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Impact of Advanced Driver Assistance Systems (ADAS) on Road Safety and Implications for Education, Licensing, Registration, and Enforcement

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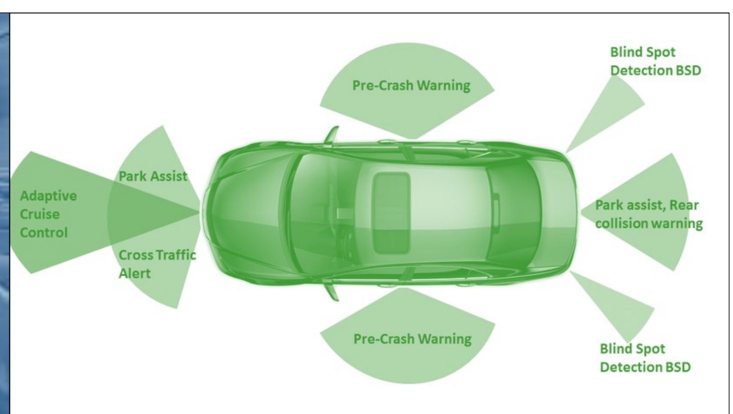

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16. Abstract
Advanced Driver Assistance Systems (ADAS) are rapidly being developed and deployed, with an increasing number of new passenger vehicles equipped with advanced ADAS. These systems promise to improve safety by assisting drivers. However, there exists a critical gap in our understanding of the potential impacts associated with driver over-reliance and disengagement in vehicles equipped with ADAS. To address these issues, this research was undertaken with three broad objectives. The first was to understand the current state of commercially available ADAS. The second was to understand driver knowledge about ADAS technologies and functionalities using a survey study. Lastly, this research involved the development and evaluation of approaches to improve drivers' understanding of ADAS functionalities and the role and responsibilities of the driver. This included an experimental driving simulator study to examine the impact of training on drivers' mental models. This document reports on this research project, with details about the methods and outcomes for each of the above-stated objectives. The outcome of this research includes an understanding of manufacturer offerings of common ADAS technologies in late-model vehicles, an examination, and drivers' understanding and perceptions of ADAS technologies, and evidence that targeted training may increase drivers' understanding of these systems.

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Impact of Advanced Driver Assistance Systems (ADAS) on Road Safety and Implications for Education, Licensing, Registration, and Enforcement

Final Report

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Disclaimer

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Executive Summary

This study of “Impact of Advanced Driver Assistance Systems (ADAS) on Road Safety and Implications for Education, Licensing, Registration, and Enforcement” was undertaken as part of the Massachusetts Department of Transportation (MassDOT) Research Program. This program is funded with Federal Highway Administration (FHWA) State Planning and Research (SPR) funds. Through this program, applied research is conducted on topics of importance to the Commonwealth of Massachusetts transportation agencies.

Advanced Driver Assistance Systems are rapidly being developed and deployed, with an increasing number of new passenger vehicles equipped with advanced ADAS These systems promise to improve safety by assisting drivers. Due to the introduction of increasingly complex ADAS functions in private passenger vehicles, drivers can misinterpret or fail to understand ADAS functionalities and capabilities and attribute more capability to these systems than what they have been designed to do. This can increase the potential for driver disengagement and over-reliance on these systems, which can impact driver behavior, distraction, and transportation safety. Additionally, there is currently no standardization of ADAS terms, functions, and design, nor standards or regulations for the inclusion of driver monitoring systems in ADAS-equipped motor vehicles. ADAS currently exist in a small proportion of newer model vehicles and constitute a small percentage of the vehicle fleet in current use, so any negative impact associated with diminished driver engagement and overreliance on ADAS may not be immediately evident. However, the continued deployment of these increasingly complex systems may increase potential negative impacts due to increased exposure. There exists a critical gap in the understanding of the potential impacts associated with driver over-reliance and disengagement in vehicles equipped with advanced driver assistance systems.

To address the above-stated issues, this research was undertaken with three broad objectives. The first objective was to understand the current state of commercially available ADAS. The team conducted a literature and market review of the current state of commercially available ADAS technologies, including driver monitoring systems, to document manufacturers’ offerings. Additionally, the team sought to develop an understanding of the distribution of ADAS-equipped motor vehicles in the State via RMV data. Given the opaque nature of ADAS available in vehicles, this task was not trivial, and the team instead formulated a process for potentially using RMV data along with manufacturers’ make and model information to derive a picture for ADAS fleet deployments.

The second objective was to understand driver knowledge about ADAS technologies and functionalities. The research conducted included a survey study aimed at examining drivers’ knowledge of ADAS, their trust in these systems, and potentially the types of driver errors associated with the use of ADAS.

Lastly, this research involved the development and evaluation of approaches to improve drivers’ understanding of ADAS functionalities and the commensurate role and responsibilities of the driver of vehicles equipped with ADAS. This included an experimental driving simulator study to examine the impact of training on drivers' mental models.

This document reports on this research project, with details about the methods and outcomes for each of the above-stated objectives. The outcome of this research includes an understanding of manufacturer offerings of common ADAS technologies in late-model vehicles, an examination of drivers' understanding and perceptions of ADAS technologies, and evidence to support how targeted training may increase drivers' understanding of these systems. The key highlights are identified below:

A. Estimating the deployment of ADAS equipped vehicles on public roadways is a nontrivial task. Nonetheless, the importance of collecting this information remains critical. While this research proposes a methodology for doing so, the team also recommends the establishment of a more robust systematic process for collecting this data, potentially leveraging vehicle registration forms.
B. Epidemiological data from crash and citation records (of ADAS-equipped vehicles) can offer novel insights into crashes related to the use of this technology.
C. While drivers may have a generally reasonable awareness of ADAS, fewer than 80% of (surveyed) drivers knew how the technology worked before they bought a vehicle. Training offered is minimal, and, alarmingly, most drivers reported a "trial and error" learning process. Such a process has safety consequences on public roads, both to the drivers of these vehicles and to other road users. There is a recognized need to explore how awareness of the benefits and/or pitfalls of ADAS can be raised and to understand potential unintended effects of popular media representation on the drivers' expectations of ADAS.
D. The role of driver training is an important one in ensuring drivers have the correct understanding of ADAS. Targeting "higher order skills" shows improvement in drivers' knowledge. Experimental evaluation shows that training holds promise for improved understanding. This report recommends expanded examination of training as an approach to improve drivers' knowledge and use of these technologies to maximize the promised benefits of advanced vehicle technologies.

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List of Acronyms

[Use this table, if needed, to list all acronyms used within the report]

Acronym	Expansion
ADAS	Advanced Driver Assistance Systems
MassDOT	Massachusetts Department of Transportation
FHWA	Federal Highway Administration
SPR	State Planning and Research
SAE	Society of Automotive Engineers
AEB	Automatic Emergency Braking
BSW	Blind Spot Warning
FCW	Forward Collision Warning
ACC	Adaptive Cruise Control
RMV	Registry of Motor Vehicles
DMS	Driver Monitoring Systems
VIN	Vehicle Identification Number
LKA	Lane Keeping Assist
LDW	Lane Departure Warning
RTI	Realtime Technologies
CAMMS	Completeness and Accuracy Mental Models Survey
HMI	Human Machine Interface
ADS	Automated Driving Systems

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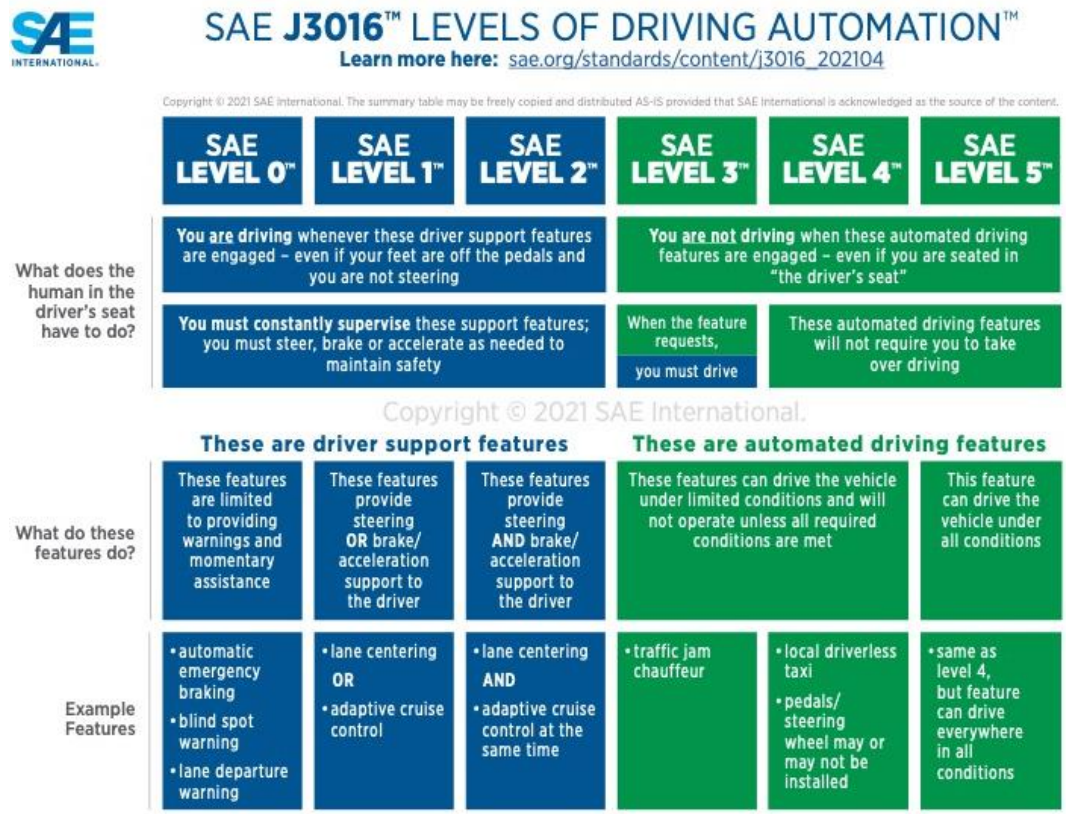
1.0 Introduction

This study on the Impact of Advanced Driver Assistance Systems (ADAS) on Road Safety and Implications for Education, Licensing, Registration, and Enforcement was undertaken as part of the Massachusetts Department of Transportation (MassDOT) Research Program. Through this program, applied research is conducted on topics of importance to the Commonwealth of Massachusetts transportation agencies. This program is funded with Federal Highway Administration (FHWA) State Planning and Research (SPR) funds.

1.1 Background on Advanced Driver Assistance Systems (ADAS)

Advanced driver assistance systems (ADAS) are automated driving features present in a vehicle that are designed to assist drivers with the main task of driving. The functions of ADAS can be broadly split into two main categories—safety features and comfort features.

Comfort features deliver warnings and suggestions to advise drivers to best manage a safe driving experience. Safety features are designed to respond to certain situations and manage some of the vehicle's functions while driving. Based on the Society of Automotive Engineers (SAE), we can classify automation features based on the level of control and assistance they provide. Level 0 refers to conventional driving with warning features; Level 1 refers to features that provide steering or brake/acceleration support to drivers; Level 2 refers to features providing steering and brake/acceleration support while driving. Level 3 refers to features that can drive the car under certain conditions and have limited operability. Levels 0 to 3 require the driver to be responsible for safe driving and be ready to take complete control of the car if required (*1*).



(from SAE, 2021)

Figure 1.1: SAE levels of automation

Since the emergence of ADAS, the use of these automated comfort and safety features and technological advancements has increased exponentially. Levels 1 through 2 of the systems described above are readily available in most vehicles. In May 2018, AAA reported 92.7% (*2*) of all new vehicles had at least one advanced driver assistance system. Some of the commonly used Level 1 systems include Automatic Emergency Braking, Adaptive Cruise Control, etc., whereas Combined Adaptive Cruise Control/Lane Keeping Assist, Auto Park, etc. are examples of Level 2 systems. At the highest level of automation, drivers will no longer be responsible for the task of driving and will either monitor or act as passengers in their own vehicles (*3*).

ADAS technology has the potential for improving road safety. A study conducted on the impact of ADAS on crash rates found that cars equipped with both Automatic Emergency Braking (AEB) and Blind Spot Warning (BSW) systems were 23% less likely to crash than unequipped cars (*4*). Specifically, this combination reduced crash likelihood in 2014 cars by 13 % and by 34% in 2017 models. A naturalistic study on evaluation of AEB found 80% of rear-end crashes were prevented and of the crashes AEB was unable to prevent, 50% occurred in poor weather conditions (*5*). A study conducted on Forward Collision Warning (FCW) and AEB systems found FCW reduced front to rear crashes by 27% and injuries by 20%; AEB reduced front to rear crashes by 43% and injury rates by 45%. Both AEB and FCW reduced front to rear crash rates by 50% and injuries by 56% (*6*).Two studies on Lane Departure Warning systems (LDW) found the rate of run-off-road crashes to be reduced by

30% (*7*) and significantly reduced rates in crashes by 18%, injuries by 24% and fatalities by 86%, as analyzed from police-reported data (*8*). There is no denying the many safety benefits ADAS provide. However, to properly experience the advantages, drivers should know when and how to use ADAS efficiently.

