of comfort
- Were there driving conditions, such as weather or traffic, that changed how you used the automated systems?
- Did you use the automated systems while driving on the express lanes this week?
- Follow up with:
- How would you describe your experiences with these lanes compared to general-purpose lanes?

- What were your thoughts when the vehicle provided you with information or alerts about the lateral or longitudinal control?
- When the lateral and/or longitudinal control feature provided a message, what were your first thoughts and actions?
- Follow-up with questions on which messages were received and the thoughts and actions the participant describes.
- If you were talking to a design team, what concerns would you have about lateral control features such as those you experienced?
- If you were talking to a design team, what concerns would you have about longitudinal control features such as those you experienced?
- Please rate your overall level of trust in the lateral control features.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- Please rate your overall level of trust in the longitudinal control features.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- Considering both lateral and longitudinal control features available in the vehicle, please rate your overall level of trust the vehicle.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

Deluxe Post-Experiment Questionnaire

Date: __________

Participant Number: __________

Circle the number that best describes your feeling or impression.

Lateral Automation Questions

- I can rely on the lateral automation to function properly while I am doing something else.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- The lateral automation provided alerts when needed.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- The lateral automation gave false alerts.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- The lateral automation is dependable.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- I am familiar with the lateral automation.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- I felt safe using the lateral automation.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- I trust the lateral automation.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

Longitudinal Automation Questions

- I can rely on the longitudinal automation to function properly while I am doing something else.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- The longitudinal automation provided alerts when needed.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- The longitudinal automation gave false alerts.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- The longitudinal automation is dependable.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- I am familiar with the longitudinal automation.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- I felt safe using the longitudinal automation.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- I trust the longitudinal automation.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

- Considering both lateral and longitudinal automation together, please rate your overall level of trust in the automated systems.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

Deluxe Post-Experiment Follow Up

Date: ___________

Participant Number: ___________

While you were participating in the study, how frequently did you:

- Pair your phone with the vehicle?

NEVER A FEW TIMES A MONTH A FEW TIMES A WEEK DAILY

- Use your phone for directions while driving?

NEVER A FEW TIMES A MONTH A FEW TIMES A WEEK DAILY

- Engage the vehicle lateral control features?

NEVER A FEW TIMES A MONTH A FEW TIMES A WEEK DAILY

- Engage the vehicle longitudinal control features?

NEVER A FEW TIMES A MONTH A FEW TIMES A WEEK DAILY

- Drive the vehicle in express lanes?

NEVER A FEW TIMES A MONTH A FEW TIMES A WEEK DAILY

- Use the parking assist features (if available)?

N/A NEVER A FEW TIMES A MONTH A FEW TIMES A WEEK DAILY

- Read the owner's manual?

NEVER A FEW TIMES A MONTH A FEW TIMES A WEEK DAILY

- Search for videos, tutorials, or other information online about the study vehicle?

NEVER A FEW TIMES A MONTH A FEW TIMES A WEEK DAILY

- Do you feel that your phone or other device was used more often when the automated features were engaged?

YES NO NA

If yes, which device:

- Do you feel that there were specific advantages or disadvantages driving vehicles with lateral and longitudinal control on express lanes?
- Response:
- What would you change about the lateral and longitudinal control features you were driving?
- Response:
- What would you change about the vehicle you were driving?
- Response:
- Were there any difficulties when using the lateral control features?
- Response:
- Were there any difficulties when using the longitudinal control features?
- Response:

- If your redesign suggestions were implemented, would you want to purchase a vehicle with full lateral and longitudinal control? If so, how much would you be willing to pay for these added features?
- Response:
- To what extent do you consider yourself aware of and interested in new technology?

NOT AT ALL   A LITTLE BIT   QUITE A BIT   VERY MUCH SO

Appendix G. Training Outlines

This appendix includes the training that will be provided to all study participants. Some material is general and will apply to all participants but vehicle-specific information will only be provided to the participants assigned to those vehicles.

E-ZPass Transponder Information

[Note: This will be covered for all participants]

Below is a general map of the express lanes available with the E-ZPass transponder in the Washington, DC, metropolitan area. Please do not remove the transponder from the vehicle. When you drive on the express lanes, toll equipment will detect the transponder automatically.

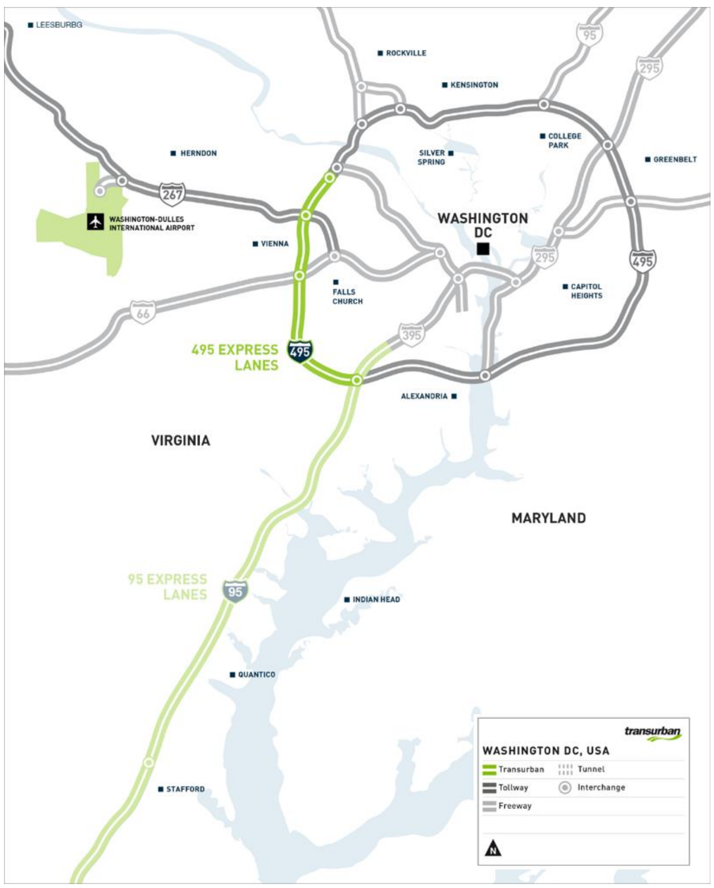

Figure 48. Map of Express Lanes With E-ZPass Transponder

More information about the express lanes can be found on the following websites.

- http://www.transurban.com/495expresslanes.htm
- http://www.ezpassva.com
- http://www.expresslanes.com/

Module 1: Outside Vehicle Familiarization

[Note: Module 1 is the same for all participants.]

Introduction

This is the [insert vehicle make and model] that you will be driving for the next month as part of our study. It is a 4-door [sedan or SUV] and is equipped with a(n) [engine type].

Vehicle	Engine
Audi Q7	3.0 L V-6
Infiniti Q50	3.7 L V-6
Mercedes E350	3.5 L V-6
Tesla Model S	Electric Motor (P90D)
Volvo XC-90	2.0 L Turbocharged 4-cylinder

Let's do a quick walk-around of the vehicle while I point out a few important features.

Fuel Door and Trunk/Lift Gate

The fuel door is located here (point out location and demonstrate opening). Press on it to open it. When the vehicle is locked, the fuel door is also locked. Located within the trunk is the spare tire and jack (where applicable; see note below).

- Audi does not have a spare tire or jack; rather it has a built in air compressor and tire sealant
- Tesla does not have a spare tire or jack

Audi, White Tesla, and Volvo

This vehicle has an automatic trunk/lift gate closure feature. Pressing this button will cause the trunk to automatically close. It has also has a safety feature that detects a person or object in the way, which will stop the trunk/lift gate from closing.

Audi and Volvo

This vehicle also has a convenience feature that allows you to place your foot under the rear bumper and the lift gate will automatically open. This is a nice feature to use if you are carrying something.

Tesla

Since the Tesla is an electric vehicle, there is no internal combustion engine under the hood. This is another trunk, also referred to as a frunk. Please do not place more than 300 lbs in the frunk. Also, please use both hands and place them directly to the sides of the Tesla emblem to close the frunk.

Comfort Features

Now let's walk back to the driver's door so I can go over some of the comfort features as well as mirror adjustments and a few other features.

The seat adjustments are located on the lower left of the seat pan. The long button parallel to the ground allows you to adjust the seat forward and backwards as well as up and down. The long vertical button allows you to adjust the incline of the backrest. This button allows you to adjust the lumbar support.

- Volvos – note the selector switch that switches between lumbar support adjustments and seat pan extender.

This button located on the steering column allows you to adjust the steering wheel both up and down and telescoping.

- Volvos – note the steering wheel adjustment is manual; there is a lever located underneath the steering column that you pull down to unlock and then adjust.

These buttons located along the arm rest are your window buttons to open and close the windows (point out the child lock button where applicable).

These buttons located right here are your mirror adjustments for both side view mirrors (point out operation including folding mirrors and mirror defrost where applicable).

Do you have any questions before getting into the vehicle?

- Answer any question(s) before proceeding.

You can go ahead and hop into the driver's seat and get comfortable. I would like you to go ahead and adjust the seat and steering wheel to your liking. I'm going to open the window and shut the door so you can adjust the side view mirrors. Also make sure to adjust the rearview mirror.

Is everything adjusted how you like it?

I will go ahead and store your settings into memory. In the event that the seat, steering wheel, or mirror adjustments are changed, for example when I perform maintenance, you can just press this button and everything will automatically return to your settings.

Left Side of Steering Wheel

Now I would like to point out some additional features that will be easier to discuss while standing here.

- Point out headlights, turn signals, and any other stalks on left side of steering column. Note that some vehicles have the windshield wipers on the left stalk.
    - For any advanced features, keep at high level until specific training.

Any questions before we continue?

- Answer all questions before getting into vehicle.

Okay great, now I will get into the passenger's seat.

Module 2: Review of Informed Consent Information

[Note: Module 2 is the same for all participants. After reviewing this module, proceed to the appropriate vehicle script for modules 3 and 4.]

Introduction

Now I would like to review some of the key information related to the vehicle and driving the vehicle that was included in the informed consent that we just reviewed and you signed today.

Learning Objectives

After reviewing the specific informed consent information, you will be able to explain:

12. Basic requirements for safe operation of the vehicle, including what to do if you are in a crash;
13. Key steps we've taken to protect your privacy; and
14. When you can expect to interact with the researchers.

Safe Operations

This vehicle is equipped with commercially available features. Any current driver could buy/lease/rent a vehicle with similar features. The systems have not been modified for use in this experiment in any way. We have installed data collection equipment, but this does not change the functionality of the vehicle in any way. You will be provided with instructions regarding the available features. You will have access to the owner's manual of the vehicle that further describes features and their limitations. You should never fully rely on the onboard systems, but should exercise normal caution when operating the vehicle.

The vehicle is equipped with a driver's side and passenger's side airbag, side airbags for both front passengers, curtain airbags for 1st and 2nd row occupants, and a supplemental restraint system. Additionally, all data collection equipment is mounted such that, to the greatest extent possible, it does not pose a hazard to you in any foreseeable case. If, at any time, you encounter any difficulties with the vehicle, or if you notice any maintenance issues with the data acquisition system (for example, a camera that comes loose and dangles), please contact us immediately.

My contact information can be found on this card. I will provide you with a contact card and there is also one located in the glove box.

- Point out glove box and how to open.

In Case of a Crash

If you are involved in a crash, follow the instructions listed on the yellow envelope located in the glove compartment. This includes immediately calling the state police. When it is safe to do so, you should also call and notify me about the crash.

- Point out the yellow envelope located in the glove compartment and the list of instructions.

E-ZPass Transponder

Also, this vehicle is equipped with an E-ZPass transponder that allows you access to all of the toll roads in the area as well as any other roads and bridges that accept E-ZPass.

- Point out transponder and show participant map.

Incident Button

I also want to point out this red button. This is called the incident button. Any time you feel something has happened please press this button. It will mark the timestamp in the data that will allow us to readily find any incidents you may have. Some examples of when to use include: (1) someone cutting you off, (2) the vehicle not functioning as it should, (3) an animal that has crossed the road in front of you, and, (4) a near-crash. These are not the only times you should use it, but rather examples of some situations. It is better to use the button if you ever have any doubts about the situation you encountered.

Protecting Your Privacy

Throughout the study, we will take all possible steps to protect your privacy and keep confidential your role in the study and the confidentiality of your personally identifying information. However, the researchers may be required by law to report matters such as child abuse, or a participant's threatened or actual harm to self or others. In terms of a vehicle, this could also include items such as driving under the influence of drugs or alcohol, allowing an unlicensed minor to drive the vehicle, or habitually running red lights at high speed. Such behaviors may result in your removal from the study and reporting of the behavior to the appropriate authorities.

I'd also like to remind you that this instrumented vehicle records both video and audio. You should not drive on to any installation or facility that prohibits recording devices. A placard has been placed in the vehicle to inform passengers that the vehicle is recording audio and video. You should refrain from discussing any sensitive, privileged, or proprietary information while in the vehicle. If you are on the phone while the vehicle is running, you should inform the other party that the vehicle is recording at the beginning of the call.

- Researcher to point out location of the placard.

At the end of the study, while you are present in the vehicle, we will delete information you have inputted into the vehicle such as phone contacts and saved destinations in the navigation system.

Further Interactions with the Research Team

During the study, it may be necessary for VTTI researchers to access the experimental vehicle (at your home or work location) to conduct maintenance on the vehicle or the data collection system. This may include transport of the vehicle to perform maintenance (such as oil changes) or may require an experimenter to access the trunk and interior of the vehicle. You do not need to be present, nor do you need to leave the vehicle unlocked (the researcher will have a key to the vehicle). Subject to your approval, this will take place between 7 a.m. and 11 p.m.

I'd also like to remind you to schedule and participate in a survey each week. The survey will be conducted over the phone with a member of the research team. This survey is expected to take 5 minutes or less, and will be scheduled at times convenient to you.

At the end of the participation period, VTTI staff will contact you to arrange a time to bring the instrumented vehicle back to a VTTI facility or other location to return the study vehicle. At this time, you will fill out a post-drive questionnaire and receive a pre-paid MasterCard loaded with **up to** $500.00. It is expected that this session will take 30 minutes.

If at any time during the study you have questions, please contact me.

- Participant liaison to provide contact information. Verify business cards with contact information are in the glove compartment.

Learning Objective Review

We've just reviewed some basic safety information, including what to do if you are in a crash, steps we've taken to protect your privacy, and when you should expect to interact with a researcher over the course of the study. Do you have any questions?

- Researcher to answer any questions.

Experimenter Notes

This note for vehicle orientation applies to all vehicles. KEEP A REASONABLE DISTANCE to the participant and DON'T TOUCH THE PARTICIPANT. If you have the need to again point out anything on the opposite side from where you are standing or sitting, WALK AROUND, DO NOT reach across the participant.

Module 3 – Audi Q7: Basic Features

Introduction

Now, we are going to spend a few minutes reviewing the basics of the vehicle so that you can begin to familiarize yourself with its features.

Learning Objectives

At the end of this process, you will be able to:

- Open the car using the key fob
- Turn the vehicle on and off
- Turn the wipers on and off
- Identify the gauges on the dash
- Pair a cell phone with the vehicle

I will also be pointing out other basic features such as the dual display, the system controls on the heads-up display (HUD)/navigation system, the audio and entertainment system, the heating, ventilation, and air conditioning, the drive mode selector (including the automatic transmission gear selector and manual shift mode), trunk and fuel door operation, the location of the spare tire/jack/tool kit, and where to find the owner's manual.

Key Fob and Start/Stop

This car features a push button start, which allows you to start the vehicle by pushing the Start/Stop button as long as the key fob is inside the vehicle. To start the vehicle, you must first depress the brake pedal, then press the Start/Stop button. If you would like only the auxiliary features on, you may push the Start/Stop button without depressing the brake pedal. To turn the vehicle off, simply hit the Start/Stop button while the vehicle is in Park. If you accidentally hit the Start/Stop button while it is in Drive or Reverse, the vehicle will switch to Neutral. If you then open the driver's or passenger's door, it will shift into Park.

Windshield Wipers

Next I would like to show you the windshield wiper controls. The windshield wipers are controlled by the stalk on the right side of the steering wheel.

- Note the adjustment features of the windshield wipers.

HVAC

Your heating, ventilation, and air conditioning controls are located here. Note that you can control the HVAC through the buttons or through the touch screen display.

- Point out all features: dual zone, mode, fan speed, temperature settings, and heated seats.

Sunroof and Interior Lights

The buttons on the overhead control panel control the lights throughout the vehicle, as well as the sliding sunroof.

- Point out all features: sunroof and vent, dome lights, and reading lights.

Multi-Media Display

Notice the multi-media display. This button allows you lower the display into the dash when not in use. Pressing the button again will raise the display. These buttons and touch pad will allow you to scroll through the various menu options. You can also change between the different audio sources as well as control the volume of the radio and seek or tune the radio.

- Demonstrate the radio and a few other features of the display.

Bluetooth Pairing

Next, I would like to show you how to pair a cell phone with the vehicle.

First, you will turn on your phone's Bluetooth. Next we select the phone settings from within the menu. Scroll through and then select connect device.

- Point out steps to pair with the vehicle.

Gauges

Now I would like to point out the gauges. You have a typical array of gauges including speed, fuel level, and engine temperature. This vehicle also has a Vehicle Information Display located between the speedometer and tachometer. Operation information is shown on the display for various warnings and indicators as well as the advanced features I am going to show you later.

- Point out all the gauges on the dash. Point out steering wheel buttons to change the display.

Gear Shift Selector

This is your gear shift selector.

- Point out operation of the gear shift selector (including the automatic transmission gear selector and manual shift mode).

Drive Mode

Point out the Drive Mode Selector switch and indicate how to select drive mode.

- Drive Mode Selector (including the automatic transmission gear selector and manual shift mode)

<u>Module 3 Learning Objectives Review</u>

You've just had the chance to practice:

- Opening the car using the key fob
- Turning the wipers on and off
- Identifying the gauges on the dash
- Pairing a cell phone with the vehicle

Do you have any questions about these features?

- Answer any questions before proceeding to Module 4: Audi Q7 Advanced Features

Module 4 – Audi Q7: Advanced Features

Introduction

We're now going to review the advanced features of the Audi Q7

There are three parts to this training:

- First, we will review the advanced features of the Audi Q7.
- Second, we will go on a short test drive. During that drive, I will demonstrate these features for you.
- Third, we will alternate and you will have a chance to drive and practice using these features.

Learning Objectives

By the end of this training session you should be able to:

- Name the advanced features of the Audi Q7 and the purpose of each feature.
- Describe the intended use of each feature and when it should not be used.
- Activate and deactivate the features.
- Identify the alerts and/or prompts associated with each feature.

Do you have any questions before we get started?

Part One: Review of Audi Q7 Driver Assistance Features

For the duration of the study, we ask that you drive it as you normally would.

This ***Audi Q7*** has several advanced features including:

- Adaptive Cruise Control (Longitudinal Control)
- Lane Departure Warning (LDW)
- Active Lane Assist (Lateral Control)
- Audi Pre-Sense
- Traffic Jam Assist
- Blind Spot Warning (BSW)
- When I'm driving, I will try to demonstrate and practice as many of these features as possible. However, there may be features that are continuously active or that we may be unable to demonstrate.

Driver Assistance Activation

In order to use the lateral and longitudinal automation features, some settings for the Driver Assistance systems will need to be activated. We are going to go ahead and practice activating the Driver Assistance systems. We ask that you keep these systems active when it is appropriate to do so.

- With the vehicle in park, have the participant/or researcher demonstrate while explaining how to activate/deactivate.

Now that we've reviewed how to activate the Driver Assistance systems, let's begin with the Adaptive Cruise Control**.** This is the longitudinal system control.

This feature regulates the speed of the vehicle while active and automatically helps you maintain the distance to the vehicle detected in front. This is an adaptive cruise control system that aids you based on vehicles detected with the use of the radar sensor system in the front of the vehicle. Adaptive Cruise Control brakes automatically so that the set speed is not exceeded. You can also control the distance at which this vehicle will follow a vehicle directly in front of you.

Now that we have discussed longitudinal control we will move onto lateral control. This is the Active Lane Control. The Lane Departure Warning will provide an auditory alert when you encroach on one of the lane lines. Active Lane Control goes one step further, when active, and will perform steering corrections to keep you within the travel lane and follow up with an auditory alert if a lane line has been touched.

Additionally, this vehicle is equipped with a Blind Spot Warning (BSW) system that alerts you when it detects a vehicle in either you driver's side or passenger's side blind spot, Audi Pre-Sense, and Traffic Jam Assist. I will discuss this during our test drive.

Do you have any questions before we head out on our test drive?

- *Answer any questions.*

Part Two: Researcher Demonstration

Now that we've reviewed basics associated with each feature, let's review how they work in a driving condition. I'm going to ask that we switch places so that I may drive.

- *Once you have switched seats, ensure that the participant has fastened his/her seatbelt. If seatbelt is not fastened ask the participant to fasten it.*
- ***Before we begin driving, please fasten your seatbelt.***
- *Drive the vehicle while demonstrating each feature for the participant.*

We'll begin with the following. For each below, insert the vehicle specific name for each technology. Although outlined here, adjust the order as necessary for safety or traffic conditions.

- [While demonstrating, remind participant of the following:]
- The purpose of the feature, that is what it does (for example, maintains your lane position)
- When it is intended to be used
- The minimum speed requirement for the system to become active.
- How the feature is activated and deactivated
- Indicator, alert and/or prompt associated with feature

*Demonstrate each additional feature in turn while encouraging the participant to refer to owner's manual pages as **appropriate**.*

Now that you've seen how these features work, I'd like for you to practice using each feature.

- *Researcher to stop at a safe location and switch places with the participant.*
- *Ensure that the participant has fastened her/his seatbelt.*

Part Three: Participant Practice Session

Please begin driving as you normally would.

- *Include any specific instructions regarding directions.*
- *As appropriate, instruct participant to activate, use, and deactivate features until s/he has had the opportunity to practice each feature that can be demonstrated at least twice.*

Module 4 Learning Objectives Review

Let's review what we've just covered. During this session you were able to practice using:

- Adaptive Cruise Control [Longitudinal Control]
- Lane Departure Warning
- Active Lane Control [Lateral Control]
- Blind Spot Warning (BSW)

Now that you have had a chance to experience the features associated with the Audi Q7, ***are there any other vehicle-specific questions that I can answer?***

- *Answer any questions.*

If you have any further questions after today, please read the owner's manual for important safety information, system limitations, and additional operating information.

Module 3 – Infiniti Q50: Basic Features

Introduction

Now, we are going to spend a few minutes reviewing the basics of the vehicle so that you can begin to familiarize yourself with its features.

Learning Objectives

At the end of this process, you will be able to:

- Open the car using the Intelligent Key
- Turn the vehicle on and off
- Turn the wipers on and off
- Identify the gauges on the dash
- Pair a cell phone with the vehicle

I will also be pointing out other basic features such as the dual display, the system controls on the heads-up display (HUD)/navigation system, the audio and entertainment system, the heating, ventilation, and air conditioning, the drive mode selector (including the automatic transmission gear selector and manual shift mode), trunk and fuel door operation, the location of the spare tire/jack/tool kit, and where to find the owner's manual.

Key Fob and Start/Stop

This car features a push button start, which allows you to start the vehicle by pushing the Start/Stop button as long as the key fob is inside the vehicle. To start the vehicle, you must first depress the brake pedal, then press the Start/Stop button. If you would like only the auxiliary features on, you may push the Start/Stop button without depressing the brake pedal. To turn the vehicle off, simply hit the Start/Stop button while the vehicle is in Park. If you accidentally hit the Start/Stop button while it is in Drive or Reverse, the vehicle will switch to Neutral. If you then open the driver's or passenger's door, it will shift into Park.