Previous literature shows that drivers are unaware or not completely informed about the ADAS functionalities and capabilities in their vehicles (*9*, *10*). The easiest method of understanding ADAS in a vehicle is to refer to the owner's manual. There is research indicating that drivers often tend not to take the owner's manual seriously and do not read through it properly (*11*, *12*),thus leading to gaps (*13*) and difficulty in understanding and using ADAS (*14*). Mental Models refer to "*a representation of the typical causal interactions involving actions and environmental factors that influence a system's functioning*"(*15*). For automobiles and ADAS, not having complete mental models could affect drivers' perception (*16*, *17*), leading to ADAS state confusion (*18*),under or over trusting the system (*19*), and misconception and overestimation of system's capabilities (*20*).

One possible method of properly calibrating drivers' mental models is training. Previous literature used surveys (*21*) to identify the state of mental models and have suggested observing driving behavior while using ADAS (*22*). A review (*23*) conducted on hazard anticipation programs revealed that although information presentation methods were different, there was still an improvement in hazard anticipation. Studies on improving drivers' visual attention (*24*, *25*) found training interventions effective.

ADAS features available in vehicles today are also misunderstood because although the definition of a system may be the same, there are differences in the naming conventions. Different manufacturers may call the same system by different names; for example, Adaptive Cruise Control (ACC) is also available as Smart Cruise Control, Traffic-Aware Cruise Control, and Intelligent Cruise Control. AAA's (*2*) study on technology names found Automatic Emergency Braking (AEB) to be known by 40 unique names, followed by ACC, with 20 names. The report by AAA listed available ADAS features, and the different naming technologies used by manufacturers. However, there is no complete dataset providing information about different vehicles and the availability of different ADAS features. We gathered data from the Registry of Motor Vehicles (RMV) to obtain data about manufacturers and the ADAS features available in different models from those manufacturers. We discuss this process in the next sections.

1.2 ADAS Technologies Available in Current Vehicle Models

To understand the ADAS provided from different automobile manufacturers, we compiled a list of automobile manufacturers, models, and ADAS functionality using publicly available data and RMV data. Data from other publicly available sources such as manufacturer websites, consumer organizations, and others were used to generate a list of ADAS features available in different models by all manufacturers.

1.2.1 Advanced Driver Assistance Systems

As an outcome of this review, we identified 207 ADAS features that could be classified into 51 broad categories of ADAS technologies. These technologies are listed in Appendix 6.1. The definitions for these technologies come from definitions that have been used by NHTSA, or by MyCarDoesWhat.com, or are suggested definitions by AAA.

These ADAS technologies can also be categorized into two types, warning systems and control systems, based on the amount of control they provide:

a) Warning Systems—ADAS technologies that provide warnings and alerts that only notify the driver of imminent risk or let them know of any changes they should make. Examples include blind-spot monitoring, lane departure warnings, collision warning, etc.
b) Control Systems—ADAS technologies that provide warnings and intervene in case of conflicts to steer or brake to prevent risky situations and crash incidents. Examples include automatic emergency braking, lane-keeping assist, ACC, etc.

Building on this initial listing, the research also focused on identifying automated driver assistance systems currently deployed by vehicle manufacturers with the objectives of collating the current systems that are available in commercially available vehicles, identifying whether these systems are offered as standard features or add-on options, and forming a database of the nomenclature and manufacturer-specific brand names associated with these systems. This task was undertaken for a large selection of vehicle manufacturers and models so as to be representative of common and popular models. Ultimately thirty manufacturers' vehicle offerings were studied via information from their websites, technical publications, and other publicly available information. This resulted in a database of the common ADAS features that are offered by these manufacturers, their naming conventions, their 'package or bundle' names from the manufacturer, and their classification as either warning or control systems. The three tables in Appendix B offer the outcome of this examination.

1.2.2 Driver State Monitoring

We also focused on obtaining information about current Driver Monitoring Systems (DMS). DMS use computers, onboard cameras, and sensors to determine when a driver is looking at the road or away from the road while a control ADAS technology is activated. If the driver is not paying attention, the system sounds an alert and may potentially limit ADAS use. Since the use of ADAS and advancements in ADAS technology, drivers have gotten comfortable with assigning part of the driving task to the system. However, one of the possible negative consequences of using ADAS is drivers paying less attention to the driving task, even when automation is not foolproof. Previous reviews conducted on ADAS use and distractions have found that given the opportunity, drivers feel comfortable to engage in secondary tasks while ADAS features are active (*26*, *27*). To keep drivers alert and ready to take back complete control of the car, vehicles could be equipped with DMS. Although DMS do not completely address the issue, they can still act as onboard warning systems, alerting drivers when they are distracted or not focused on the road. A study on effectiveness of DMS (*28*) found DMS to issue alerts faster (50 seconds sooner) than indirect or passive mitigating systems and to prevent ADAS misuse.

When examining the manufacturer offerings as described below, specific focus was also placed on the DMS offerings for these systems. The DMS offerings data have been provided in Appendix B. A little over half of the manufacturers provided some level of DMS in their offerings, ranging from rudimentary drowsiness detection systems based on vehicle kinematics information to more sophisticated eye-tracking based monitoring systems such as GM's "Driver Attention Monitor" which uses in-cab cameras to observe drivers. Many of the less sophisticated driver monitoring systems that rely on steering torque or skin conductance on the wheel may potentially be overridden (maliciously) by users. While there is now widely acknowledged merit to using DMS in vehicles for safety (*28*), misuse and abuse of such systems may be a reality. Manufacturers and policy makers may have to consider improving the DMS features and identifying and mitigating potential workarounds that drivers may utilize to either disable or circumvent these safety systems.

1.3 ADAS Deployment in MA

One important goal of this research was to gain an understanding of the deployment of ADAS technologies in the vehicle fleet in the Commonwealth of Massachusetts. There is significant benefit in understanding this, especially as the percentage of vehicles with such systems is increasing. For one, it may be important for policy and legislation, especially in terms of the use (or misuse) of such systems, and to initiate research or policies on driver training or licensing around such technologies. Also, it may be important for non-ADAS users to better understand how ADAS vehicles may exhibit different driving behaviors due to being controlled by automation. Essentially, from an epidemiological perspective, the Commonwealth of Massachusetts should have a record of any crashes/citations in vehicles equipped with ADAS. Knowing this information will provide an insight into any potential public health burden of these systems as well as an understanding of any negative consequences of using ADAS.

However, there is no straightforward and direct method to access information about the ADAS features available for specific automobiles. While the original plan was to extract information about a vehicle's ADAS features from each vehicle's unique vehicle identification number (VIN), it became clear to the project team that such information was not transparent nor readily discernable. After a significant effort was undertaken to try to gain insight into the VINs, including conversations with insurance providers, the Alliance of Automobile Manufacturers, and other institutes, the team realized that an alternate method would have to be designed to gain this information. To that end, we proposed randomly sampling vehicle registration data for any given year from the RMV and then cross-referencing the vehicle make, model, and year with publicly available manufacturer data about vehicle ADAS features (and whether they come standard or not). A dataset similar to the one in Appendix B can be used for cross-checking vehicle makes/models and manufacturer ADAS offerings. While admittedly painstaking and burdensome, this may be the only (and most feasible) approach to understanding ADAS deployment. One important outcome of this process was the recognition that during the registration process, drivers could be required to report the ADAS technology in their vehicles. This is currently done for features such as passenger-side airbags and anti-theft systems. However, we should also recognize that relying on drivers to manually provide that data could mean that the data may potentially be incomplete, inaccurate, or both, although his still may be better than no data at all. Supplementary questions could be added to the registration forms to gain information about the ADAS.

2.0 Research Methodology

To properly understand the information and knowledge drivers have about the ADAS features available today, we conducted a two-part study. The first part, a survey study gathered information regarding Adaptive Cruise Control (ACC) and Lane Keeping Assist (LKA) use, perceptions, and knowledge. The second part, a simulator study compared understanding of ACC before and after drivers were given different methods of education and measure the change in knowledge.

2.1 Survey Study—Drivers' Perceptions of ADAS

2.1.1 Introduction

The objective of ADAS is to provide increased safety and comfort while driving. These features provide support and assistance in response to specific circumstances. This indicates that drivers are responsible for the driving task and should be alert if required to take complete control of the vehicle. Even if ADAS is available in their vehicles, drivers may not use these features to their full extent. With features such as Adaptive Cruise Control (ACC) and Lane Keeping Assist (LKA) becoming more widely available, research on drivers' use and knowledge of such systems is becoming increasingly important. This knowledge is critical to their using these systems safely and efficiently. Understanding the shortcomings of drivers' knowledge and the factors that influence drivers to use ADAS properly can help us better provide information and training materials to prevent any misuse of ADAS.

Past research indicates that although drivers may use ADAS features, they are not always knowledgeable about the limitations and usability conditions of such technologies. For example, multiple studies conducted with experienced and inexperienced drivers of ACC found that almost 72% of drivers are unaware of ACC's limitations (*9*) and lack a proper understanding of the use of ACC (*29*), despite reporting a higher understanding of the system (*30*). In addition, other factors such as perceptions (*31*), experience (*14*, *32–34*) and age (*34*, *35*) may affect ADAS use and knowledge.

To understand the extent to which ADAS (ACC and LKA) are used and understood, we conducted an online survey among current drivers of Massachusetts. This survey assessed ACC and LKA knowledge among experienced and inexperienced users of ADAS. Variables related to demographics, ACC and LKA experience, training methods, trust, willingness to use, and possible future use were collected. The survey design and procedure are discussed in section 2.2, with results and implications discussed in sections 2.3 and 2.4, respectively.

2.1.2 Methods

2.1.2.1 Survey Design

Survey items were developed based on previous studies conducted on similar aims (*10*, *36*–*38*). The survey was separated by technology first—ACC or LKA—and experience level next. Participants were first asked if they had experience with ACC; if their response was affirmative, they were directed to a questionnaire with 26 items, otherwise to a questionnaire for novice drivers with 12 items. The same procedure was followed for the LKA survey—drivers with LKA experience completed a survey with 23 questions, and novice drivers a survey with 11 items. Surveys provided to experienced drivers asked about their use of ADAS systems and novice drivers were asked about the statements and their perceptions of how the system would help their driving. The surveys were administered online via Qualtrics and included information about driver sex, age, zip code, drivers' responses to items about use, knowledge, and perceptions of ADAS. The survey approximately took 10–15 minutes to complete. (The complete survey items are available in Appendix C)

2.1.2.2 Procedure

Participants were recruited through university mailing lists and RMV centers and were compensated $5 for completing the survey. Participants completing the survey would also be automatically entered into a $95 raffle. Participants were provided with a link to a screening survey to screen out drivers that did not meet the inclusion criteria: have at least three months of driving experience, have a valid driver's license, and be residents of Massachusetts. Following the screening process, participants were given access to the main survey, consisting of four parts: Experienced ACC, Experienced LKA, Inexperienced ACC, Inexperienced LKA. Participants were asked if they were experienced or novice to ACC or LKA, and based on their responses, they were directed to the appropriate survey. Experienced drivers were asked to respond to survey items relating to their experience, knowledge, materials used to gain knowledge, perceptions, and attitudes regarding ACC and LKA. Novice drivers responded to survey items related to general knowledge, perceptions, attitudes, and future use regarding ACC and LKA.

2.1.3 Analyses

2.1.3.1. Participants

Overall, recruitment yielded 153 participants, out of which data for 11 participants were not usable. The responses of 142 remaining participants were analyzed.

The number of responses gathered for the entire survey as well as by section is described below, along with age and sex statistics. The average age for all participants was 26.47 (SD = 10.75), with 60% male respondents.

Table 1: Descriptive statistics

Statistics	All	ACC Experienced	ACC Inexperienced	LKA Experienced	LKA Inexperienced
(n)	142	44	98	30	112
Age	Mean = 26.47 SD = 10.75	Mean = 27.11 SD = 11.75	Mean = 26.18 SD = 10.31	Mean = 31.16 SD = 13.18	Mean = 25.21 SD = 9.98
Sex	Males = 85 Females = 56 Prefer Not to Answer = 1	Males = 23 Females = 20 Prefer Not to Answer = 1	Males = 62 Females = 36	Males = 17 Females = 12 Prefer Not to Answer = 1	Males = 68 Females = 44

2.1.3.2. Analysis

All four sections of the survey (ACC Experienced, LKA Experienced, ACC Inexperienced, LKA Inexperienced) were analyzed separately as experienced drivers were evaluated based on their responses regarding ADAS and inexperienced drivers' responses were evaluated based on their perceived knowledge of ADAS. The surveys can be broadly separated by intent.

1 <u>System Knowledge</u>: Questions such as "When can you use LKA/ACC?" or "Please select all roadway environments where you think it would be appropriate to use LKA/ACC." were used to understand driver's knowledge regarding ADAS limitations whereas similar questions were given to nonusers to gain insight into what they thought limitations would be.

2 <u>Training/Learning Methods</u>: Experienced participants were also asked about learning methods and if they had received any training prior to using ADAS. If they answered "Yes," participants were asked to answer questions regarding their experience and if the training answered their questions.

3 <u>Functionality</u>: Participants were asked to respond on a scale between Strongly Disagree to Strongly Agree to statements such as "Using the system … enables me to adjust to the traffic conditions more efficiently and keep my vehicle within the lanes" or "… would help me avoid collisions" to understand how useful drivers thought the system to be.

4 <u>Trust/Willingness to Use</u>: Participants were asked questions such as "I would be comfortable looking away from the road or making a phone call, sending a text, etc. when my LKA/ACC is activated" or "I think using LKA/ACC reduces the risk of a crash" to understand if drivers trusted the system or if they would be willing to use the system.

Sections were visualized and analyzed using R (R Core team 2021), accessed through RStudio (RStudio Team 2021), and mainly using ggplot2 and dpylr for visualizations.