Windshield Wipers

Next I would like to show you the windshield wiper controls. The windshield wipers are controlled by the stalk on the right side of the steering wheel.

- Note the adjustment features of the windshield wipers.

HVAC

Your heating, ventilation, and air conditioning controls are located here. Note, you can control the HVAC through the buttons or through the touch screen display.

- Point out all features: dual zone, mode, fan speed, temperature settings, and heated seats.

Sunroof and Interior Lights

The buttons on the overhead control panel control the lights throughout the vehicle, as well as the sliding sunroof.

- Point out all features: sunroof and vent, dome lights, and reading lights.

Touch Screen Display

Notice the dual displays in the center stack. The top display shows your navigation. The bottom display is a touch screen and allows you to control many features including the radio. You can also use these three buttons to jump between the radio, main menu, and climate control. These buttons on your steering wheel will control the volume of the radio and allow you to seek or tune the radio.

- Demonstrate the radio and a few other features of the display.

Bluetooth Pairing

Next, I would like to show you how to pair a cell phone with the vehicle. First, you will turn on your phone's Bluetooth. Navigate to the phone menu on the display. Select "Connect Device". The system will search for available Bluetooth devices. Select your device when it appears in the display. You are now connected to this vehicle's Bluetooth.

- Point out steps to pair with the vehicle.

Gauges

Now I would like to point out the gauges. You have a typical array of gauges including speed, fuel level, and engine temperature. This vehicle also has a Vehicle Information Display located between the speedometer and tachometer. Operation information is shown on the display for various warnings and indicators as well as the advanced features I am going to show you later.

- Point out all the gauges on the dash. Point out steering wheel buttons to change the display.

Gear Shift Selector

This is your gear shift selector.

- Point out operation of the gear shift selector (including the automatic transmission gear selector and manual shift mode).

Drive Mode

Point out the Drive Mode Selector switch and indicate how to select drive mode.

- Drive Mode Selector (including the automatic transmission gear selector and manual shift mode)

<u>Module 2 Learning Objectives Review</u>

You've just had the chance to practice:

- Opening the car using the Intelligent Key
- Turning the wipers on and off
- Adjusting the mirrors
- Identifying the gauges on the dash
- Pairing a cell phone with the vehicle

Do you have any questions about these features?

- Answer any questions before proceeding to Module 4.

Module 4 – Infiniti Q50: Advanced Features

Introduction

We're now going to review the advanced features of the Infiniti Q50***.***

There are three parts to this training:

- First, we will review the advanced features of the Infiniti Q50.
- Second, we will go on a short test drive. During that drive, I will demonstrate these features for you.
- Third, we will alternate and you will have a chance to drive and practice using these features.

Learning Objectives

By the end of this training session you should be able to:

- Name the advanced features of the Infiniti Q50 and the purpose of each feature.
- Describe the intended use of each feature and when it should not be used.
- Activate and deactivate the features.
- Identify the alerts and/or prompts associated with each feature.

Do you have any questions before we get started?

Part One: Review of Infiniti Q50 Dynamic Driver Assistance Features

For the duration of the study, we ask that you drive it as you normally would.

This ***Infiniti Q50*** has several advanced features including:

- Intelligent Cruise Control (Longitudinal Control)
- Distance Control Assist (DCA)
- Lane Departure Warning and Prevention
- Active Lane Control (Lateral Control)
- Blind Spot Warning (BSW) and Blind Spot Intervention (BSI) Systems
- Back-up Collision Intervention (BCI)
- Approach Warning
- When I'm driving, I will try to demonstrate and practice as many of these features as possible. However, there may be features that are continuously active or that we may be unable to demonstrate.

Dynamic Driver Assistance Activation

In order to use the lateral and longitudinal automation features, some settings for the Dynamic Driver Assistance systems will need to be activated. We are going to go ahead and practice activating the Dynamic Driver Assistance systems. We ask that you keep these systems active when it is appropriate to do so.

- With the vehicle in park, have the participant/or researcher demonstrate while explaining how to activate/deactivate.

Now that we've reviewed how to activate the Dynamic Driver Assistance systems, let's begin with the Intelligent Cruise Control***. This is the longitudinal system control.***

This feature regulates the speed of the vehicle while active and automatically helps you maintain the distance to the vehicle detected in front. This is an adaptive cruise control system that aids you based on vehicles detected with the use of the radar sensor system in the front of the vehicle. Intelligent Cruise Control brakes automatically so that the set speed is not exceeded. You can also control the distance at which this vehicle will follow a vehicle directly in front of you.

Now that we have discussed longitudinal control we will move onto lateral control. These are the Lane Keeping Assist and Active Lane Keeping Assist. Lane Keeping Assist will provide an auditory alert when you encroach on one of the lane lines. Active Lane Keeping Assist goes one step further, when active, and will perform steering corrections to keep you within the travel lane and follow up with an auditory alert if a lane line has been touched.

Additionally, this vehicle is equipped with a Blind Spot Warning (BSW) and Blind Spot Intervention (BSI) system, Back-up Collision Intervention (BCI), and Approach Warning. I will discuss these during our test drive.

Do you have any questions before we head out on our test drive?

- *Answer any questions.*

Part Two: Researcher Demonstration

Now that we've reviewed basics associated with each feature, let's review how they work in a driving condition. I'm going to ask that we switch places so that I may drive.

- *Once you have switched seats, ensure that the participant has fastened his/her seatbelt. If seatbelt is not fastened ask the participant to fasten it.*
- ***Before we begin driving, please fasten your seatbelt.***
- *Drive the vehicle while demonstrating each feature for the participant.*

We'll begin with the following. For each below, insert the vehicle specific name for each technology. Although outlined here, adjust the order as necessary for safety or traffic conditions:

- [While demonstrating, remind participant of the following:]
- The purpose of the feature, that is what it does (for example, maintains your lane position)
- When it is intended to be used
- The minimum speed requirement for the system to become active.
- How the feature is activated and deactivated

- Indicator, alert and/or prompt associated with feature

Demonstrate each additional feature in turn while encouraging the participant to refer to owner's manual pages as appropriate.

Now that you've seen how these features work, I'd like for you to practice using each feature.

- *Researcher to stop at a safe location and switch places with the participant.*
- *Ensure that the participant has fastened her/his seatbelt.*

Part Three: Participant Practice Session

Please begin driving as you normally would.

- *Include any specific instructions regarding directions.*
- *As appropriate, instruct participant to activate, use, and deactivate features until s/he has had the opportunity to practice each feature that can be demonstrated at least twice.*

Module 4 Learning Objectives Review

Let's review what we've just covered. During this session you were able to practice using:

- Intelligent Cruise Control [Longitudinal Control]
- Including Distance Control Assist
- Lane Departure Warning
- Active Lane Control [Lateral Control]
- Including Lane Departure Prevention
- Blind Spot Warning (BSW)
- Back-up Collision Intervention [Rear Assist]

In addition, we discussed several other related features that we were unable to demonstrate and practice. These features included:

- Blind Spot Intervention System (BSI) [Blind Spot Assist]
- Approach Warning [Forward Assist]
- Including Predictive Forward Collision Warning and Forward Emergency Braking

Now that you have had a chance to experience the features associated with the Infiniti Q50, are there any other vehicle-specific questions that I can answer?

- *Answer any questions.*

If you have any further questions after today, please read the owner's manual for important safety information, system limitations, and additional operating information.

Module 3 – Mercedes-Benz E350: Basic Features

Introduction

Now, we are going to spend a few minutes reviewing the basics of the vehicle so that you can begin to familiarize yourself with its features.

Learning Objectives

At the end of this process, you will be able to:

- Open the car using the Intelligent Key
- Turn the vehicle on and off
- Identify the gauges on the dash
- Pair a cell phone with the vehicle

I will also be pointing out other basic features such as the display, the Mercedes-Benzo and entertainment system, the heating, ventilation, and air conditioning, the drive mode selector (including the automatic transmission gear selector and manual shift mode), and where to find the owner's manual.

Key Fob and Start/Stop

White Mercedes-Benz E350

This car features KEYLESS-GO, which allows you to start the vehicle by pushing the Start/Stop button as long as the KEYLESS-GO key is inside the vehicle. To start the vehicle, you must first depress the brake pedal, then press the Start/Stop button. If you would like only the auxiliary features on, you may push the Start/Stop button without depressing the brake pedal. To turn the vehicle off, simply hit the Start/Stop button while the vehicle is in Park. If you accidentally hit the Start/Stop button while it is in Drive or Reverse, the vehicle will switch to Neutral. If you then open the driver's or passenger's door, it will shift into Park.

Red Mercedes-Benz E350

To turn on the vehicle, first insert the key. Rotate the key once to turn on select auxiliary functions, like the windshield wipers. Turning it again will turn on the remaining functions. Turning it a third time will start the vehicle. After the vehicle is started, it will return to the second position. To turn off the vehicle, rotate the key fully counterclockwise until it is in the off position. You are free to remove the key.

Do you have any questions before we continue?

- Answer any questions before continuing.

HVAC

Your heating, ventilation, and air conditioning controls are located here.

- Point out all features: dual zone, mode, fan speed, temperature settings, and heated seats.

Sunroof and Interior Lights

The buttons on the overhead control panel control the lights throughout the vehicle, as well as the sliding sunroof. In addition, there are three different buttons that will call Mercedes-Benz Customer Assistance Center. We ask that you do not use any of these three buttons. I do want to point out, that, in the event an airbag is deployed or the Emergency Tensioning Device is triggered, an emergency call is automatically dialed. If there is no response to the call from the vehicle, an ambulance will be sent to the GPS coordinates transmitted.

COMAND Display

The center screen on the dashboard is called the COMAND display. To turn the COMAND display on or off, push the “ON” button in the center command. You can navigate the menus within it using the knob, called the controller, in the lower section of the center console. You may also go to direct menus using the buttons on the upper section of the center console: Radio, Media, Navi, Tel, and the Vehicle button, represented by a side view of a car. You also have the mute, reject or end call, and make or accept call button on the left panel. These buttons are also on the right side of the steering wheel, along with voice-operated control and volume buttons. The controller used to navigate the COMAND menus can rotate or be pushed in any direction, including in. Surrounding the controller, you have the back button, favorites button, and screen on/off button.

This button allows you to change between the Eco/Sport drive mode.

Now I’ll show you how to access the radio.

- Demonstrate the radio

In addition to the hard copy of the owner’s manual in the glove box, an electronic version can be pulled up on the COMAND display.

- Show location of electronic owner’s manual

Bluetooth Pairing

Next, I would like to show you how to pair a cell phone with the vehicle.

First, you will turn on your phone’s Bluetooth. Press the vehicle button in the center console, or navigate to the vehicle menu. Then press the “TEL” telephone button on the center console to bring up the menu for the telephone. It will take you to a screen of Mercedes-Benz apps if no other telephone menus are brought up prior to this. Push up on the controller to return to the telephone menu, then rotate the controller to phone and select it by pushing in the controller. Select “Connect Device” by pushing the controller down and pushing in. Then you may either search for phone if your Bluetooth on the phone is enabled and visible, or you may input a code into the phone from the car.

- Point out steps to pair with the vehicle.

Gauges

Now I would like to point out the gauges. You have a typical array of gauges, including fuel level, engine temperature, speed, and engine RPM.

- Point out all the gauges on the dash. Point out steering wheel buttons used to change the Multifunction display

There are many functions that can be called upon in the multifunction display. This display is controlled by the OK, back, and directional arrow buttons located on the left of the steering wheel. The left and right keys will cycle through menus, while the up and down arrows will select a submenu based on the current menu.

Gear Shift Selector

This is your gear shift selector.

- Point out operation of the gear shift selector (including the automatic transmission gear selector and manual shift mode).

Module 3 Learning Objectives Review

You've just had the chance to learn:

- About the key fob and start up/shutdown procedures
- How to operate the HVAC system, sunroof, and interior lights
- The features and how to use the COMAND display
- How to pair your phone to the vehicle
- And the different gauges and how to use the multifunction display

Do you have any questions about these features before proceeding?

Answer any questions before proceeding to Module 4.

Module 4 – Mercedes-Benz E350: Advanced Features

Introduction

We're now going to review the advanced features of the Mercedes-Benz E350.

There are three parts to this training:

- First, we will review the advanced features of the E350.
- Second, we will go on a short test drive. During that drive, I will demonstrate these features for you.
- Third, we will alternate and you will have a chance to drive and practice using these features.

Learning Objectives

By the end of this portion of training you should be able to:

- Name the advanced features of the Mercedes-Benz E350 and the purpose of each feature.
- Describe the intended use of each feature and when it should not be used.
- How to activate and deactivate the features.
- Identify the alerts and/or prompts associated with each feature.

Do you have any questions before we get started?

Part One: Review of Mercedes-Benz E350 Driver Assistance Features

For the duration of the study, we ask that you drive this vehicle as you normally would.

This ***Mercedes-Benz E350*** has several advanced driver safety features including:

- DISTRONIC PLUS with steering assist and Stop&Go Pilot (Longitudinal Control)
- Lane Keeping Assist and Active Lane Keeping Assist (Lateral Control)
- Blind Spot Assist and Active Blind Spot Assist
- PRE-SAFE Brake System
- Brake Assist System (BAS) PLUS with cross-traffic assist
- Collision Prevention Assist Plus

When I'm driving, I will try to demonstrate and practice as many of these features as possible. However, there may be features that are continuously active or that we may be unable to demonstrate.

Driver Assistance Settings Review

In order to use lateral and longitudinal control features, certain settings of the Driver Assistance system will need to be activated. We are going to go ahead and practice activating these features. Once activated, we ask that you keep these systems active when it is appropriate to do so.

- With the vehicle in park, walk through the steps on how to activate/deactivate the features.

Now that we've reviewed how to activate the Driving Assistance package, let's begin with the ***DISTRONIC PLUS with Steering Assist and Stop&Go Pilot. This is the longitudinal system control with partial lateral system control.***

This feature regulates the speed of the vehicle while active and automatically helps you maintain the distance to the vehicle detected in front. This is an adaptive cruise control system that aids you based on vehicles detected with the use of the radar sensor system in the front of the vehicle. DISTRONIC PLUS brakes automatically so that the set speed is not exceeded. The Steering Assist function will try to keep you centered in your driving lane by means of moderate steering corrections. It monitors the area in front of your vehicle by means of multifunction cameras at the top of your windshield. Last, Stop&Go Pilot is meant to assist you when driving in areas of heavy or stopped traffic. If active, this system will stop the vehicle if the vehicle in front of you also stops. If you come to a complete stop, you may start moving again, either by resuming DISTRONIC PLUS using the lever or by tapping the acceleration pedal. The steering assist and Stop&Go Pilot features are activated automatically when DISTRONIC PLUS is activated.

Now that we have discussed longitudinal control with some lateral control inputs, we will discuss the other components of lateral control. These are the Lane Keeping Assist and Active Lane Keeping Assist.

The Lane Keeping Assist feature will provide alerts to you if you break the road lines on either side of your vehicle without using your blinker. These alerts are in the form of a visual alert displayed on the multifunction display, and haptic feedback through the steering wheel for up to one and a half seconds. Active Lane Keeping Assist will follow up with a course-corrective action to place you back into your lane while performing a minor braking action.

Additionally, this vehicle is equipped with a blind spot warning system, PRE-SAFE Plus, Brake Assist System Plus, and Collision Prevention Assist Plus. I will discuss those during our test drive.

Do you have any question before we head out on our test drives?

- Answer any questions before proceeding.

Part Two: Researcher Demonstration

Now that we've reviewed basics associated with each feature, let's review how they work in a driving condition. I'm going to ask that we switch places so that I may drive.

- *Once you have switched seats, ensure that the participant has fastened his/her safety belt. If seat belt is not fastened ask to fasten.*
- ***Before we begin driving, please fasten your safety belt.***
- *Drive the vehicle while demonstrating each feature for the participant.*

We'll begin with the [for each below, insert the vehicle specific name for each technology]:

- DISTRONIC PLUS with steering assist and Stop&Go Pilot (Longitudinal Control) **[As demonstrating, remind participant of the following]**
- The purpose of the feature, that is what it does (for example, adaptive cruise control),
- When it is intended to be used
- How the feature is activated and deactivated
- Indicator, alert and/or prompt associated with feature

Demonstrate each additional feature in turn while encouraging the participant to refer to owner's manual pages as appropriate.

- Lane Keeping Assist and Active Lane Keeping Assist (Lateral Control)
- Blind Spot Assist and Active Blind Spot Assist
- PRE-SAFE Brake System
- Brake Assist System (BAS) PLUS with cross-traffic assist
- Collision Prevention Assist Plus

Now that you've seen how these features work, I'd like for you to practice using each feature.

- *Researcher to stop at a safe location and switch places with the participant.*
- *Ensure that the participant has fastened her/his safety belt.*

Part Three: Participant Practice Session

Please begin driving as you normally would.

- *Include any specific instructions regarding directions.*
- *As appropriate, instruct participant to activate, use, and deactivate features until s/he has had the opportunity to practice each feature that can be safely demonstrated at least twice.*

Module 4 Learning Objectives Review

Let's review what we've just covered. During this session you were able to practice using:

- DISTRONIC PLUS with steering assist and Stop&Go Pilot (Longitudinal Control)
- Lane Keeping Assist and Active Lane Keeping Assist (Lateral Control)
- Blind Spot Assist

In addition, we discussed several other safety-related features that we were unable to demonstrate and practice safely. These features included:

- Active Blind Spot Assist
- PRE-SAFE Brake System
- Brake Assist System (BAS) PLUS with cross-traffic assist
- Collision Prevention Assist Plus

Now that you have had a chance to experience the features associated with the ***Mercedes-Benz E350 are there any other vehicle-specific questions that I can answer?***

- *Answer any questions.*

If you have any further questions after today, please read the owner's manual for important safety information, system limitations, and additional operating information.

Module 3 – Tesla Model S: Basic Features

Introduction

Now, we are going to spend a few minutes reviewing the basics of the vehicle so that you can begin to familiarize yourself with its features.

Learning Objectives

At the end of this process, you will be able to:

- Open the car using the Intelligent Key
- Turn the vehicle on and off
- Turn the wipers on and off
- Identify the gauges on the dash
- Pair a cell phone with the vehicle

I will also be pointing out other basic features such as the 17-inch touchscreen display, the system controls on the display as well as the navigation system, the audio and entertainment system, the heating, ventilation, and air conditioning, the drive mode selection (including the automatic transmission gear selector), and where to find the owner's manual.

Key Fob and Start/Stop

Think of the key as a miniature version of the Model S, with the Tesla badge representing the front. The key has three buttons that feel like softer areas on the surface. These buttons represent the truck, frunk, and the lock/unlock all buttons.

When opening the door the Tesla automatically powers on the instrument panel and touchscreen display. The instrument panel has three modes – off, driving, and charging. When the Tesla is off, as it is now, the instrument panel shows the remaining estimated range, status of doors, and outside temperature.

By pressing the brake pedal, the vehicle will start. The center circle will now display the Speed, power consumption, range remaining, and drive mode in the center circle. Unless an indicator light applies to a current situation, it should turn off. If an indicator light fails to turn on or off, contact Tesla. Note, if the vehicle does not detect a key when you press the brake, the instrument panel displays a message telling you that a key was not detected.

Touch Screen Display

Now we're going to look at how to control the lights. At the bottom of the Touchscreen you'll see the controls bar. This is where you can see vehicle controls, climate controls, as well as volume. Think of the vehicle controls as the command center for the vehicle. Here, you can see doors and locks, and can easily open the charge port, open and close the trunk, and open the front trunk. You also have access to the interior lights and external lights as well as headlights.

- Point out all features: sunroof and vent, dome lights, and reading lights.
- Point out all features: dual zone, mode, fan speed, temperature settings, and heated seats.
- Demonstrate the radio and a few other features of the display.

Bluetooth Pairing

Next, I would like to show you how to pair a cell phone with the vehicle. First, you will turn on your phone's Bluetooth. On the touchscreen display, navigate to the phone options and then select connect device. It will search for Bluetooth devices. Select your device and then accept the push notification you receive on your phone. Your device is now connected to the Bluetooth of this vehicle.

- Point out steps to pair with the vehicle.

Gauges

Now I would like to point out the instrument panel. As we discussed, the instrument panel changes depending on whether the Model S is **OFF, DRIVING,** or **CHARGING.** Now that the vehicle is ready to drive, the instrument panel shows your current driving status and a real-time visualization of the road as detected by Model S's Autopilot components.

- Point out all the gauges on the dash. Point out steering wheel buttons.

Gear Shift Selector

This is your gear shift selector. To select a gear, with your foot pressing down on the brake pedal, press the stalk all the way down for DRIVE and all the way up for REVERSE. When you shift the vehicle into gear, the dash display changes and everything you need to know when driving on the instrument panel. You'll be able to see the current driving status and a real-time visualization of the road. To shift into PARK, press the button at the end of the stalk.

- Point out operation of the gear shift selector (including the automatic transmission gear selector and manual shift mode).

Charging

Now I want to go over the charging of the vehicle. I have previously shown you where the charging cable and adapters are located in the trunk and where the charging port is located on the driver's side rear of the vehicle. When plugged in, the lighted circle around the charging port will pulsate similar to a heartbeat. Once fully charged, the lighted circle will change to a steady state.

- Point out where the charging level should be set in the touchscreen menu for daily driving and longer trips.
- Review charging adapters and charging rates.

Now I would like to show you how to find charging stations in your area so when you are out and about you can charge the vehicle.

- Show participant how to use the navigation to display all charging stations in the area.

Additional Info

Here is where you can find the owner's manual.

- Point out location in touchscreen display.

Finally, I'd like to discuss some important information regarding cleaning the vehicle. You are not required to wash the vehicle; however, should you decide to, please keep the following information in mind.

- Discuss exterior washing guidelines. (For example, do not use windshield treatment fluids or abrasive cleaning fluids. If washing in an automatic car wash, use touchless car washes only. In hot weather, do not wash in direct sunlight.)
- Discuss cleaning the touchscreen using a soft, lint-free cloth specifically designed to clean monitors and displays (no cleaners like glass cleaner) or wet wipes or dry statically-charged cloths.
- Demonstrate changing touchscreen to clean mode. – Control – Displays – clean mode.

Module 3 Learning Objectives Review

You've just had the chance to practice:

- Opening the car using the Intelligent Key
- Turning the wipers on and off
- Adjusting the mirrors
- Identifying the gauges on the dash
- Pairing a cell phone with the vehicle
- How to charge the vehicle

Do you have any questions about these features?

- Answer any questions before proceeding to Module 4.

Module 4 – Tesla Model S: Advanced Features

Introduction

We're now going to review the advanced features of the Tesla Model S*.*

There are three parts to this training:

- First, we will review the advanced features of the Tesla Model S
- Second, we will go on a short test drive. During that drive, I will demonstrate these features for you.
- Third, we will alternate and you will have a chance to drive and practice using these features.

Learning Objectives

By the end of this training session you should be able to:

- Name the advanced features of the Tesla Model S and the purpose of each feature.
- Describe the intended use of each feature and when it should not be used.
- Activate and deactivate the features.
- Identify the alerts and/or prompts associated with each feature.

Do you have any questions before we get started?

Part One: Review of Tesla Model S Autopilot

For the duration of the study, we ask that you drive it as you normally would.

This Tesla S has several advanced features including Autopilot. The Autopilot suite consists of:

- Traffic Aware Cruise Control (Longitudinal Control)
- Researcher Note: Speed Assist will be integrated with the Traffic Aware Cruise Control training
- Autosteer and Auto Lane Change (Lateral Control)
- Researcher Note: Lane Assist including Lane Departure Warning and Side Collision Warning and Overtake Acceleration will be integrated with the Autosteer and Auto Lane Change training
- Collision Avoidance Assist including Forward Collision Warning and Automatic
- When I'm driving, I will try to demonstrate and practice as many of these features as possible. However, there may be features that are continuously active or that we may be unable to demonstrate.