2.2 Simulator Study—Improving Drivers' Knowledge of ADAS

2.2.1 Introduction

A survey of ADAS users found that drivers are willing to use the system and gain experience through practice despite not having complete knowledge of the ADAS. However, ADAS features are complex, and drivers must understand the limitations as well as conditions in which these systems are meant to be used. This is an essential point as the ADAS available today are not capable of taking control of the car and are only offered as support systems (*1*). Drivers must always monitor the driving task and be ready to take complete control of the car, if necessary.

Research shows that drivers use different training methods to understand ACC. Although the owner's manual is generally the preferred method (*10*, *39*), it is also extremely lengthy and not user-friendly (*11*). Providing proper information can help drivers understand when and how to use ADAS as well as help calibrate trust in ADAS (*19*). Experience with ADAS can also help develop favorable attitudes towards using these technologies. A study with older drivers (*40*) found that through user friendly interfaces, training programs and real-time use of ADAS, older drivers can be encouraged to use ADAS frequently. In a demonstration-aided study, participants who received a demonstration were four times more likely to rate usefulness and seven times as likely to rate trust in ACC than drivers who only referred to owner's manual (*41*).

Previous survey studies on using training to improve knowledge, understanding, and trust in ADAS (*42*, *43*) have yielded positive results, but analyzing self-reported responses may be difficult to translate to actual use of ADAS. To understand the changes in knowledge, understanding, and trust based on training and real-time use, this study uses a simulator and measures the change before and after training in three groups of participants who have been provided different types of training. In previous studies, despite receiving training, participants had forgotten about limitations of the systems as they had not experienced them (*19*, *44*).

To examine if drivers' understanding of ADAS and therefore their use of such systems can be improved, the researchers first designed a novel training methodology aimed at improving drivers' mental models of vehicle automation and then evaluated the impact of this method with a randomized controlled experiment using an advanced driving simulator. The study subjected participants to one of three training types and measured their knowledge of ADAS via surveys as well as by using verbal probes and instructions while they were experiencing the systems in a driving simulator. The following sections detail the experimental study.

2.2.2 Methods

2.2.2.1 Training Methods

Three training methods were designed for the study: Text-Based User Manual (M), Visualization (V), and Sham (S). The three methods are described below.

1 <u>Text-Based User Manual (Method M):</u>

A pdf document was created based on the written descriptions and warnings about ACC generally found in an ACC manual. The main issue with the owner's manual is the complexity of the text and length of the manual. The document described the offered ACC features and limitations in a simplified form for this method, thus minimizing the time spent searching for necessary information.

2 <u>Visualization (Method V):</u>

This method was based on prior conceptual work on advanced driver assistance systems (Pradhan et al., 2020). The training material included a visual representation of an ACC system in the form of a state diagram (Figure 2). The state diagram describes the possible states of ACC, and the connectors between the states indicate how the states could be reached. The method also included details mentioned in an owner's manual, such as usability conditions and limitations.

3 <u>Sham (Method S):</u>

This method is included as a control measure in this study. This training method consisted of written descriptions of unrelated ADAS features, namely Forward Collision Warning (FCW) and Lane Departure Warning (LDW).

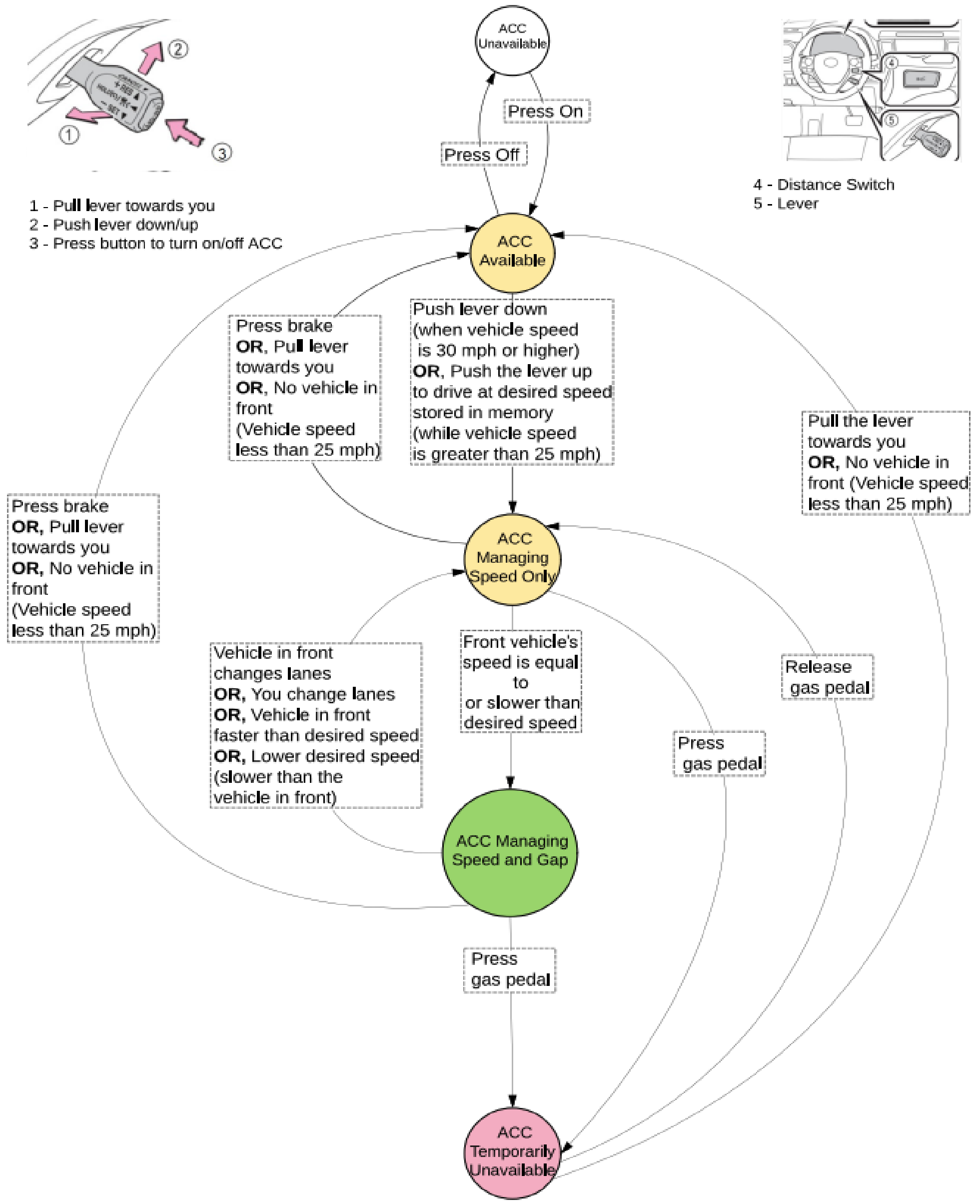


Figure 2.1: Visualization State Diagram

2.2.2.2 Participants

Twenty-four participants were recruited through university email lists and flyers. Participants were first screened for age, licensure, and experience with ACC. Only drivers with valid licenses, with at least three months of driving experience, between the ages of 18 and 65, and inexperienced with ACC were eligible for the study (Mean Age = 24.8, SD = 8.57, 50% Female). This was an essential point as drivers with ACC experience would have perceptions and knowledge of the system already. Once eligible and confirmed for the study, participants were randomly assigned to one of three groups.

2.2.2.3 Experimental Design

A mixed between- and within-groups study design was used for this study with test conditions (pre-training vs. post-training) as the within-subjects variable and training methods (user manual, visualization, and sham) as the between-subjects variable.

Drivers' knowledge was measured before and after training using a mental model survey CAMMS (Completeness and Accuracy of Mental Models Survey) (Pradhan et al., 2022). The survey examined drivers' knowledge of ACC, its functionality, capabilities, and limitations. The survey consisted of 75 unique items, and all responses were on a scale of 1 = Strongly Disagree to 6 = Strongly Agree. Participants' responses were then scaled and scored from 0 to 100 to derive an average score of all questions per participant.

Upon completion of the mental model survey, participants drove in the simulator with ACC and experienced various naturalistic scenarios. Researchers measured drivers' accuracy in real-time responses to questions about ADAS status during the drive. Participants were given pre-recorded verbal questions (Table 2), and their responses and response times were recorded.

Table 2: Verbal questions and expected responses

Verbal Questions	**Expected Response**
What is your current ACC set speed?	Respond with speed displayed on dashboard
What speed are you travelling at?	Respond with speed displayed on the speedometer
Is the current vehicle speed lower than the ACC set speed?	Respond with yes or no based on participant's status
What is the current ACC distance setting?	Respond with the current distance setting from dashboard
Is ACC currently active?	Yes
Is ACC currently activated?	No

Participants were also given prerecorded verbal instructions to follow throughout the drive (Table 3). The researchers measured the accuracy of participants' real-time responses to instructions and drivers' response times. The operations included actions such as changing ACC speed or distance settings.

Table 3: **Verbal instructions and expected responses**

Verbal Instructions	Expected Response
Set ACC to 5 miles per hour below the speed limit	Decrease speed to 5 miles per hour below speed limit
Set ACC to the posted speed limit	Set speed to the speed limit
Set ACC to 5 miles per hour above the speed limit	Increase speed to 5 miles per hour above speed limit
Deactivate Adaptive Cruise Control without using your pedals	Deactivate ACC by pressing the cancel or off button
Reactivate ACC at posted speed limit	Set ACC to the speed limit shown on speed signs.

2.2.2.4 Driving Simulator and Simulated Roads

Figure 2.2: Human performance laboratory fixed-base driving simulator

The simulator used in this study was a high fidelity fixed-base full-cab driving simulator running the Realtime Technologies (RTI) SimCreator engine. The RTI fixed-based driving simulator consists of a fully equipped 2013 Ford Fusion cab placed in front of five screens and has a 330-degree field of view. The cab also features two dynamic side mirrors and a rear-view mirror which provide multiple views of the scenarios for the participants. It has a five-speaker surround system for exterior noise and a two-speaker system for simulating in-vehicle noise (Figure 3.2). RTI's SimADAS equips the simulator with ADAS features such as Adaptive Cruise Control, Traffic Jam Assist, etc. The ACC system mimics those in the real world and can maintain the vehicle's speed and distance from the lead vehicle according to the operator's set parameters. The SimCreator engine also makes it possible to script various traffic and edge case events and introduce alerts and visual notifications to the drivers through the cab's instrument panel and center console of the cab. In addition to vehicle measures, the simulator also collects real-time video recordings of the participants' hand movements, feet movements, and verbal responses.

Participants drove for approximately 10 minutes in the simulator. Two drives were designed for the experiment and contained reversed sequences of driving scenarios for counterbalancing. Participants drove one of the two drives. They consisted of both urban and rural roadways with traffic and naturalistic driving events and scenarios.

2.2.2.5 Study Procedure

The study was conducted at the Human Performance Laboratory in UMass Amherst. All participants completed an informed consent form, following which study surveys were provided. Participants completed a demographics survey, CAMMS, and a 'Trust' survey (*45*) and were then provided with a training method. Participants were randomly assigned to one of three groups and were given a training method based on their group (M, V, or S). Following the training, participants were administered Trust, CAMMS, and a debriefing survey. After completing all surveys, participants were directed to the simulator cab. Participants initially drove a familiarization drive to experience the driving simulator platform and the ACC system available in the simulator. Once comfortable, drivers started the experimental drive. The simulated drive offered multiple opportunities to interact with ACC through verbal instructions and questions.

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3.0 Results

3.1 Survey Study—Drivers' Perceptions of ADAS

3.1.1 System Knowledge

Survey items were designed to understand the limitations and operational knowledge of LKA/ACC. Overall, a majority of the drivers had information about which conditions are necessary for ADAS to work efficiently. Despite using ACC, 10 participants responded that ACC could not be used when there was a vehicle in front of theirs. Fifteen participants of the LKA survey thought ACC could be used on curved roads and 11 thought they could use ACC with one lane marking present. (Figure 3.1)

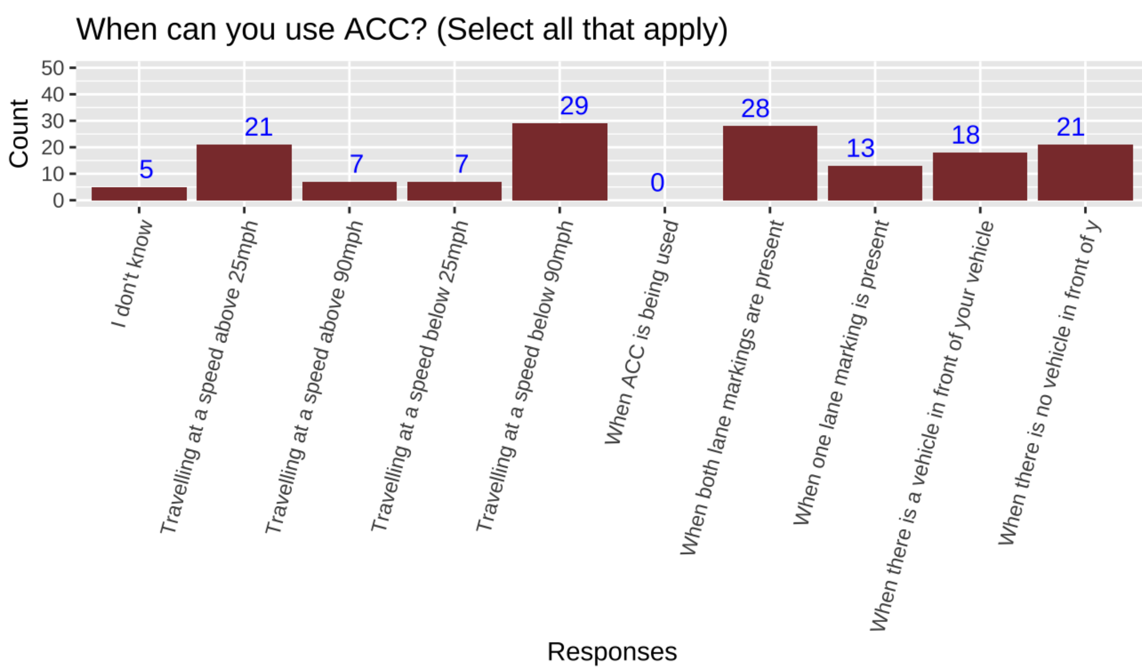

Figure 3.1: System knowledge (1)—experienced drivers (ACC)

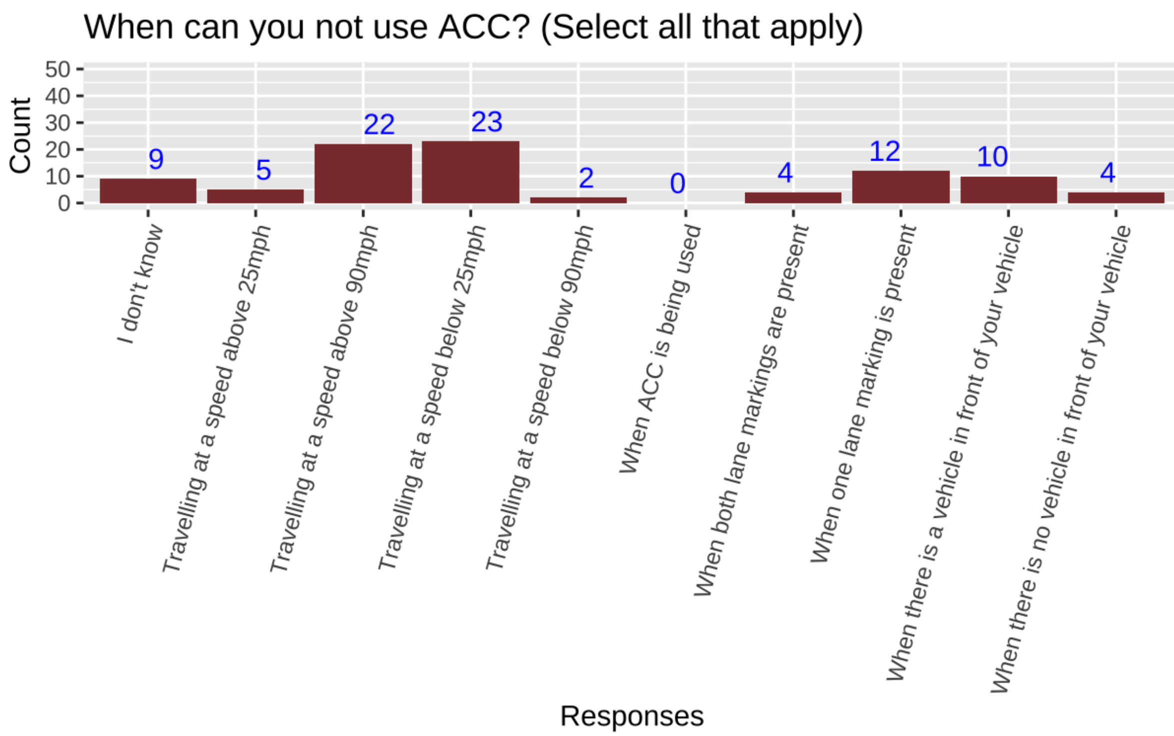

Figure 3.2 System knowledge (1)—experienced drivers (ACC)

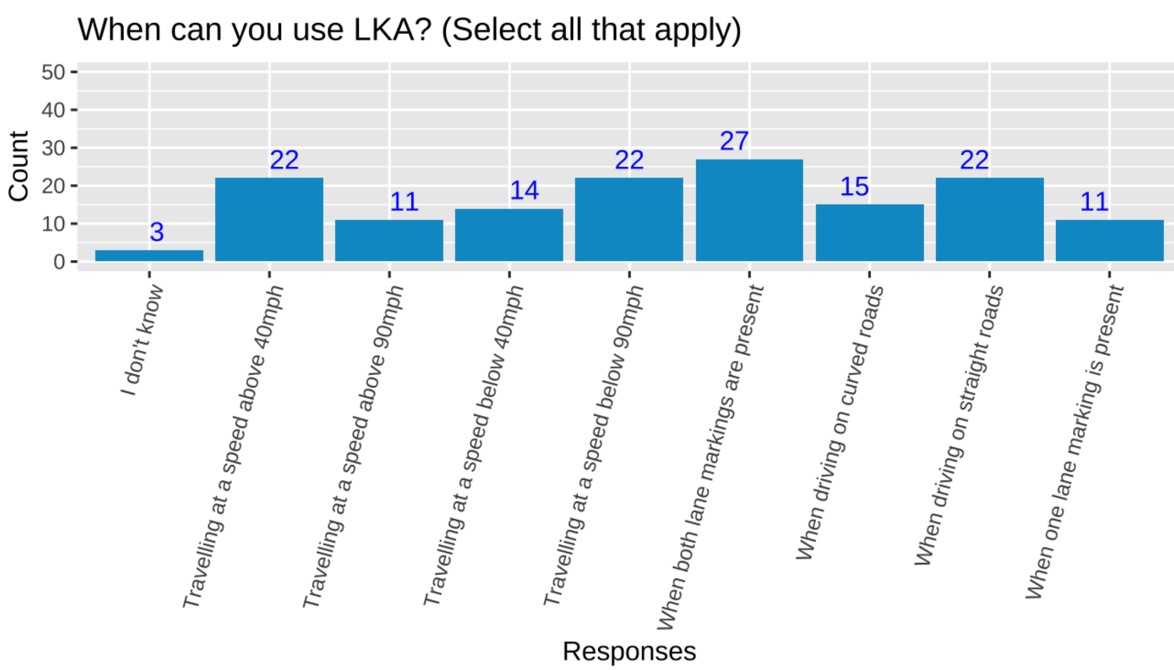

Figure 3.3: System knowledge (1)—experienced drivers (LKA)

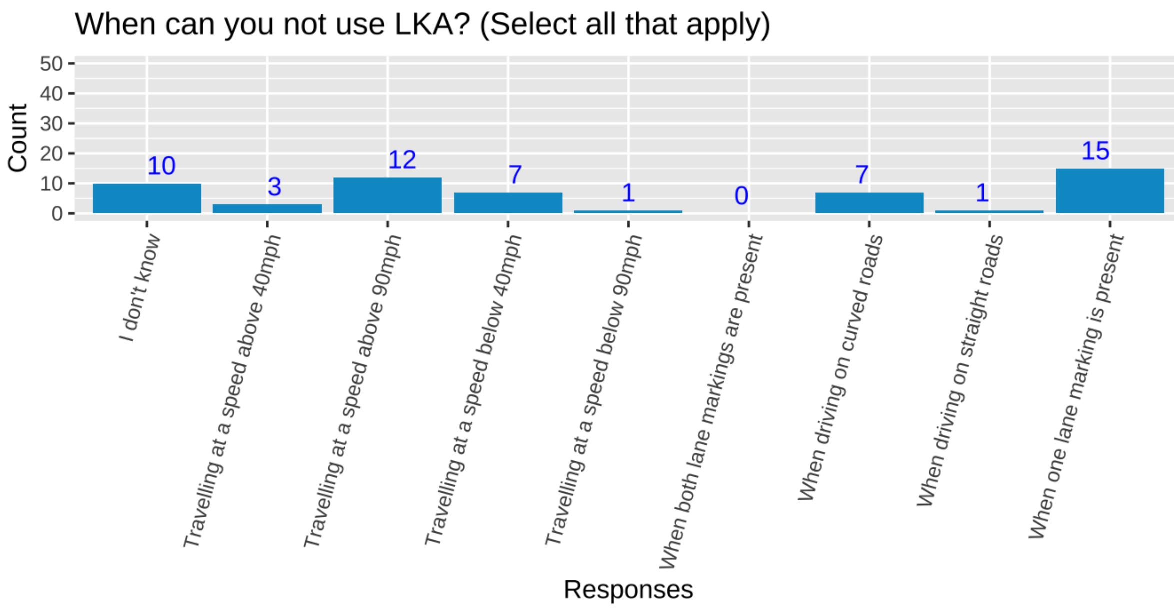

Figure 3.4 System knowledge (1)—experienced drivers (LKA

Questions were also designed to gauge if experienced drivers understood the conditions in which LKA/ACC can be used and in which cases limitations might be triggered, requiring drivers to disengage the ADAS and drive without it. Like the previous questions, a majority of the drivers did have accurate knowledge about the roadways and environments ADAS can be used in. (Figure 3.5 to Figure 3.8)

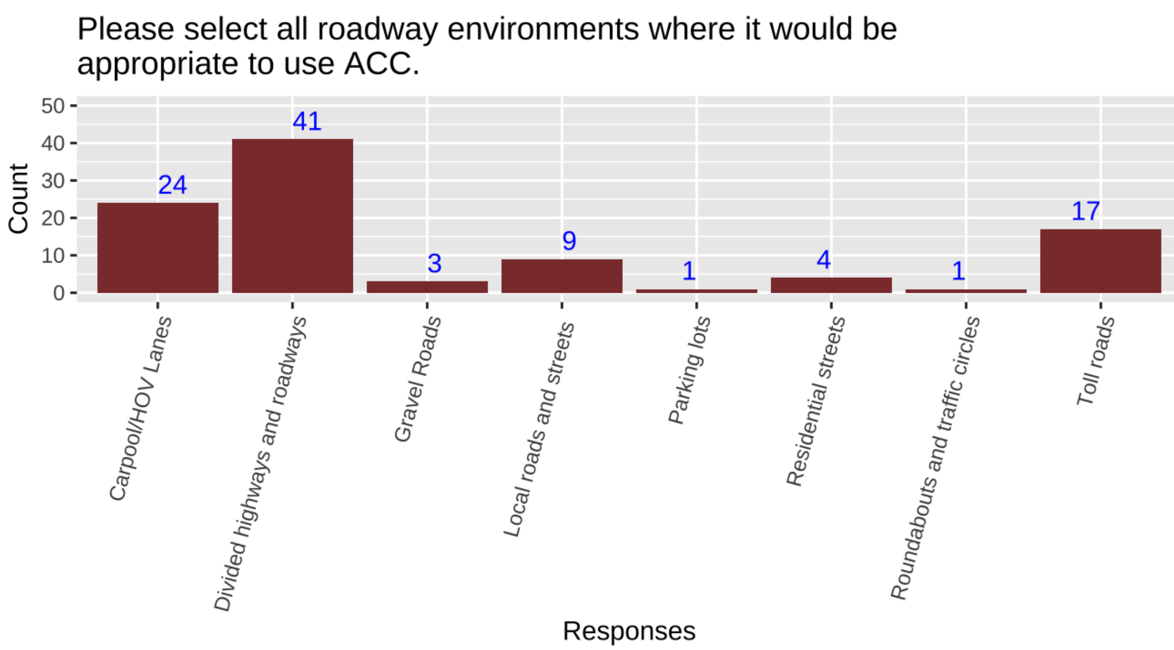

Figure 3.5: System Knowledge (2)—Experienced Drivers (ACC)

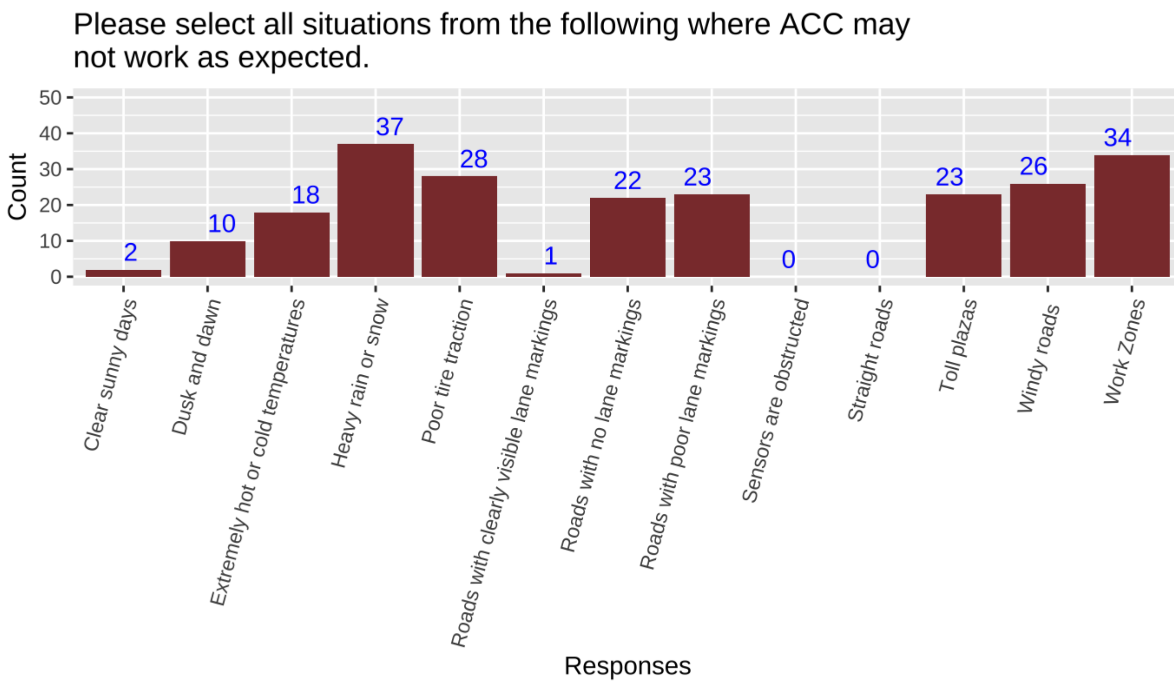

Figure 3.6: System knowledge (2)—experienced drivers (ACC)