Autopilot Features

In order to use the lateral and longitudinal features, certain settings of the Autopilot Convenience system will need to be activated. We are going to go ahead and practice activating these settings. Once activated, we ask that you keep these systems active when it is safe to do so.

- With the vehicle in park, have the participant/or researcher demonstrate while explaining how to activate/deactivate.

Autopilot Features Review

Now that we've reviewed how to activate the driver assistance features, let's begin with Traffic Aware Cruise Control with Overtake Acceleration. *[While explaining, refer to the status release notes that provides illustrations of the features. May also refer to the "driving" section of the electronic owners' manual.].*

This feature regulates the speed of the vehicle while active and automatically helps you maintain the distance to the vehicle detected in front. This is an adaptive cruise control system that aids you based on vehicles detected with the use of the radar sensor system and camera in the front of the vehicle. Traffic Aware Cruise Control brakes automatically so that the set speed is not exceeded. You can also control the distance at which this vehicle will follow a vehicle directly in front of you.

Now that we have discussed longitudinal control we will move onto lateral control. These are the Autosteer and Auto Lane Change systems. Once Traffic Aware Cruise Control with Overtake Acceleration is active, you can engage the Autosteer and Auto Lane Change System. Autosteer will perform steering corrections to keep you within the travel lane and follow up with an auditory alert if a lane line has been touched. Auto Lane Change will automatically change lanes for you when you use your turn signal.

Additionally, this vehicle is equipped with a Blind Spot Warning (BSW) and Back-up Collision Warning. I will discuss these during our test drive.

Do you have any questions before we head out on our test drive?

- *Answer any questions.*

Part Two: Researcher Demonstration

Now that we've reviewed basics associated with each feature, let's review how they work in a driving condition. I'm going to ask that we switch places so that I may drive.

- *Once you have switched seats, ensure that the participant has fastened his/her seatbelt. If seatbelt is not fastened ask the participant to fasten it.*
- ***Before we begin driving, please fasten your seatbelt.***
- *Drive the vehicle while demonstrating each feature for the participant.*

We'll begin with the following. For each below, insert the vehicle specific name for each technology. Although outlined here, adjust the order as necessary for safety or traffic conditions:

- [While demonstrating, remind participant of the following:]
- The purpose of the feature, that is what it does (for example, maintains your lane position)
- When it is intended to be used
- The minimum speed requirement for the system to become active.
- How the feature is activated and deactivated
- Indicator, alert and/or prompt associated with feature

Demonstrate each additional feature in turn while encouraging the participant to refer to owner's manual pages as appropriate.

Now that you've seen how these features work, I'd like for you to practice using each feature.

- *Researcher to stop at a safe location and switch places with the participant.*
- *Ensure that the participant has fastened her/his seatbelt.*

Part Three: Participant Practice Session

Please begin driving as you normally would.

- *Include any specific instructions regarding directions.*
- *As appropriate, instruct participant to activate, use, and deactivate features until s/he has had the opportunity to practice each feature that can be demonstrated at least twice.*

Module 4 Learning Objectives Review

Let's review what we've just covered. During this session you were able to practice using:

- Traffic Aware Cruise Control with Overtake Acceleration [Longitudinal Control]
- Autosteer
- Auto Lane Change
- Blind Spot Warning (BSW)
- Back-up Collision Warning

Now that you have had a chance to experience the features associated with the Tesla Model S, ***are there any other vehicle-specific questions that I can answer?***

- *Answer any questions.*

If you have any further questions after today, please read the owner's manual for important safety information, system limitations, and additional operating information.

Module 3 – Volvo XC90: Basic Features

Introduction

Now, we are going to spend a few minutes reviewing the basics of the vehicle so that you can begin to familiarize yourself with its features.

Learning Objectives

At the end of this process, you will be able to:

- Open the car using the Intelligent Key
- Turn the vehicle on and off
- Identify the gauges on the dash
- Pair a cell phone with the vehicle

I will also be pointing out other basic features such as the display, the entertainment system, the heating, ventilation, and air conditioning, the drive mode selector (including the automatic transmission gear selector and manual shift mode), and where to find the owner's manual.

Key Fob and Start/Stop

This is the key fob for the vehicle.

- Point out buttons.

To start the vehicle, press the brake pedal and twist this knob to the right. You can see it is labeled Start. To turn off the vehicle, twist the knob to the right.

Do you have any questions before we continue?

- Answer any questions before continuing.

Windshield Wipers

Next I would like to show you the windshield wiper controls. The windshield wipers are controlled by the stalk on the right side of the steering wheel. The button on the front of the lever activates and deactivates the rain sensor. When activated, the wipers will run automatically if rain is detected. When deactivated, the wipers must be set manually. You also have intermittent, low, and high settings when in manual mode. The toggle switch on the end of the lever adjusts the rear-window windshield wiper.

- Note the adjustment features of the windshield wipers.

HVAC

Your heating, ventilation, and air conditioning controls are located here from the bar at the bottom of the center display. Temperature is set by tapping the displayed temperature reading and sliding the selection up or down or using the plus and minus button. Fan level is set by tapping the icon in the center of the HVAC bar and selecting the desired level. Selecting vent area is done by tapping the shaded area between the fan icon and the seated person icon. Front and rear defrost can be selected from the Fan level menu or by either button next to the audio controls below the center display. Seat heating can be adjusted by tapping the seat icon on the HVAC bar. Rear climate and third row climate are controlled by swiping the HVAC menu to the left.

- Point out all features: dual zone, mode, fan speed, temperature settings, and heated seats.

Sunroof and Interior Lights

The buttons on the overhead control panel control the lights throughout the vehicle, as well as the sliding sunroof.

Center Display

I'd also like to point out some other features in the vehicle starting with the center display.

- System controls on the center display
- Point out the home button below the center display. Holding the home button will turn the center display off. Tapping the button again will turn the display on.
- Point out the Vehicle Functions (Swipe right from the home screen).
- Point out the Applications menu (Swipe left from the home screen).
- Point out the Settings menu (Swipe the notifications tab down from any screen).

Point out basic features of the navigation, audio and entertainment system.

- Navigation, Audio and Entertainment System
- Media, Navigation and Phone controls all have separate tabs on the home screen.
- Media can be controlled with the right steering wheel keypad, the media controls below the center display, or the Media tab on the home screen.
- Point out the USB and Auxiliary ports in the storage compartment in the center armrest.
- Audio can be played via FM, AM, Auxiliary, USB, or Bluetooth. Satellite radio is available with subscription from XM Radio.
- Navigation is started from the center display. Once navigation has been started, the right steering wheel keypad can be used to pause, mute guidance, repeat guidance or recalculate the route.

Bluetooth Pairing

Next, I would like to show you how to pair a cell phone with the vehicle. To pair a phone, select the Phone tab on the home screen, the Bluetooth button on the Applications menu, or the Connections menu within the Settings menu. The vehicle is also capable of connecting to the phone via the USB port in the center armrest storage compartment.

- Activate the Bluetooth feature on the phone, then
- Phone tab: Press Add phone. The vehicle and phone will begin searching for Bluetooth devices. Once found, security questions must be answered on the phone display and the center display to continue.
- Bluetooth application: Tapping the Bluetooth application will return to the Media tab on the home screen. Tap Add device. The vehicle will search until the phone is found. Once found, security questions must be answered on the phone display and the center display to continue.
- Communication menu: Swipe the notifications bar down from any screen. Tap Settings. Tap Communication. Tap Bluetooth. Tap Add device at the bottom, the vehicle will begin to search for connections. Once the phone connect has been found, security questions must be answered on the phone display and the center display to continue.
- Point out steps to pair with the vehicle.

Gauges

Now I would like to point out the gauges. The vehicle is equipped with a digital driver display of a standard instrument cluster, which includes speedometer, tachometer, vehicle mileage and fuel level. Between the speedometer and the tachometer you will see alerts from the advanced features of the vehicle, vehicle maintenance notifications, and optional navigation information, phone or media system controls. You can select options using the right keypad on the steering wheel or on the center display in the Settings menu under Display.

- Point out all the gauges on the driver display.
- Point out steering wheel buttons used to operate the trip computer and information settings.
- Point out the trip computer reset on end of the headlight control stalk.
- Point out the *Settings* menu on the center display.

Gear Shift Selector

This is your gear shift selector.

- Point out operation of the gear shift selector (including the automatic transmission gear selector and manual shift mode).

You also have a drive mode selector located here.

Module 3 Learning Objectives Review

You've just had the chance to learn:

- About the key fob and start up/shutdown procedures
- How to operate the HVAC system, sunroof, and interior lights
- The features and how to use the center display
- How to pair your phone to the vehicle
- And the different gauges and how to use the multifunction display

Do you have any questions about these features before proceeding?

Answer any questions before proceeding to Module 4.

Module 4 – Volvo XC90: Advanced Features

Introduction

We're now going to review the advanced features of the Volvo XC-90.

There are three parts to this training:

- First, we will review the advanced features of the XC-90.
- Second, we will go on a short test drive. During that drive, I will demonstrate these features for you.
- Third, we will alternate and you will have a chance to drive and practice using these features.

Learning Objectives

By the end of this portion of training you should be able to:

- Name the advanced features of the Volvo XC-90 and the purpose of each feature.
- Describe the intended use of each feature and when it should not be used.
- How to activate and deactivate the features.
- Identify the alerts and/or prompts associated with each feature.

Do you have any questions before we get started?

Part One: Review of Volvo XC-90 IntelliSafe Features

For the duration of the study, we ask that you drive this vehicle as you normally would.

This ***Volvo XC90*** has several advanced features including:

- Adaptive Cruise Control (Longitudinal Control)
- Lane Assistance (Lateral Control)
- Pilot Assist (Stop & Go Assistance system)
- City Safety (Forward Collision Warning)
- Blind Spot Information
- Park Assist
- Cross Traffic Alert
- Distance Alert
- Driver Alert Control

When I'm driving, I will try to demonstrate and practice as many of these features as possible. However, there may be features that are continuously active or that we may be unable to demonstrate.

IntelliSafe Feature Review

In order to use lateral and longitudinal control features, certain system settings will need to be activated. We are going to go ahead and practice activating these features. Once activated, we ask that you keep these systems active when it is appropriate to do so.

- With the vehicle in park, walk through the steps on how to activate/deactivate the features.

Now that we've reviewed how to activate the IntelliSafe package, let's begin with the longitudinal system control.

This feature regulates the speed of the vehicle while active and automatically helps you maintain the distance to the vehicle detected in front. This is an adaptive cruise control system that aids you based on vehicles detected with the use of the radar sensor system in the front of the vehicle. ACC is activated and deactivated using the left steering wheel key pad. The center key activates and deactivates the system. The plus and minus key increases or decreases the set speed. The plus and minus keys on the left keypad increase or decrease the speed by 5 mph when tapped. If the keys are held, the speed will increase or decrease by 1 mph. The keys with two and three bars select the distance setting. Five distance settings are available, indicated by bars between vehicles on the driver display. One bar is approximately equivalent to a 1-second follow interval. Five bars is approximately equivalent to a 3-second follow interval. ACC will deactivate if the driver holds the accelerator pedal higher than the set speed for one minute. The system will also deactivate if the driver applies the brake pedal. If the vehicle is traveling above approximately 45 mph, there is a lead vehicle and the speed differential between the lead vehicle and the set speed is great enough, ACC is capable of accelerating the vehicle when the left turn signal is activated. This feature is used to assist the driver in overtaking a slow lead vehicle.

Now that we have discussed longitudinal control with some lateral control inputs, we will discuss the other components of lateral control. This is the Lane Assistance system.

Lane Assistance is an aid to help the driver keep the vehicle with in the lane lines. It is not a lane centering system. Lane Assistance consists of two systems, Lane Departure Warning and Lane Keeping Aid. Lane Departure Warning uses auditory or haptic alerts to warn the driver of a lane departure. Lane Keeping Aid will apply steering force to keep the vehicle in the lane. When activated, Lane Assistance will automatically begin to track lane lines when the vehicle is traveling 40 mph and above. The driver's hands must be on the steering wheel, the system monitors this and will automatically enter standby mode if steering is not applied by the driver. If set, Lane Assistance will steer the vehicle back into the lane to prevent a lane departure while displaying colored lane lines on the driver display. If the vehicle crosses the lane line the auditory or haptic alert will be emitted to warn the driver of the departure. If the driver does not take control of the vehicle, the system will prompt the driver with a visual alert on the driver display requesting that the driver apply steering. If the driver does not apply steering after the prompt, Lane Keep Aid will emit a chime and enter standby mode, discontinuing any steering assistance.

Additionally, this vehicle is equipped with a blind spot warning system, Pilot Assist, City Safety, Cross Traffic Alert, and Distance Alert. I will discuss those during our test drive.

Do you have any question before we head out on our test drives?

- Answer any questions before proceeding.

Part Two: Researcher Demonstration

Now that we've reviewed basics associated with each feature, let's review how they work in a driving condition. I'm going to ask that we switch places so that I may drive.

- *Once you have switched seats, ensure that the participant has fastened his/her safety belt. If seat belt is not fastened ask to fasten.*

- ***Before we begin driving, please fasten your safety belt.***
- *Drive the vehicle while demonstrating each feature for the participant.*

We'll begin with the following. For each below, insert the vehicle specific name for each technology. Although outlined here, adjust the order as necessary for safety or traffic conditions:

[While demonstrating, remind participant of the following:]

- The purpose of the feature, that is what it does (for example, maintains your lane position)
- When it is intended to be used
- The minimum speed requirement for the system to become active.
- How the feature is activated and deactivated
- Indicator, alert and/or prompt associated with feature

Demonstrate each additional feature in turn while encouraging the participant to refer to owner's manual pages as appropriate.

Now that you've seen how these features work, I'd like for you to practice using each feature.

- *Researcher to stop at a safe location and switch places with the participant.*
- *Ensure that the participant has fastened her/his seatbelt.*

Part Three: Participant Practice Session

Please begin driving as you normally would.

- *Include any specific instructions regarding directions.*
- *As appropriate, instruct participant to activate, use, and deactivate features until s/he has had the opportunity to practice each feature that can be demonstrated at least twice.*

Module 4 Learning Objectives Review

Let's review what we've just covered. During this session you were able to practice using:

- Adaptive Cruise Control [Longitudinal Control]
- Lane Departure Warning
- Lane Keeping Aid [Lateral Control]
- Blind Spot Warning (BSW)
- Distance Alert

In addition, we discussed several other related features that we were unable to demonstrate and practice. These features included:

- Cross Traffic Alert
- City Safety
- Pilot Assist

Now that you have had a chance to experience the features associated with the Volvo XC-90, ***are there any other vehicle-specific questions that I can answer?***

- *Answer any questions.*

If you have any further questions after today, please read the owner's manual for important safety information, system limitations, and additional operating information.

Appendix H. Informed Consent Document

The language presented has been approved by the Virginia Tech Institutional Review Board.

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants

In Research Projects Involving Human Subjects

Title of Project: Deluxe Naturalistic Driving Study

Investigator(s): Myra Blanco, Sheldon Russell, Scott Tidwell, and Shane McLaughlin

I. Purpose of this Research Project

Currently, there are vehicles on the market that automate parts of the driving experience, but still require the driver to pay attention at all times. The purpose of the project is to investigate how drivers use these advanced vehicles. The study vehicle allow drivers to activate longitudinal control assistance features (a.k.a., Adaptive Cruise Control, Intelligent Cruise Control, Distronic Plus, Traffic-Aware Cruse Control) and lateral control assistance features (a.k.a., Active Lane Assist, Active Lane Control, Steering Assist, Lane Centering, Lane Keep Aid). The study vehicles also generate different types of alerts to notify drivers of situations where they need to pay attention. This study will recruit drivers from the Northern Virginia/Washington, D.C. region to investigate how different drivers interact with the new vehicles, and how the vehicles operate. The study will observe how drivers operate vehicles in various levels of traffic, on different types of roads, in different driving conditions, and at different speeds. If you decide and are eligible to participate, the study will record your image and voice while you are driving the vehicle and will also record data from the vehicle.

II. Procedures

Previously, you gave verbal consent to check your driving history. This check was performed by personnel at Virginia Tech Human Resources in cooperation with a third-party vendor using the same processes that VTTI personnel undergo upon hiring. To review, the procedures for this check were as follows:

- You provided your full name as it appears on your driver’s license and your primary email account.
- This information was then provided to Human Resources personnel.
- Human Resources personnel initiated the check with the third-party vendor.
- The third-party vendor contacted you via email and provided a secure link for you to provide your information.
- Information that you provided included: Name as it appears on driver’s license, current address, social security number, primary phone number, email address, state from which your driver’s license was issued, driver’s license number, and expiration date. You were also asked if you have other current addresses, and any other names or aliases.
- After you submitted your information, the vendor returned only the results of the check to Human Resources personnel; note that no personal information was submitted back to Human Resources. The results of this check confirmed your eligibility for the study.

This study will take place in two different sessions. The first session is an initial meeting to go over the informed consent document, complete study paperwork, ensure study eligibility, and provide an orientation of the study vehicle. The final session is to return the study vehicle. More detail about each session is described below.

Today's Meeting (at Your Home)

Today, we will go over the Informed Consent Document, and have you sign (if you wish to participate; you are still under no obligation to participate); ask to see your driver's license; and fill out a tax form. Afterwards, we will be checking the area that you plan to store the vehicle, completing some additional paperwork, and completing an orientation of the vehicle features. The additional paperwork will include a demographic questionnaire and a pre-drive questionnaire. After completing the orientation of the vehicle, we will go over a checklist confirming the vehicle's current condition and odometer reading. This step is expected to take around an hour.

After completing paperwork and the vehicle orientation, we will go on a test drive so you can ask any questions about the vehicle features before you take possession. The test drive will be from your home to a VTTI facility. The exact route will vary based on the location of your home, but the test drive is expected to take an hour or less and will include both highway and city driving.

After completing the test drive, you will be loaned the study vehicle. We ask that you drive this vehicle instead of your own vehicle for the 4-week time period. A short survey about your use of the vehicle and vehicle features will be conducted by telephone or via online survey once during each week of participation.

Final Meeting

At the end of the participation period, VTTI staff will contact you to arrange a time to bring the instrumented vehicle back to a VTTI facility or other location to return the study vehicle. At this time, you will fill out a post-drive questionnaire and receive a pre-paid MasterCard loaded with up to $500.00. When you leave the study, we may ask you whether we can keep your contact information to contact you for participation in future follow-on studies. This will be optional, and if you do not agree, we will delete your contact information one year after data collection is complete. It is expected that this session will take 30 minutes.

During your participation, we ask that you do the following tasks:

- Prior to receiving the vehicle, allow experimenters to view your garage or vehicle storage area. For one of our study vehicles it is necessary that the participant have a garage at home in which they can charge the study vehicle.
- Drive the instrumented vehicle as you normally would if it was your own vehicle to your normal destinations. The study has attempted to recruit participants who are likely to drive 1,200 miles over the four weeks of participation. However, we are providing an incentive for you to drive over 1,200 miles over the four weeks of participation (this equates to 43 or more miles of driving per day of participation).
- Contact the research team in the event that you encounter any difficulties with the vehicle, or if you notice any maintenance issues with the data acquisition system (for example, a camera that comes loose and dangles).
- Schedule and participate in weekly surveys online or with a member of the research team. This survey is expected to take 5 minutes or less, and will be scheduled at times convenient to you.
- Permit VTTI researchers to access the experimental vehicle (at your home or work location) if necessary to conduct maintenance on the vehicle or the data collection system. This may include

transport of the vehicle to perform maintenance (such as oil changes) or may require an experimenter to access the trunk and interior of the vehicle. You do not need to be present, nor do you need to leave the vehicle unlocked (the researcher will have a key to the vehicle). Subject to your approval, this will take place between 7 a.m. and 11 p.m.

- If you are involved in a crash, you are instructed to follow the instructions listed on the orange envelope located in the glove compartment. When it is safe to do so, you should call the research team to notify them about the crash.
- At the end of the participation period, VTTI staff will contact you to arrange a time to bring the instrumented vehicle back to a VTTI facility or other location to return the study vehicle. At this time, you will fill out a post-drive questionnaire and receive a pre-paid Master Card loaded with up to $500.00. It is expected that this session will take 30 minutes. Please notify the research team immediately if your circumstances change and you need to end your participation before the scheduled time.
- The instrumented vehicle records both video and audio. You should not drive onto any installation or facility that prohibits recording devices. A placard will be placed in the vehicle to inform passengers that the vehicle is recording audio and video. You should refrain from discussing any sensitive, privileged, or proprietary information while in the vehicle. If you are on the phone while the vehicle is running, you should inform the other party that the vehicle is recording at the beginning of the call.

Please be aware that VTTI may end your participation at any time for any reason, including but not limited to, vehicle maintenance issues, driving history issues, or failure to meet responsibilities described above. If so, you will be compensated for the time that you did participate.

Again, your role during this study will be to drive this vehicle instead of your own vehicle at all times to your normal destinations. We are providing added compensation if you drive over 1,200 miles during your participation, which may or may not be part of your normal routine. Additionally, we are providing an E-ZPass transponder that will allow access to some routes that may or may not be part of your normal routine. It is important that you understand that we are not evaluating <u>you</u> in any way. We are collecting information about assistive safety systems and are interested in your opinion about their usefulness.

III. Risks

You are being asked to drive a certain amount of miles while in the study; any increase above your normal mileage increases your exposure risk for a crash. You are also being provided an E-ZPass transponder for the lanes in the Washington, DC, metropolitan area. If you do not ordinarily use these lanes, you may be at increased risk while you become familiar with their operation.

The operation or drivability of the vehicle should not be affected by the instrumentation, and thus carries a similar risk as when you operate any unfamiliar vehicle containing new or unfamiliar technologies. However, if you violate state or local driving laws (such as driving under the influence, exceeding posted speed limits, or driving while distracted), the instrumentation could record evidence of these violations. This has the potential to pose greater than minimal risk of legal harm. A variety of strategies and procedures have been developed to reduce the potential for legal or economic harm. These strategies include encrypting the data obtained by sensors and cameras and using a code number to identify you with the code key maintained in a secure location. More details on these strategies are provided below.

All data collection equipment is mounted such that, to the greatest extent possible, it does not pose a hazard or problem for you when you drive. None of the data collection equipment should get in the way of your normal field of view.

There are non-driving risks resulting from participation. Cameras will be placed in the vehicle. If you drive into an area where cameras are not allowed, including international border crossings, certain military and intelligence locations and certain manufacturing plants, there is a risk that you may be detained or arrested or that the vehicle may be impounded. For this reason, by signing this Informed Consent and thereby agreeing to participate in the study, you also are agreeing not to drive into any such areas while you are in this study. We have provided a letter which you should keep in the glove box for these cases. The letter describes the vehicle’s role in the study without identifying you as a participant in the study.

Throughout the study, we will take all possible steps to protect your privacy and keep confidential your role in the study and the confidentiality of your personally identifying information. However, the researchers may be required by law to report matters such as child abuse, or a participant’s threatened or actual harm to self or others. In terms of a vehicle, this could also include items such as driving under the influence of drugs or alcohol, allowing an unlicensed minor to drive the vehicle, or habitually running red lights at high speed. Such behaviors may result in your removal from the study and reporting of the behavior to the appropriate authorities. In the event of a crash, it may not be possible to prevent the equipment and the data from falling into the hands of the police; if this happens, however, the data are still encrypted and inaccessible and unreadable to these individuals.

You are also responsible for protecting your privacy. Do not post or disclose your participation on any public forum including websites, newspapers, radio, and television. Protect your role in the study the same way that you protect other personal and private information. If you do not keep confidential your role in the study, there is a risk that some of the data collected during the study, including your personally identifying information, may be used against you in a court case or other legal proceeding.