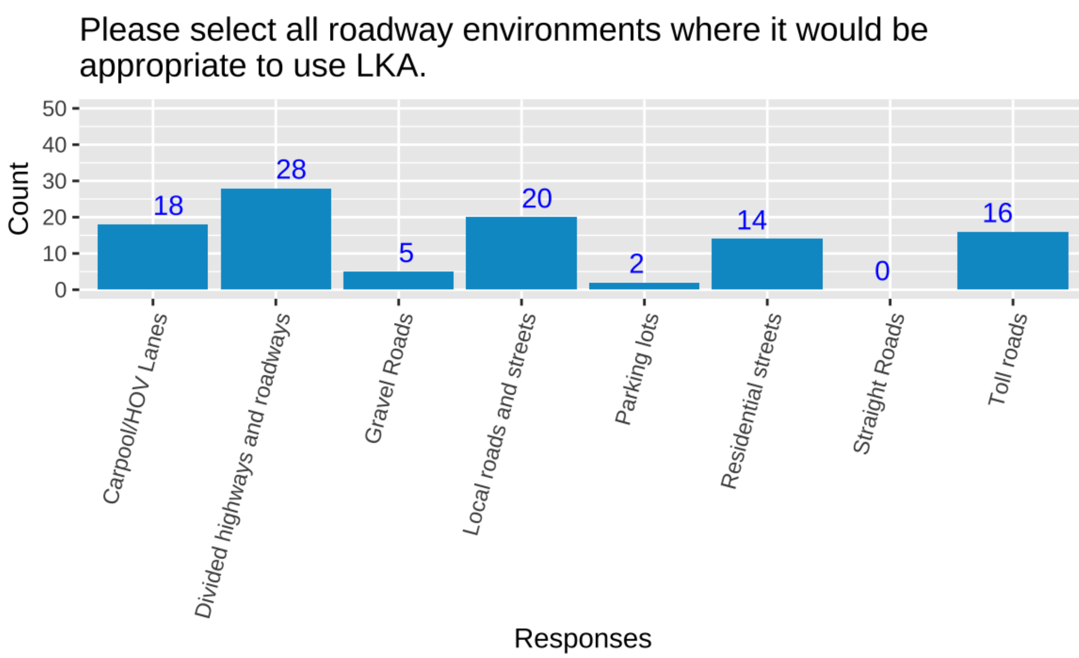

Figure 3.7: System knowledge (2)—experienced drivers (LKA)

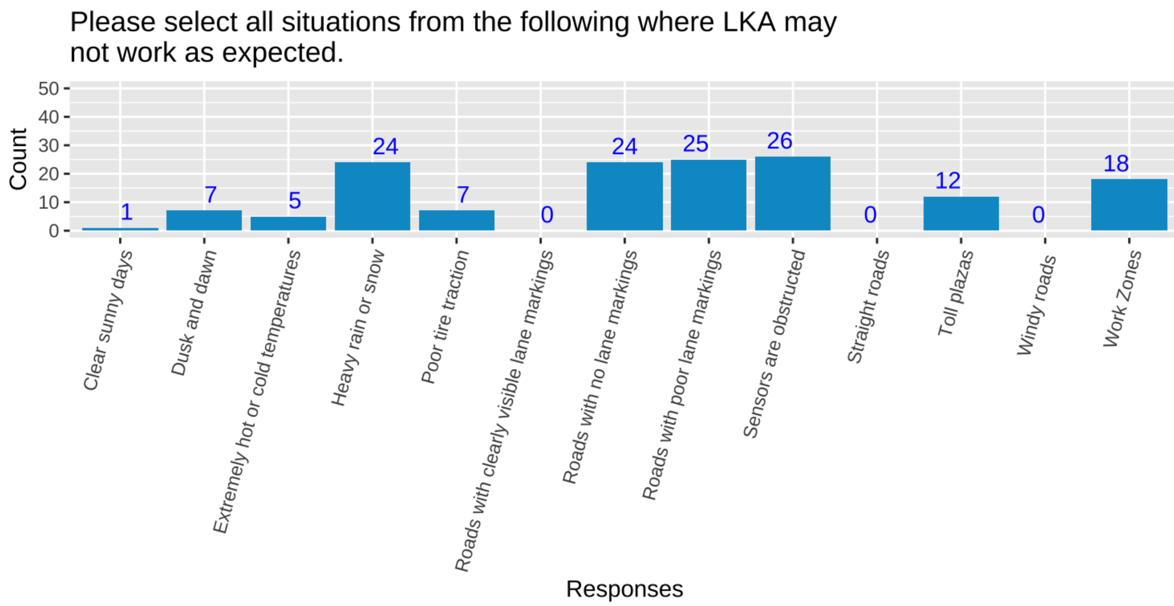

Figure 3.8: System knowledge (2)—experienced drivers (LKA)

Although inexperienced drivers do not have the same exposure to ADAS as experienced drivers have, there are a lot of resources, such as media, friends, family, etc. available for drivers wanting to know more about ADAS. We believe this may be a reason for the information novice ADAS users have about these systems. The perceived knowledge and limitations of ACC were close to actual ACC use and limitations, as all participants responded that ACC would require a minimum speed before being activated, in this case, 25 mph. About 50% of participants also perceived correctly that ACC can operate with or without a vehicle in front of it. Similarly, with LKA, more than 85% of participants perceived correctly that LKA required both lane markings, and more than 80% realized LKA works best on straight roads. Similarly for the conditions and roadway environments best suited for the use of ADAS, novice users perceived correctly that ACC or LKA are best utilized on roads such as highways, those with clearly marked lanes, local streets, and residential streets. Participants also discerned that ACC and LKA both cannot be used in heavy snow and rain (87% & 82% respectively) or in work zones (77% & 69%). (Figures 3.9 to 2.16).

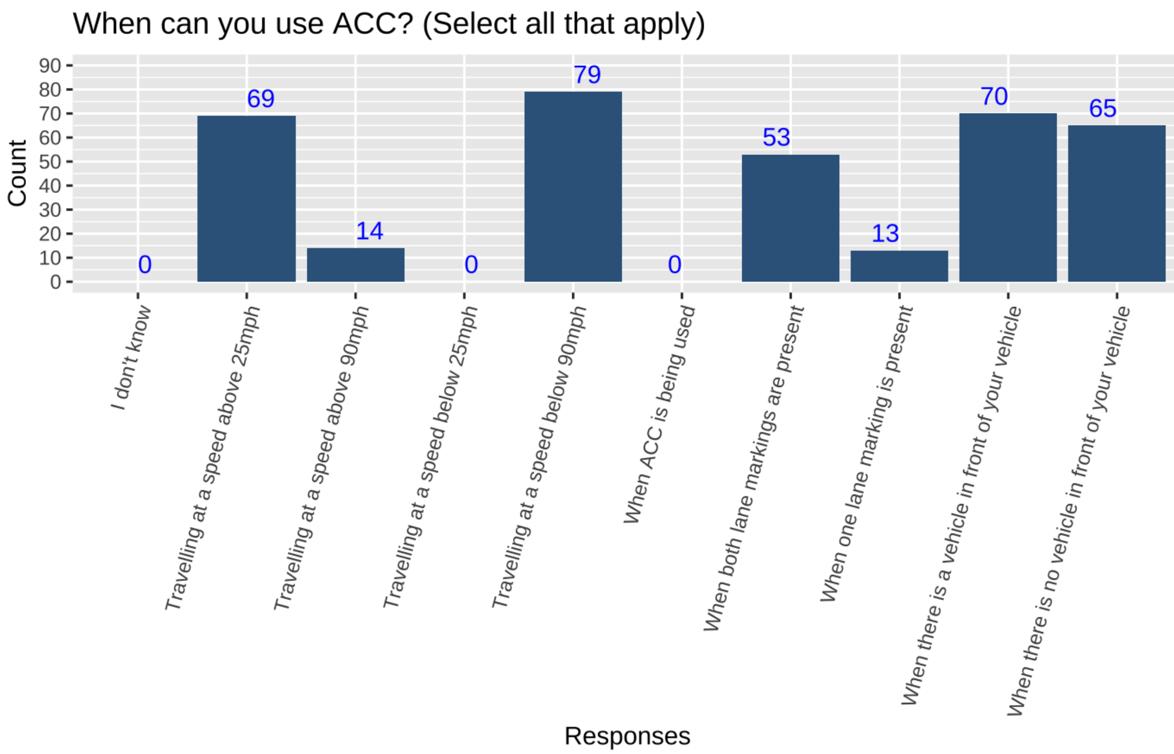

Figure 3.9: System knowledge (1)—inexperienced drivers (ACC)

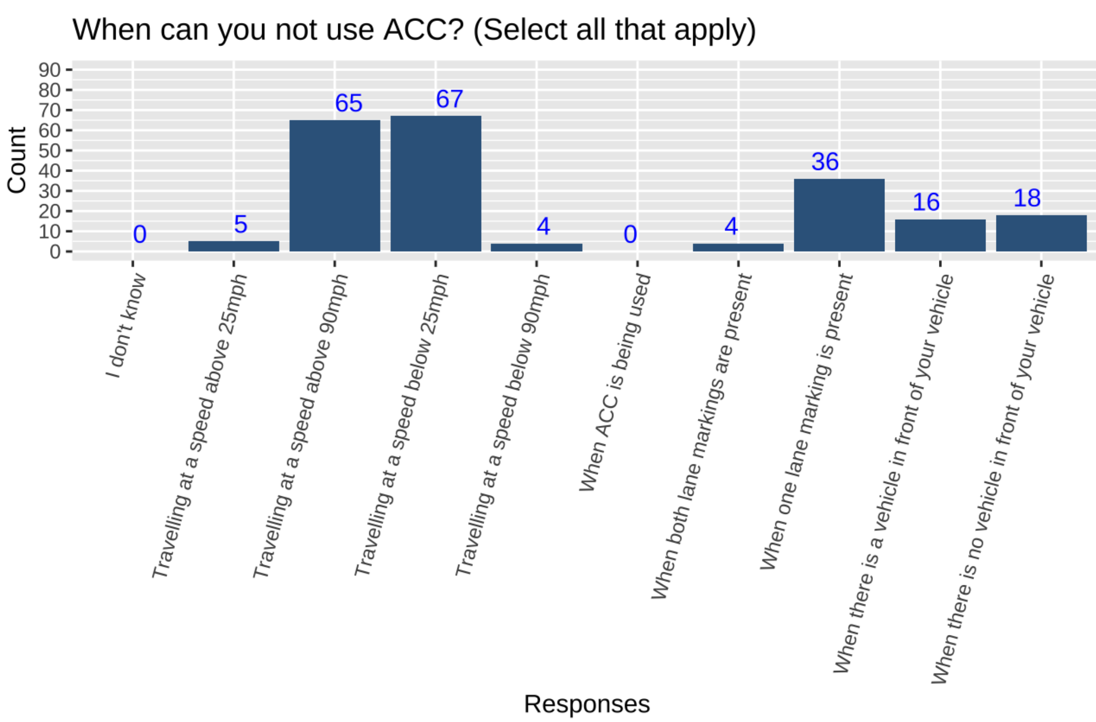

Figure 3.10: System knowledge (1)—inexperienced drivers (ACC)

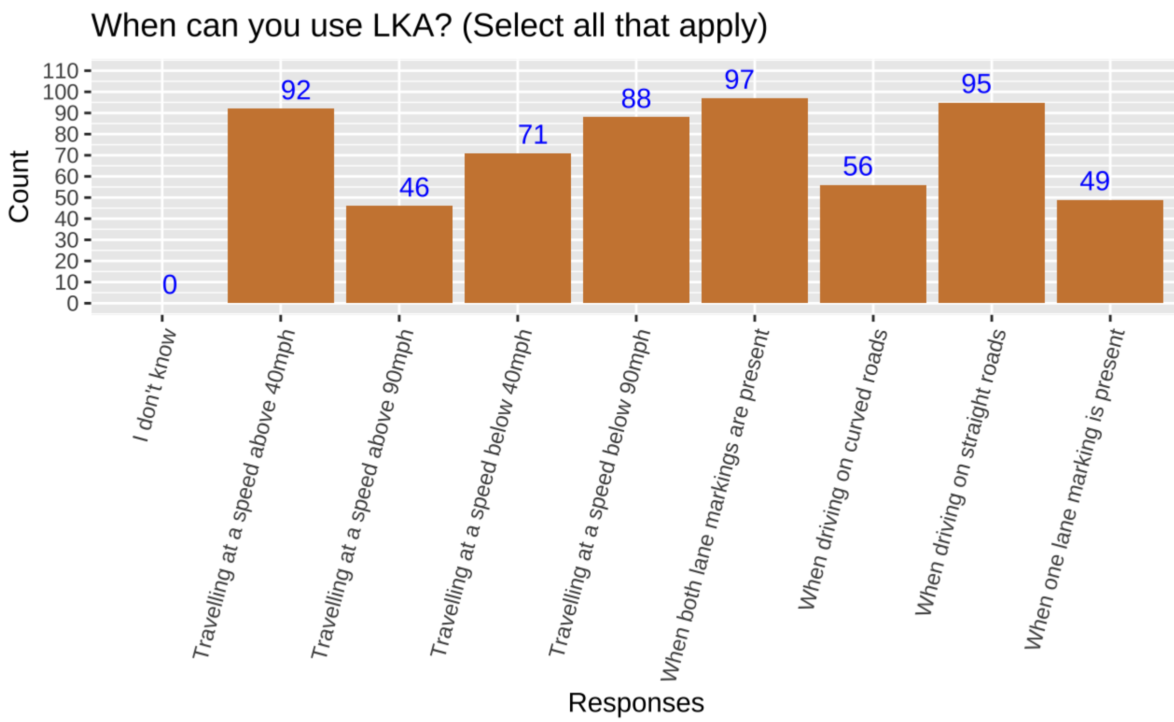

Figure 3.11: System knowledge (1)—inexperienced drivers (LKA)

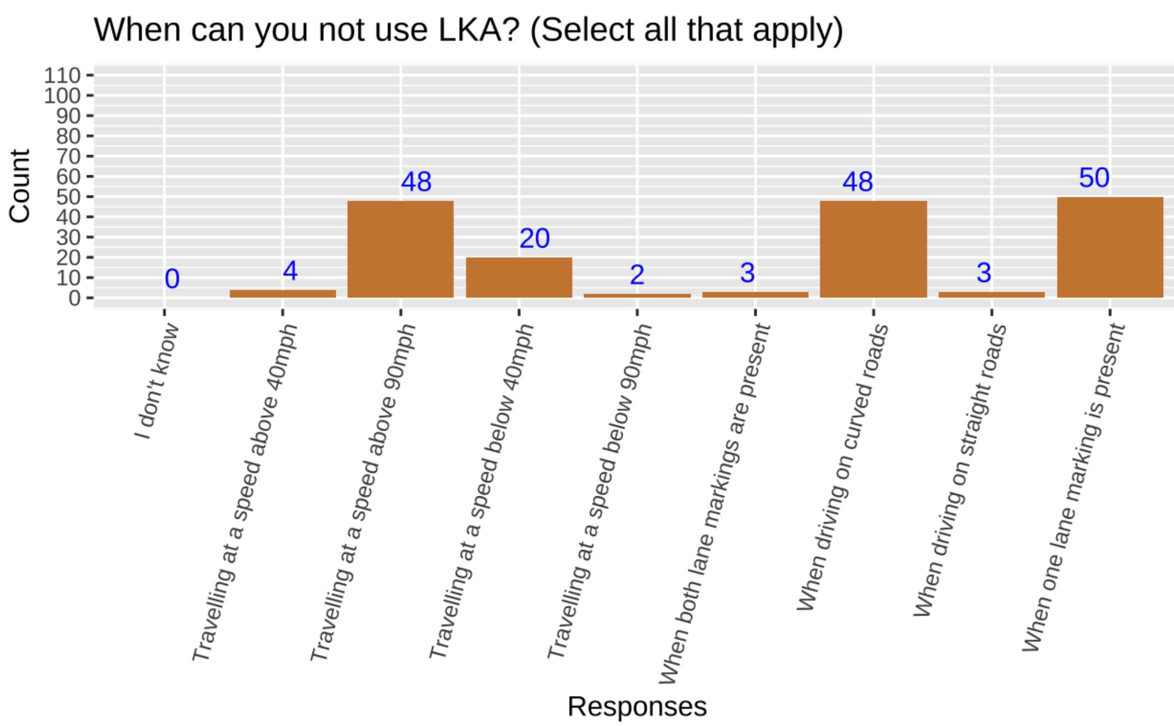

Figure 3.12: System knowledge (1)—inexperienced drivers (LKA)

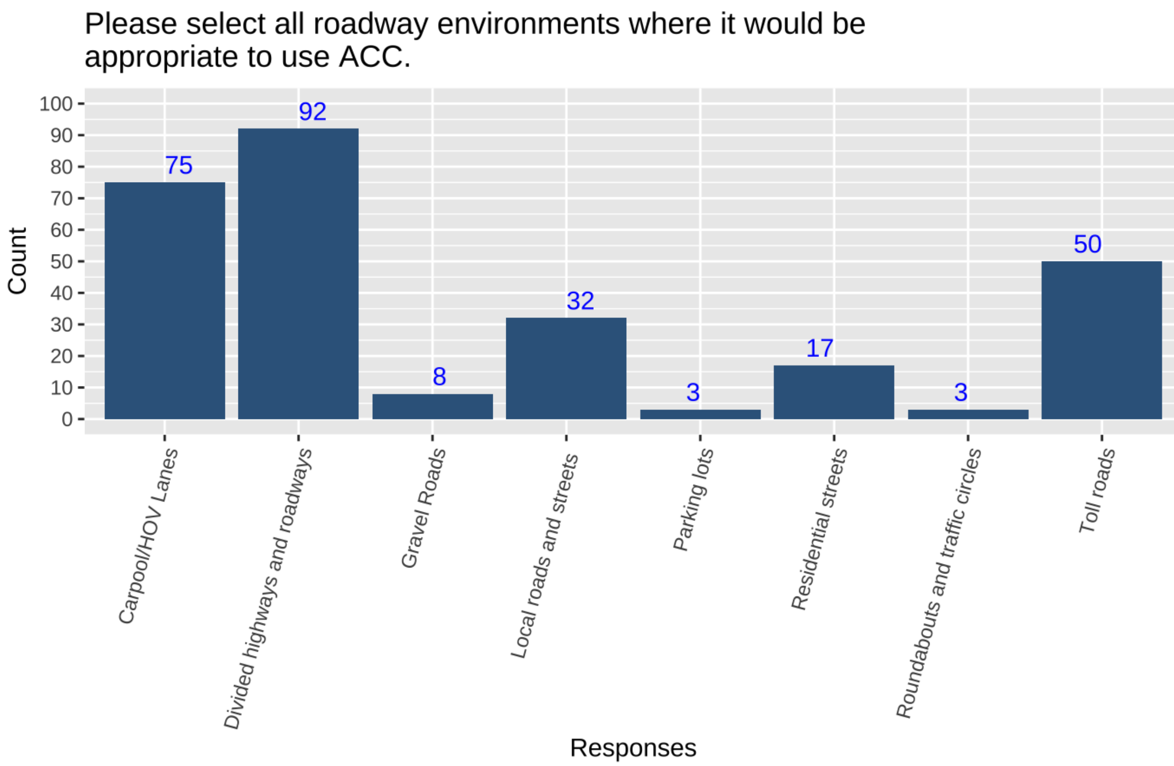

Figure 3.13: System knowledge (2)—inexperienced drivers (ACC)

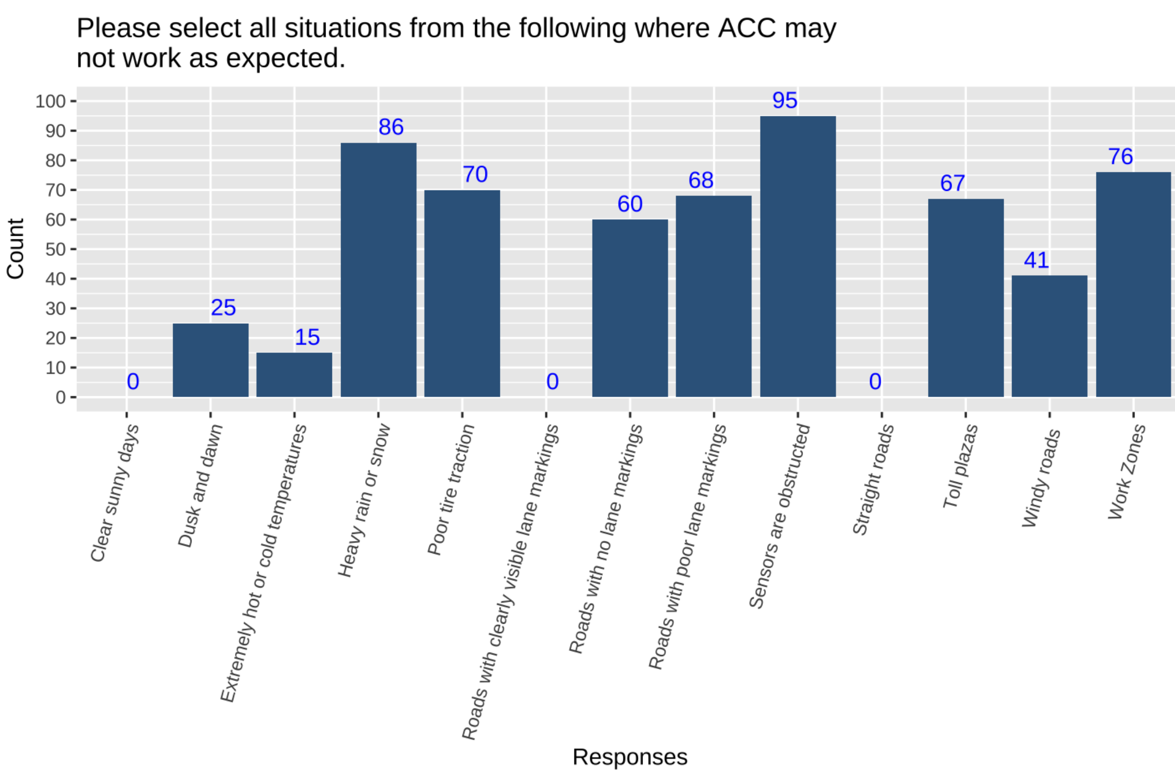

Figure 3.14: System knowledge (2)—inexperienced drivers (ACC)

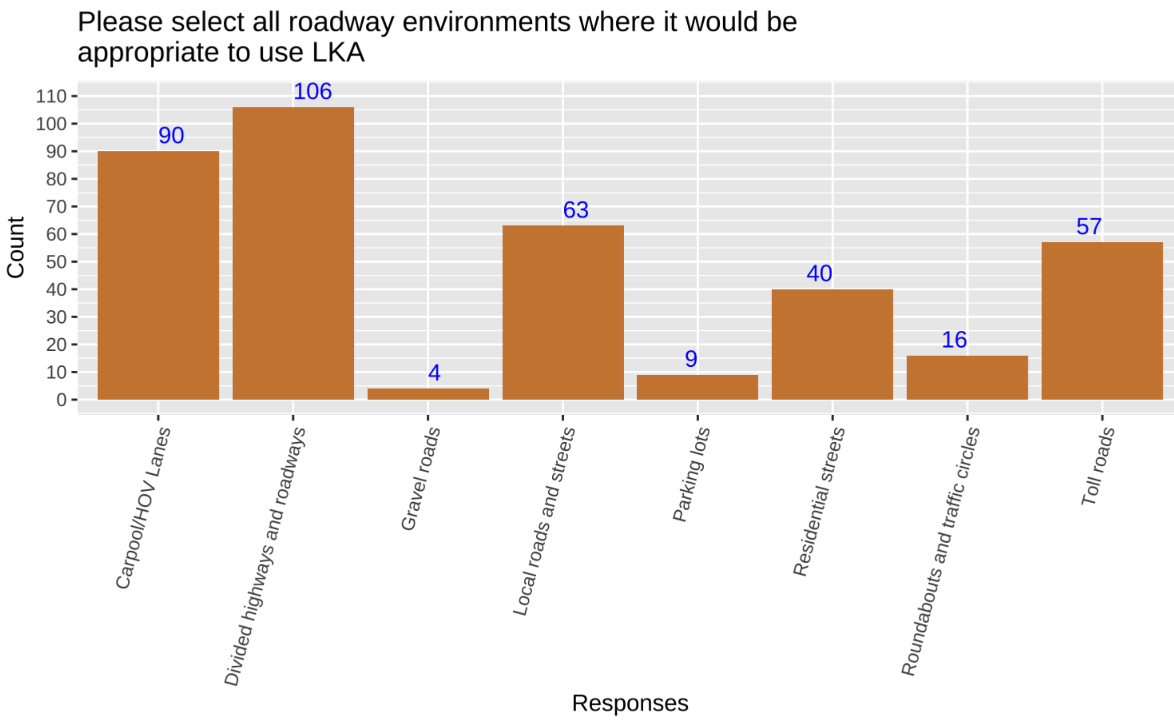

Figure 3.15: System knowledge (2)—inexperienced drivers (LKA)