The following precautions will be taken to minimize the risk to you:

- You may decide not to participate at any time.
- The study vehicles are all commercially available vehicles with commercially available technology packages. Any current driver could buy/lease/rent a similar vehicle. The systems are not modified for use in this experiment in any way.
- The vehicle is equipped with a driver's side and passenger's side airbag, side airbags for both front passengers, curtain airbags for first and second row occupants, and supplemental restraint system.
- All data collection equipment is mounted such that, to the greatest extent possible, it does not pose a hazard to you in any foreseeable case.
- You will be provided with instructions regarding the available features. You will have access to the owner’s manual of the vehicle that further describes features and their limitations. You should never fully rely on the onboard systems, but should exercise normal caution when operating the vehicle.
- The vehicles will be maintained by the research team, including routine maintenance, to ensure they are safe to operate.

Insurance

In the event of a crash or injury in an automobile owned or leased by Virginia Tech, the automobile liability coverage for property damage and personal injury is provided. The total policy amount per occurrence is $2,000,000. This coverage (unless the other party was at fault, which would mean all expense would go to the insurer of the other party's vehicle) would apply in case of a crash for all volunteers and would cover medical expenses up to the policy limit. For example, if you were injured in an automobile owned or leased by Virginia Tech, the cost of transportation to the hospital emergency room would be covered by this policy. Any coverage of the participant is limited to the terms and conditions of the insurance policy.

Participants in this study are considered volunteers, regardless of whether they receive payment for their participation; under Commonwealth of Virginia law, worker's compensation does not apply to volunteers; therefore, if not in the automobile, the participants are responsible for their own medical insurance for bodily injury. Appropriate health insurance is strongly recommended to cover these types of expenses.

For example, if you were injured outside of the automobile owned or leased by Virginia Tech, the cost of transportation to the hospital emergency room would be covered by your insurance.

IV. Benefits

While there are no direct benefits to you from this research, you may find the experiment interesting. No promise or guarantee of benefits is made to encourage you to participate. Participation in this study will contribute to the improvement of future studies concerning advanced vehicle systems.

V. Extent of Anonymity and Confidentiality

The data being collected in this experiment includes several forms of personally identifiable information (PII) that is linked or linkable to you personally, as well as other non-PII data:

- Personal information, including your name, home address, work address, driver's license number, telephone number, email address, insurance information, and Social Security Number. This is personally identifiable information. This is required for payment purposes and is not for use in any analysis, nor will it be reported in any way. Personal information necessary for the driving history check is never transmitted back to VTTI and will not be reported in any way.
- Video recordings collected during the experiment. These recordings will include your face. This data is personally identifiable because it shows your image. It is not, however, linked to your name.
- Audio recordings collected during the experiment. This data is treated as personally identifiable because your voice may be recognizable. However, the records will not be linked to your name.
- GPS data collected while driving. Although this data is linked only to your participant number, we treat it with enhanced protection (as if it were personally identifiable) because it contains location information that may reveal your activities and routes.
- Driving measures/data, such as following distance, lane keeping, and vehicle speed. These are collected by recording instruments in the vehicle. These data are linked only to your participant number.
- There will also be an ambient atmospheric analyzer that is capable of detecting the presence of alcohol in the passenger compartment under certain conditions. It may not be able to distinguish whether the alcohol was imbibed or applied (as in hand sanitizer), and it will be unable to determine whether it is emanating from the driver or a passenger. However, this sensor will flag the data for possible indications of impaired driving. This data will only be linked to your participant number.
- Subjective responses to questionnaires. You will be asked questions at specified times during your participation. This data will be linked only to your participant number.

We take steps to protect your privacy with respect to the data gathered in this experiment by separating your name from the data and replacing it with a number (e.g., Driver 001). It is possible that the Institutional Review Board (IRB) or study sponsor may view this study's collected data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in research.

All video and other data recorded in this study will be stored in a secured area at Virginia Tech. Access to the data files will be under the supervision of the Principal Investigator and lead VTTI researchers involved in the project. All data will be encrypted at the time of data collection and will be decrypted only for approved analyses. The study sponsor also will have access to the data collected throughout all phases of this experiment. It is possible that, after data collection is complete one copy of study data will be transferred to the project sponsor (the U.S. Department of Transportation) for permanent storage and oversight. Please note that they will follow the same procedures for protecting participant privacy.

Audio data will be analyzed as it relates to specific research questions regarding vehicle system use. The content of these or any other conversations or other interactions will not be analyzed. Once the necessary data is extracted from the audio recordings, audio files will be deleted and will not be available for any future studies. This data will not be transferred to the project sponsor, as it will be erased during data reduction and will no longer exist at the conclusion of this study.

Authorized project personnel and authorized employees of the research sponsors will have access to the study data that personally identifies you or that could be used to personally identify you. As explained below, other qualified research partners may also be given limited access to your driver, vehicle, and driving data, solely for authorized research purposes and with the consent of an IRB. This limited access will be under the terms of a data sharing agreement or contract that, at a minimum, provides you with the same level of confidentiality and privacy protection provided by this document. However, even these qualified researchers will not be permitted to copy raw study data that identifies you, or that could be used to identify you, or to remove it from the secure facilities in which it is stored without your consent.

VTTI research staff or the study sponsor may present video files in conference presentations or technical briefings. Those portions of video displaying your image will be de-identified with video editing software prior to being shown.

The sponsor of this project, NHTSA, may publicly release data, in final reports or other publication or media for scientific, educational, research or outreach purposes. Additionally, NHTSA may be required to release data under the Freedom of Information Act (FOIA) or other Open Government Initiative request or court order. Generally, data will not be: (1) released in raw form; (2) linked to your name or contact information; and (3) will be redacted or edited to remove personally identifying information. This includes editing of video files to remove personally identifying information if necessary. This also includes redaction/exclusion of GPS data when it identifies a location that could be used to personally identify you, such as your home.

If Involved in a Crash

If you are involved in a crash while participating in this study, the data collection equipment in your vehicle will likely capture the events leading up to the event. The data collection equipment SHOULD NOT be given to police officers or any other party. You are under NO LEGAL OBLIGATION to voluntarily mention the data collection equipment or your participation in this study at the time of a crash or traffic offense. We have provided a letter which you should keep in the glove box for these cases. The letter describes the vehicle’s role in the study without identifying you as a participant in the study.

We will do everything we can to keep others from learning about your participation in the research. We may disclose information about you as required by law, in conjunction with a government inquiry, or in litigation or dispute resolution. You should understand that this informed consent does not prevent you or a member of your family from voluntarily releasing information about yourself or your involvement in this research.

VI. Compensation

If you complete the initial meeting session for this study, have signed your informed consent, but are unable or ineligible to participate in the study, you will be paid $30.00 for your time. If you are eligible and able to participate further, in addition to having access to the research vehicle for 4 weeks, you will be paid up to $500 as follows: (1) up to $300 if your total mileage is equal to or less than 1,200 miles ($0.25 per mile); and (2) $440 flat if you exceed 1,200 miles. You will be compensated separately for three weekly questionnaires, at $20 each, for an additional $60 in either mileage condition. You will also be lent an E-ZPass transponder that gives you free access to the (high-occupancy toll) HOT lanes managed by Transurban. You will be paid with a preloaded MasterCard when you return the vehicle and the transponder. Please allow up to one full business day for the activation of the card. Once activated, this card cannot be used past its expiration date. If there is no activity on the card for 5 months, the card will become inactive.

If you choose to withdraw at any time, you will be compensated for the mileage driven for the portion of time that you participated in the study and for any weekly questionnaires you completed. You will also be compensated for the portion of time that you participated in the study if your participation in the study is ended by VTTI.

If these payments are in excess of $600.00 in any one calendar year, then by law, Virginia Tech is required to file Form 1099 with the IRS. For any amount less than $600.00, it is up to you as the participant to report any additional income as Virginia Tech will not file Form 1099 with the IRS.

Also, you will be asked to provide researchers with your Social Security Number or Virginia Tech I.D. number for the purposes of being paid for your participation. For tax recording purposes, the fiscal and accounting services office at Virginia Tech (also known as the Controller's Office) requires that all participants provide their Social Security Number or Virginia Tech I.D. number to receive payment for participation in our studies.

The vehicle will be provided to you with a full tank of gas or a fully charged battery. You are not required to return the vehicle with a full tank of gas or a fully charged battery. You will, however, be responsible for paying all parking tickets and/or traffic violations issued to the research vehicle during the time the vehicle is in your possession.

VII. Freedom to Withdraw

As a participant in this research, you are free to withdraw at any time without penalty.

If you choose to withdraw, please notify VTTI staff immediately, and arrangements will be made for you to meet with a VTTI researcher or bring the vehicle to a research facility where you will be compensated for the portion of the time of the study for which you participated. If you are unable to bring the car, then arrangements will be made for VTTI staff to pick up the test vehicle. You can either ride with us or drive your own vehicle to meet with a VTTI researcher, where you will be compensated for your time of participation in the study. Circumstances could arise in which VTTI opts to end the study early. These could include, but are not limited to, safety concerns and/or equipment malfunctions. If this occurs, VTTI staff will contact you to make arrangements to pick up the test vehicle. VTTI staff will meet with you, at which time you will be compensated for the portion of time of the study for which you participated. Afterwards, the experimenter will offer you a ride back home or to your workplace.

Furthermore, you are free not to answer any question or respond to experimental situations without penalty.

VIII. Approval of Research

Before data can be collected, the research must be approved, as required, by the Institutional Review Board for Research Involving Human Subjects at Virginia Polytechnic Institute and State University and by the Virginia Tech Transportation Institute. You should know that this approval has been obtained and is valid until the date listed at the bottom of this page.

IX. Participant's Responsibilities

In addition to the study tasks mentioned above, you will have the following responsibilities during their participation:

You may not remove, modify, or tamper with any components of the research vehicle. This includes the E-ZPass transponder. If mechanical work is needed on the vehicle, please notify the research team.

- You are responsible for purchasing premium fuel for the vehicle (or charging the vehicle if it is an electric vehicle), and for all tickets and violations received for the duration that the vehicle is assigned to you.
- You must house the vehicle in a garage or other secure area. Note that one study vehicle, Tesla Model S, can only be assigned to you if you have a garage with the capability to charge the vehicle.
- You must not allow anyone else to drive the vehicle. You alone have been trained to use the research vehicle.
- You must possess and maintain a valid, unrestricted driver's license.
- You must not use the study vehicle in a 'for hire' capacity such as a taxi, Uber, Lyft or other similar service.
- Wear your seatbelt at all times and ensure the proper use of safety belts and child safety restraints for all other occupants of the vehicle.
- Not to use the vehicle to tow any form of trailer, or haul any material greater than what the vehicle was designed to accommodate. The vehicle cannot be used to transport flammable or hazardous materials (e.g., gasoline, acid, dynamite, lime). The vehicle cannot be driven off-road.
- You should not wear sunglasses unless absolutely necessary. Sunglasses are recommended if at any time you are suffering from glare problems (e.g., from the sun shining directly into their face) and cannot see the roadway and surrounding environment.
- You must not smoke or allow others to smoke in the vehicle.
- Please keep the interior clean and odor free.
- Please note that the study may end or you could be dismissed from the study any time for any reason prior to the designated 4-week time. Reasons include, but are not limited to, vehicle maintenance issues, driving history issues, or participant failure to perform the tasks above.

XI. Participant's Permission

I have read the Consent Form and conditions of this project. I have had all of my questions answered. If I participate, I may withdraw at any time without penalty. I agree to abide by the rules of this project. I hereby acknowledge the above and give my voluntary consent:

____

Participant printed name

____ Date__________

Participant signature

____ Date __________

Experimenter

If I should have any questions about this study, I may contact the investigators:

Myra Blanco	mblanco@vtti.vt.edu	[Redacted]
Sheldon Russell	srussell@vtti.vt.edu	[Redacted]

If I should have any questions about the protection of human research participants regarding this study, I may contact: Dr. David Moore, Chair of the Virginia Tech Institutional Review Board for the Protection of Human Subjects, telephone: [Redacted]; email: moored@vt.edu.

[NOTE: Subjects must be given a complete copy (or duplicate original) of the signed Informed Consent.]