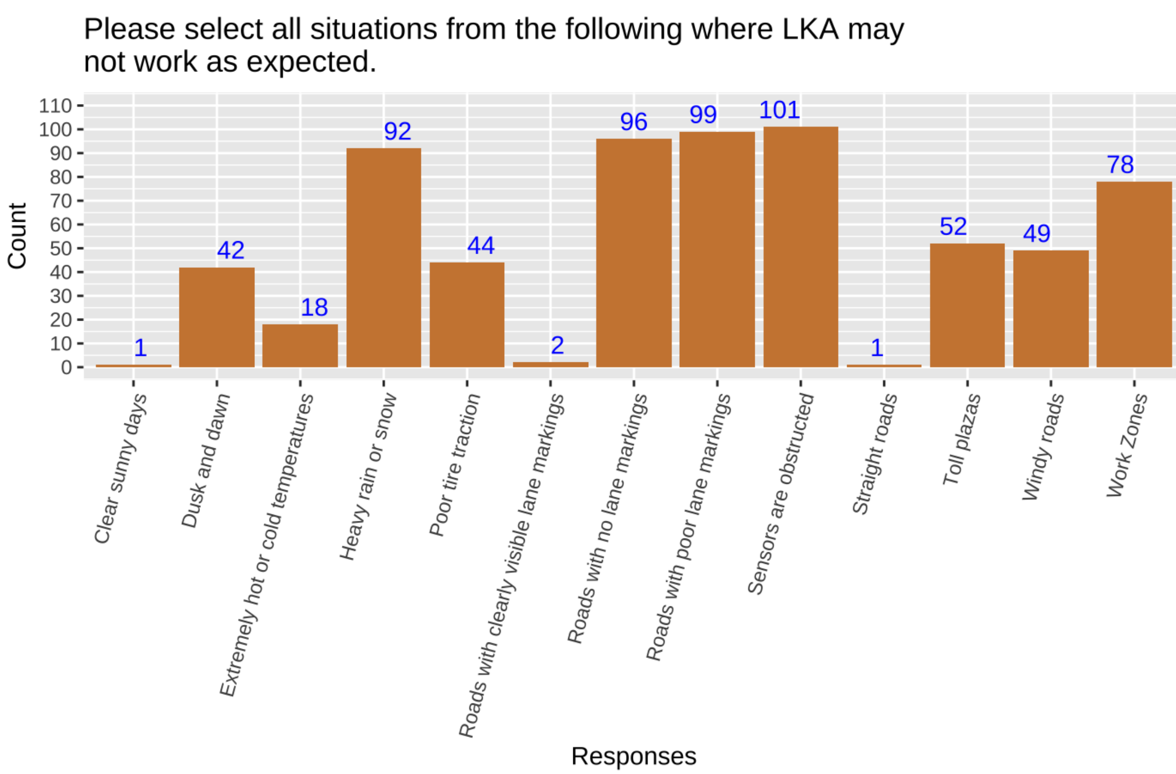

Figure 3.16: System knowledge (2)—inexperienced drivers (LKA)

3.1.2 Training/Learning Methods

Fewer than 80% of experienced ACC drivers understood how ACC worked before they bought an ACC-equipped vehicle. At the time of purchase, only 8 of the 44 drivers were offered some kind of training or information about the ACC by someone at the dealership, which was completed by only 6. Although offered to less than 15% of drivers, participants still found the training satisfactory, indicating they found it informative enough to be able to use ACC. However, 50% of the participants that received training still had uncertainties about the system. A multiple-choice question was asked about the references drivers used to get familiar with ADAS. ACC users preferred the methods “learning by trial and error” and “friends or family.” Only 29%referred to the Owner’s Manual. Of the 44 participants, 34 agreed that their understanding of ACC increased after they’d driven with it for some time (Figure 3.17).

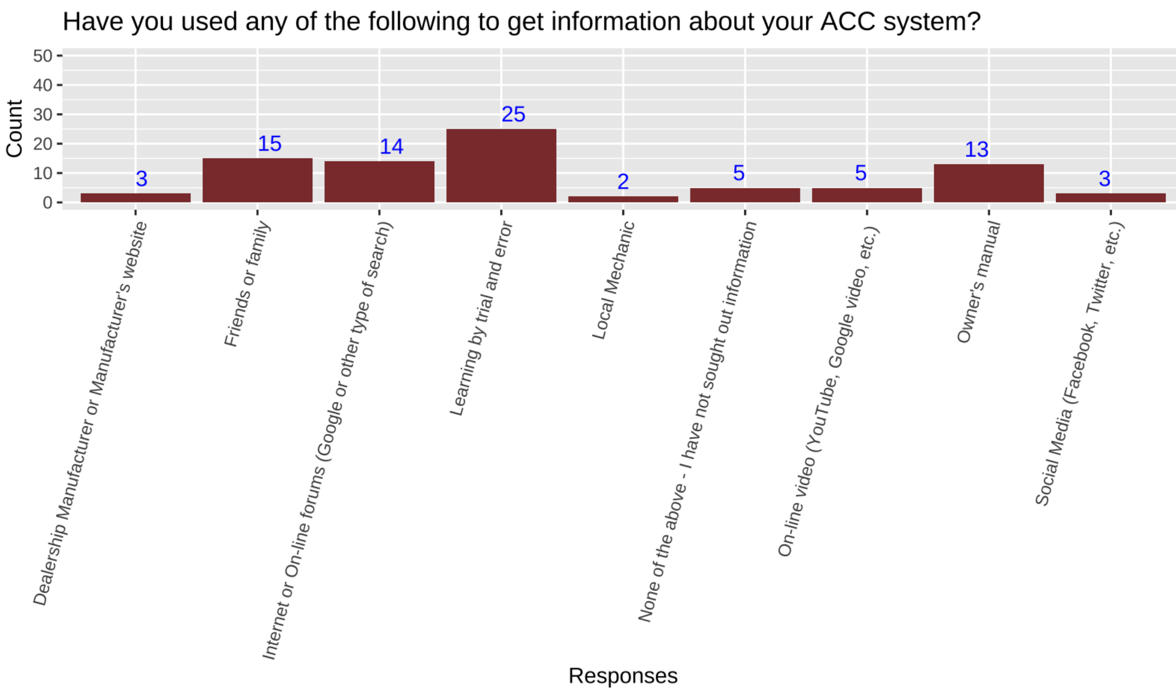

Figure 3.17: Training methods used by experienced ACC drivers

Of the 30 LKA users, 19 drivers knew how to use LKA before they bought their first LKA-equipped vehicle. At the time of purchase, less than 40% (11 drivers) were offered training to help understand how to use the system. Of the buyers offered training, all participants completed the training although on average drivers found it unsatisfactory. Five of the 11 participants that received training then used other methods (internet or online forums and learning by trial and error) to properly understand LKA. On average, when asked to all LKA users, drivers preferred “learning by trial and error,” followed by “internet or online forums,” as with ACC users. All participants agreed that their understanding of LKA increased after driving with it. (Figure 3.18)

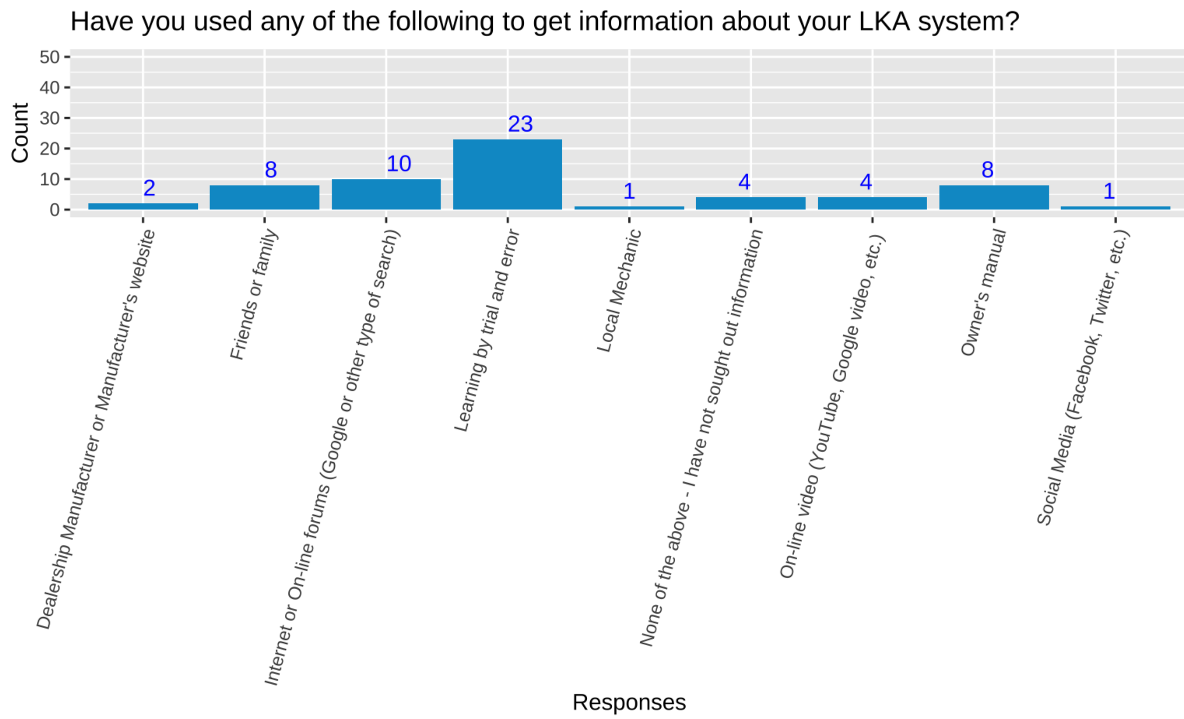

Figure 3.18: Training methods used by experienced LKA drivers

3.1.3 Functionality

Unless travelling at higher speeds, drivers don't really tend to change their distance setting, even with changes in traffic. This shows that although drivers use ACC to maintain speed, they tend not to operate the distance setting too much, indicating they use ACC as a regular Cruise Control system. Interestingly, of the 44 experienced ACC drivers, most participants either rarely (N=11) or never (N=12) use CC (Figure 3.19 to 3.22).

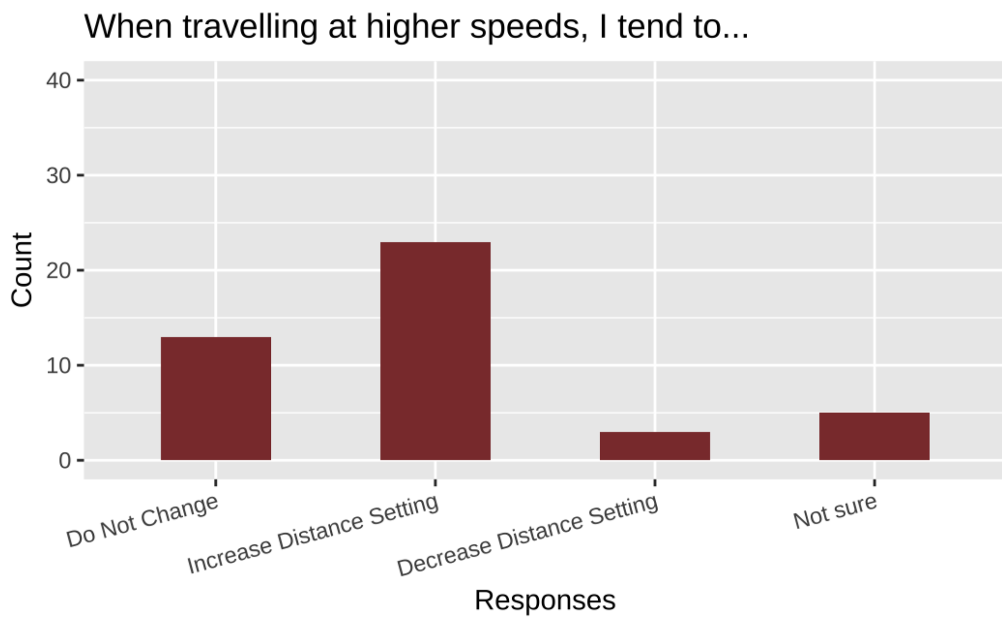

Figure 3.19: Changes in distance settings—experienced drivers (higher speeds)

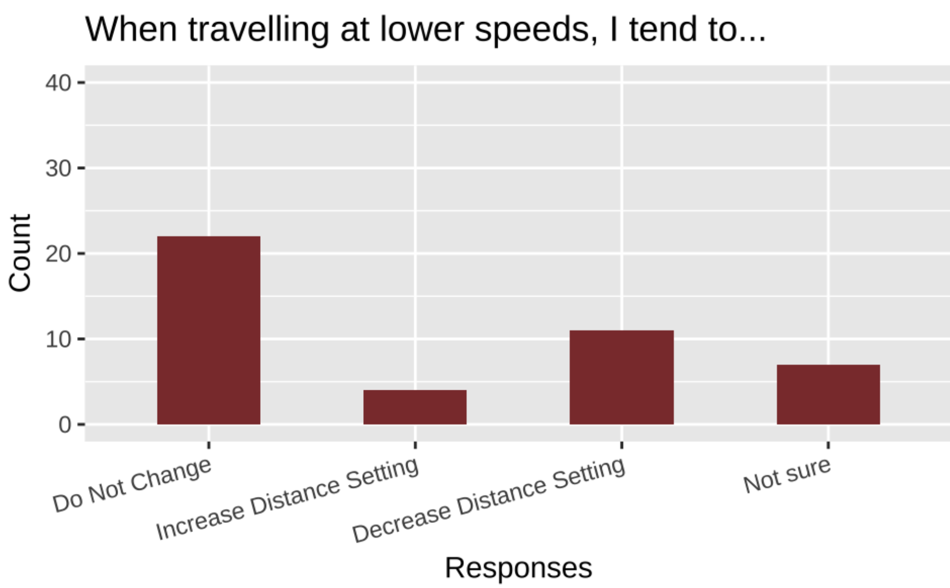

Figure 3.20: Changes in distance settings—experienced drivers (lower speeds)