Appendix I. Vehicle Condition Checklist

This appendix contains a copy of the vehicle inspection form that will be filled out prior to a participant taking possession of the vehicle and upon vehicle return.

VEHICLE CONDITION CHECKLIST

Will be filled out 2 times: before participant takes possession of the vehicle and when the vehicle is returned. Both initial and return checklists require photos.

This inspection was conducted:

☐ Prior to participant possession

☐ Upon vehicle return

Odometer Reading:___________________

VISUAL INSPECTION OF BODY EXTERIOR	
Frame and Body (Panels, Bumpers, Doors, Hood, Trunk, Tailgate, Grill, Trim, Molding, Roof Rack, License plate, etc.): (dings, dents, alignment, mismatched paint, overall paint condition)	Photograph any damaged, dinged or dented areas prior to installation
Glass, Mirrors, Wipers: Note damage such as glass or mirrors which are pitted, repaired, cracked, or not properly attached including front and rear windshields and side windows. Condition of wiper blades.	Photograph any damaged, dinged or dented areas prior to installation
Exterior Lights (lens condition and operation) includes: Head lights and Assembly, Tail lights, Brake lights, Parking lights, Hazard lights, Reverse lights, Turn signal/side marker lights, License plate lights, Fog/driving lights	Photograph any damaged, dinged or dented areas prior to installation
VISUAL INSPECTION OF BODY INTERIOR	
Seat Belts (Condition/Operation)	Photograph any damaged areas prior to installation
Carpet (Condition/Appearance) Floor Mats (Condition/Appearance)	Photograph any damaged areas prior to installation

Door Trim/Panels (Condition/Appearance/Attachment) Headliner (Condition/Appearance) Sun Visors (Condition/Appearance/Vanity Mirror and Light) Ceiling and Door handles	Photograph any damaged areas prior to installation
Trunk/Luggage Compartment (note condition of mat, trim, carpet, cargo net, jack, tools and operation of luggage compartment light)	Photograph any damaged areas prior to installation
Seats (note condition). Is interior upholstery worn, ripped, cracked or faded? Are seat and/or headrest adjustments made manually or automatically? Is the seat heated?	Photograph any damaged areas prior to installation
Dashboard functionality, HVAC and audio systems	Photograph any damaged areas prior to installation

Photo Documentation of Study Vehicles before participant takes possession and prior to vehicle return

- Take 8 pictures of outside of vehicle, starting with front view and then every 45 degrees around the vehicle.
- Take close-ups of existing damage/scratches.
- Document damage/scratches.
- Have participant sign off on vehicle condition before releasing vehicle.

Sample 8 pictures:

Front View

Front Left

Left side

Left rear side

Rear View

Rear Right Side

Right Side

Front Right Side

I, <u>[participant name]</u> have read the above description of my vehicle's condition and agree that it accurately reflects the current condition of my vehicle. This inspection was conducted:

☐ Prior to participant possession

☐ Vehicle Return

Signature | Date and time

Appendix J. Supplemental Analysis

This section includes supplemental analyses not included in the main body of the report.

Coding for Environmental Variables

This section describes the method in which variables were recoded for analysis of RQ 3.2.1. Where applicable, the original category and recoded categories are described for the following environmental variables: traffic density, weather, locality, and traffic flow. The original definitions for these variables and each category are available in the most recent data dictionary (VTTI, 2015).

Traffic Density

Traffic density is based on the number of other cars in the participant's lane and other lanes traveling in the same direction of the driver, as well as the ability of the participant to navigate lanes and drive at a certain speed (VTTI, 2015). Original and recoded categories for traffic density are described in Table 15.

Table 15. Original and Recoded Traffic Density Categories

Original Category	Recoded Category
Level-of-service A1: Free flow, no lead traffic	Free Flow
Level-of-service A2: Free flow, leading traffic present	Free Flow
Level-of-service B: Flow with some restrictions	Stable Flow
Level-of-service C: Stable flow, maneuverability and speed are more restricted	Stable Flow
Level-of-service D: Unstable flow - temporary restrictions substantially slow driver	Unstable Flow
Level-of-service E: Flow is unstable, vehicles are unable to pass, temporary stoppages, etc.	Unstable Flow
Level-of-service F: Forced traffic flow condition with low speeds and traffic volumes that are below capacity	Unstable Flow

Locality

Locality is defined based on a description of the road's surrounding area and is not defined based on traffic conditions (VTTI, 2015). Original and recoded categories for locality are described in Table 16.

Table 16. Original and Recoded Locality Categories

Original Category	Recoded Category
Business/Industrial	Business/Industrial
Bypass/divided highway, access not controlled	Uncontrolled Highway
Interstate/bypass/divided highway, controlled access	Controlled Highway
Moderate Residential	Moderate Residential
Open Residential	Open Residential
Playground	Other
School	Other
Urban	Other
Church	Other
Airport	Other
Open Country	Other

Weather

Weather categories were not recoded and are listed in Table 17. Additional categories exist that account for snowy weather (VTTI, 2015), but they did not appear in the sampled data.

Table 17. Weather Categories

Original Category
Clear/Partly Cloudy
Overcast
Mist/Light Rain
Rain
Fog
Rain and Fog

Traffic Flow

Traffic flow is defined in terms of the roadway design. This refers to whether or not the road is one-way, or whether it is divided by a median or not (VTTI, 2015). Original and recoded categories for traffic flow are described in Table 18.

Table 18. Original and Recoded Traffic Flow Categories

Original Category	Recoded Category
One-way traffic	One-Way
Divided (median strip or barrier)	Two-Way, Divided
Not divided - center 2-way left turn lane	Two-Way, Not Divided
Not divided - simple 2-way traffic	Two-Way, Not Divided

Non-Driving Tasks

The primary statistical analysis for RQ 4.1 was to compare the likelihood of performing any non-driving task between different activation levels. Subsequent analysis provided descriptive results for non-driving task performance both by distraction type (cognitive, manual, or visual) and specific task. Table 19 shows the non-driving task percentage in the NDS study by activation level, while Table 20 shows the percentage in the LD study.

Table 19. Non-Driving Tasks, Types, and Feature Engagement Prevalence Observed in the NDS

Non-Driving Task	Type	None Engaged	One Engaged	Both Engaged
Adjusting/monitoring climate control	Visual-Manual	0.3	0	0.2
Adjusting/monitoring other devices integral to vehicle	Visual-Manual	1.5	2.4	1.7
Adjusting/monitoring other/unknown Instrument Panel device	Visual-Manual	18.8	19.4	17.7
Adjusting/monitoring radio	Visual-Manual	2.9	3	3.2
Applying make-up	Visual-Manual	0.3	0	0
Biting nails/cuticles	Visual-Manual	1	0.7	0.8
Cell phone, Browsing	Visual-Manual	4.9	3.4	3.8
Cell phone, Dialing hand-held	Visual-Manual	0	0.1	0
Cell phone, Dialing hands-free using voice-activated software	Cognitive	0	0	0.2
Cell phone, Holding	Manual	2.4	2	1.6
Cell phone, Locating/reaching/answering	Visual-Manual	1.7	1.3	1.4
Cell phone, Talking/listening, hand-held	Manual	1.3	0.8	0.5

Cell phone, Talking/listening, hands-free	Cognitive	10.1	8.4	5.8
Cell phone, Texting	Visual-Manual	0.4	0.2	0.4
Cell phone, other	Visual-Manual	1.1	0.9	0.8
Child in adjacent seat - interaction	Cognitive	0.3	0.2	0
Child in rear seat - interaction	Cognitive	1.7	1.6	1.2
Combing/brushing/fixing hair	Visual-Manual	1.3	0.8	1.2
DAS, Interact	Visual-Manual	0	0.1	0.2
Dancing	Cognitive	2.9	2	3.1
Distracted by construction	Visual	0	0.1	0
Drinking from open container	Visual-Manual	0.4	0	0.5
Drinking with lid and straw	Visual-Manual	0.6	0.3	0.8
Drinking with lid, no straw	Visual-Manual	1.1	0.4	1.9
Eating with utensils	Visual-Manual	0.1	0	0
Eating without utensils	Visual-Manual	1.8	1.5	1.3
Looking at an object external to the vehicle	Visual	0.6	0.8	0.3
Looking at pedestrian	Visual	0	0	0.1
Looking at previous crash or incident	Visual	0.2	0.2	0.3
Moving object in vehicle	Visual	0.1	0	0
No Secondary Tasks	None	34	38	40.1
Object in vehicle, other	Visual-Manual	2.2	1.9	2.4
Other electronic device, Interact with	Visual-Manual	0	0.1	0.2
Other external distraction	Visual	5.9	5	4.6
Other known secondary task	Manual	0.4	0	0.2
Other non-specific internal eye glance	Visual	2.9	1.1	2.5
Other personal hygiene	Unknown	1.7	1.5	2.4
Passenger in adjacent seat - interaction	Cognitive	18.2	17.2	15.7
Passenger in rear seat - interaction	Cognitive	2.4	3.3	2.9

Reaching for food-related or drink-related item	Visual-Manual	0.9	0.6	1.6
Reaching for object, other	Visual-Manual	0.3	0.2	0.2
Reaching for personal body-related item	Visual-Manual	0	0	0
Reading	Visual-Manual	0	0	0
Removing/adjusting clothing	Visual-Manual	0.2	0.7	0.8
Removing/adjusting jewelry	Visual-Manual	0	0.1	0
Removing/inserting/ adjusting contact lenses or glasses	Visual-Manual	0.6	0.5	0.8
Tablet device, Operating	Visual-Manual	0	0	0.1
Talking/singing, audience unknown	Cognitive	5.2	6.6	5.2
Tobacco, other	Manual	0	0	0.1
Unknown	Manual	0	0	0.1

Table 20. Non-Driving Tasks, Types, and Feature Engagement Prevalence Observed in the LD Sub-Study

Non-Driving Task	Type	None Engaged	One Engaged	Both Engaged
Adjusting/monitoring climate control	Visual-Manual	0	0	0
Adjusting/monitoring other devices integral to vehicle	Visual-Manual	3	2.6	2.1
Adjusting/monitoring other/unknown Instrument Panel device	Visual-Manual	37.9	37.7	29.5
Adjusting/monitoring radio	Visual-Manual	6.1	1.3	3.2
Biting nails/cuticles	Visual-Manual	0	0	0.5
Cell phone, Browsing	Visual-Manual	6.1	2.6	1.6
Cell phone, Holding	Manual	3	0	0
Cell phone, Locating/reaching/answering	Visual-Manual	3	2.6	0.5
Cell phone, Talking/listening, hand-held	Manual	1.5	2.6	0.5

Cell phone, Talking/listening, hands-free	Cognitive	3	6.5	6.8
Cell phone, other	Visual-Manual	3	0	0
Combing/brushing/fixing hair	Visual-Manual	1.5	1.3	0
DAS, Interact	Visual-Manual	0	0	0
Dancing	Cognitive	4.5	2.6	4.7
Drinking from open container	Visual-Manual	0	0	0
Drinking with lid, no straw	Visual-Manual	0	0	0
Eating without utensils	Visual-Manual	0	2.6	8.4
Looking at previous crash or incident	Visual	1.5	0	0
No Secondary Tasks	None	27.3	23.4	35.3
Object in vehicle, other	Visual-Manual	0	1.3	1.6
Other external distraction	Visual	6.1	9.1	11.1
Other non-specific internal eye glance	Visual	1.5	0	2.6
Other personal hygiene	Unknown	0	2.6	1.6
Reaching for food-related or drink-related item	Visual-Manual	0	0	3.7
Reaching for object, other	Visual-Manual	0	0	0.5
Removing/adjusting clothing	Visual-Manual	0	1.3	2.1
Removing/inserting/ adjusting contact lenses or glasses	Visual-Manual	0	1.3	0
Talking/singing, audience unknown	Cognitive	15.2	24.7	14.2
Unknown type (secondary task present)	Visual-Manual	0	2.6	0

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U.S. Department
of Transportation

National Highway
Traffic Safety
Administration

NHTSA

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