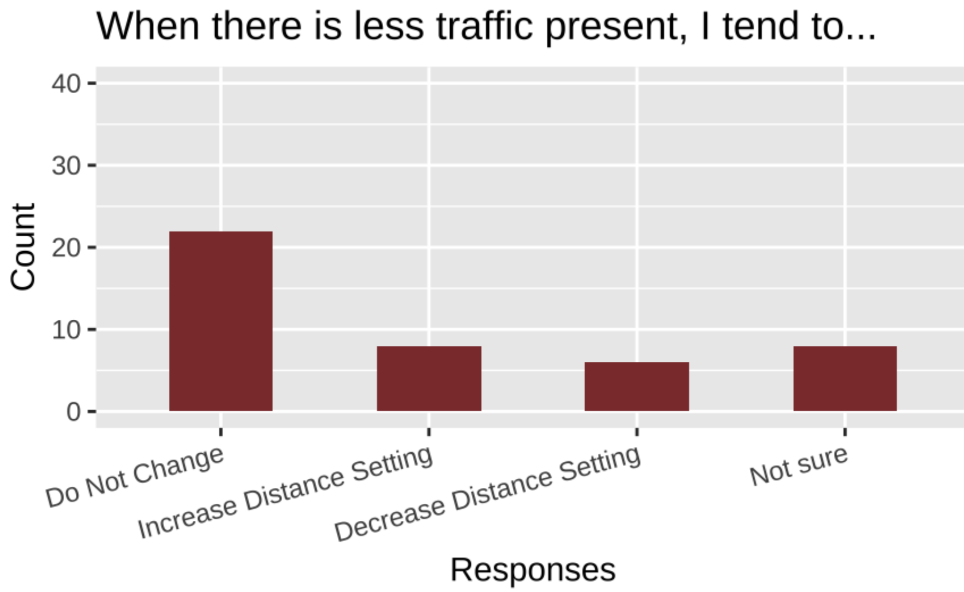

Figure 3.21: Changes in distance settings—experienced drivers (less traffic)

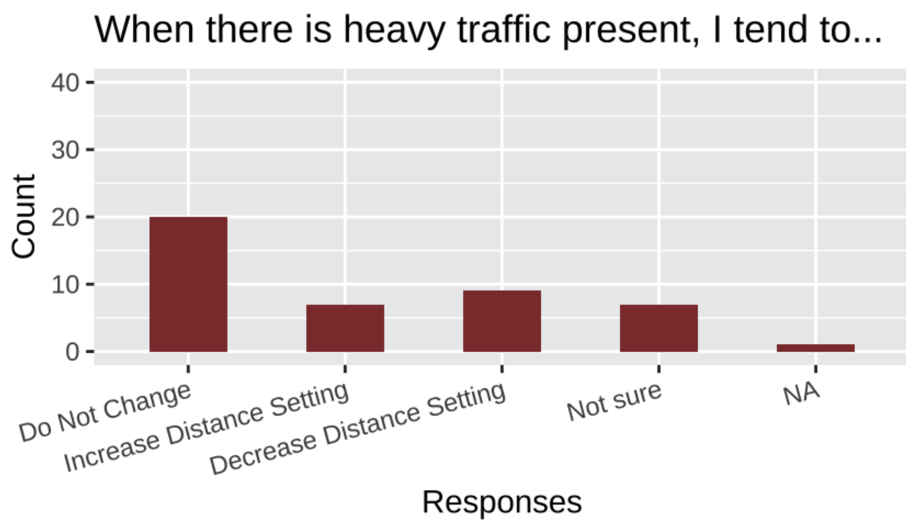

Figure 3.22: Changes in distance settings—experienced drivers (heavy traffic)

Most of the participants did not offer conclusive statements regarding the changes in their driving behavior or increase in their safety after using ACC, although a high number—72 percent—would be willing to get ACC in their next vehicle (Figure 3.23 to 3.25).

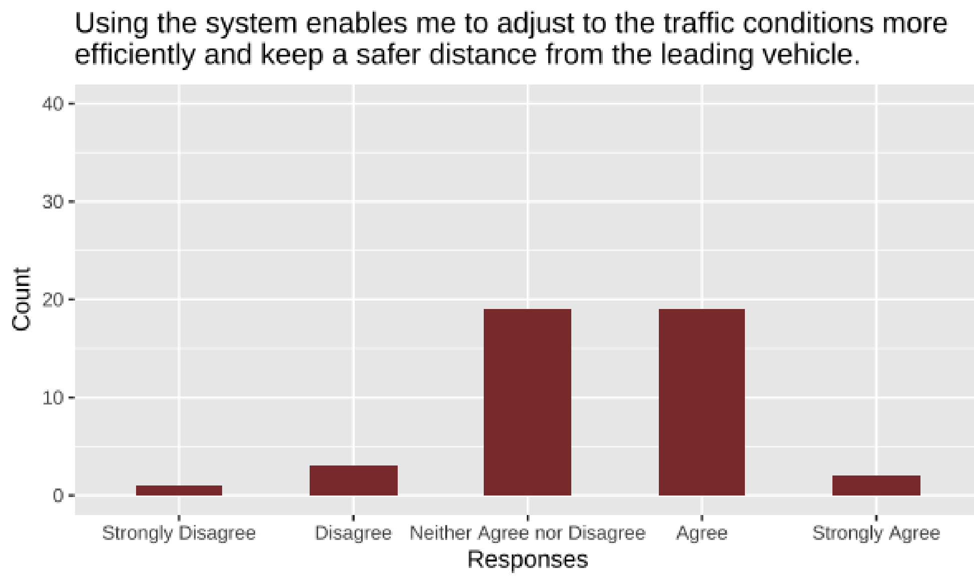

Figure 3.23: Self-reported functional use of ACC—experienced drivers

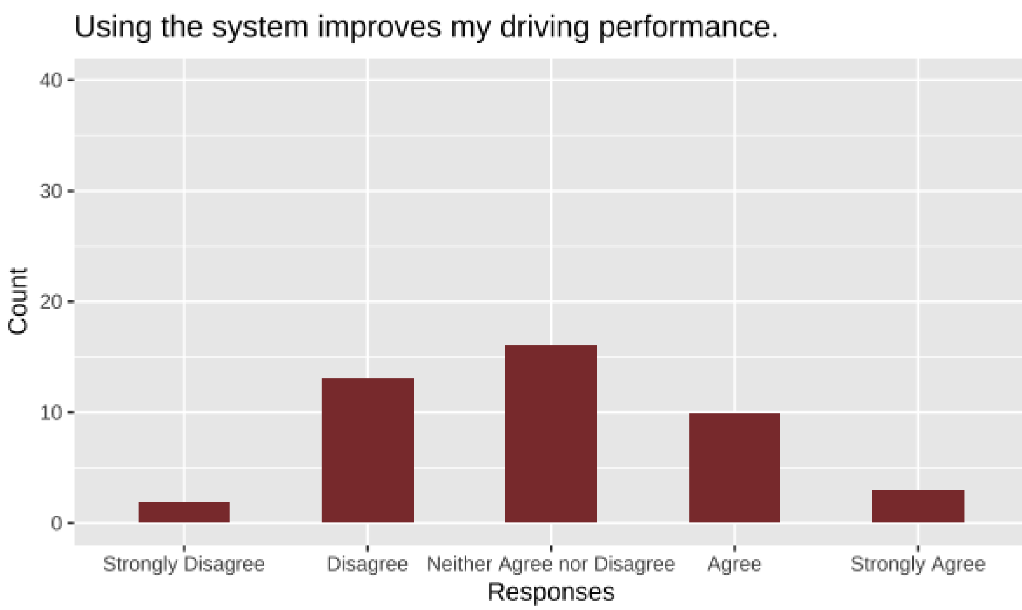

Figure 3.24: Self-Reported Functional Use of ACC—Experienced Drivers

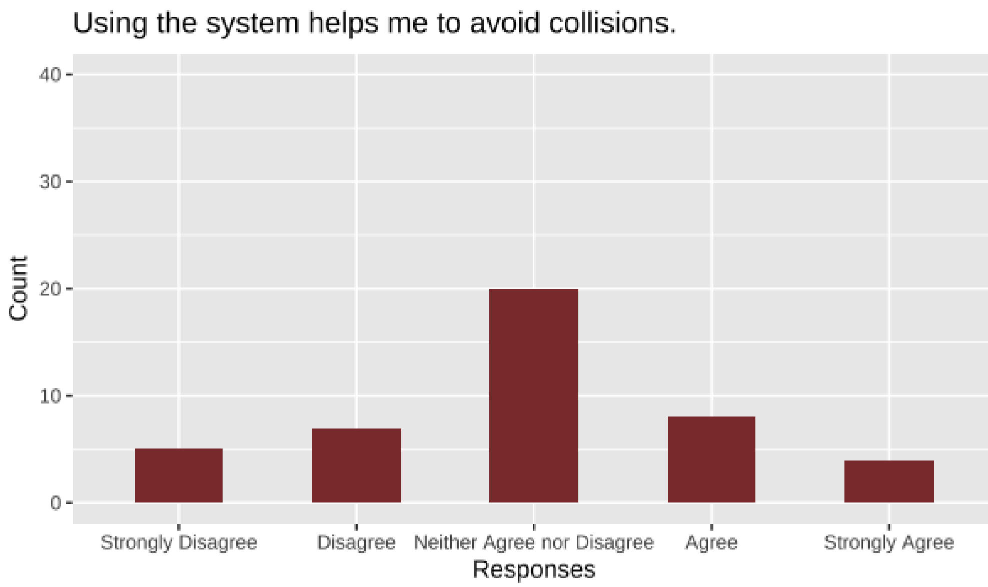

Figure 3.25: Self-reported functional use of ACC—experienced drivers

Most participants using LKA agreed that it helped reduce collisions and helped center their vehicle while driving, overall improving their driving performance. This indicates that a lateral control system may be more useful while driving than a longitudinal one. (3.26 to 3.28).

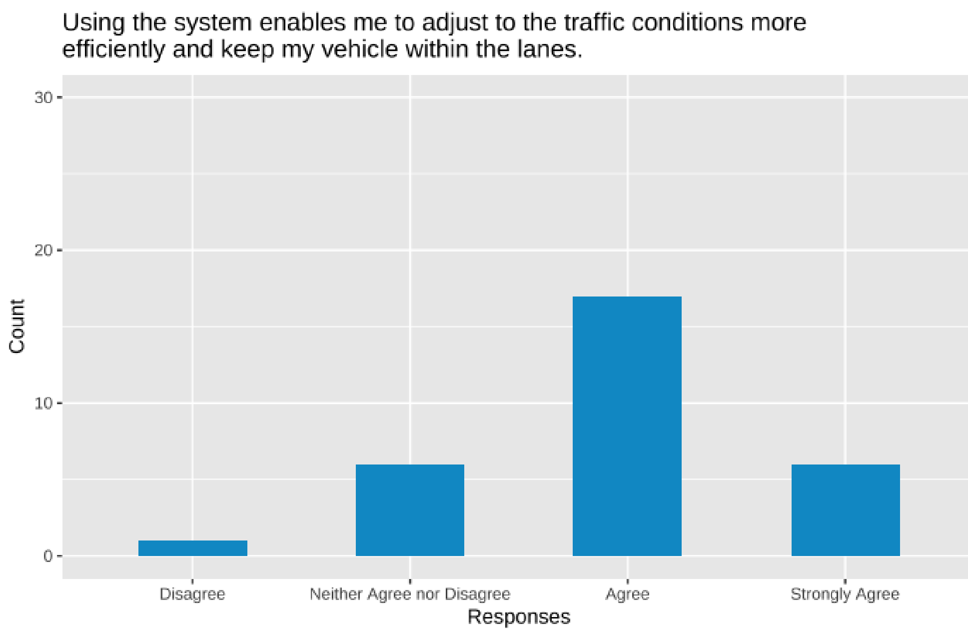

Figure 3.26: Self-reported functional use of LKA—experienced drivers

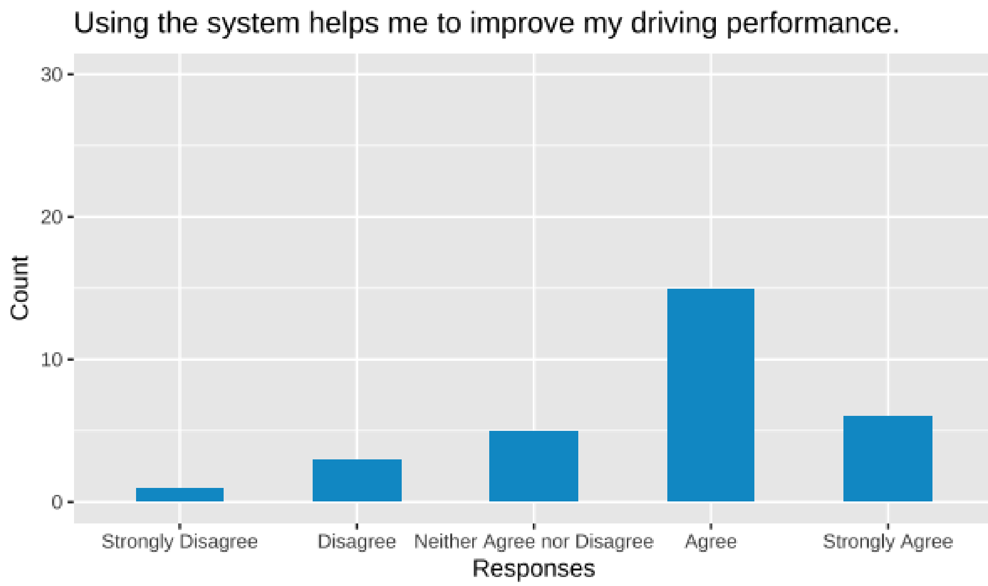

Figure 3.27: Self-reported functional use of LKA—experienced drivers

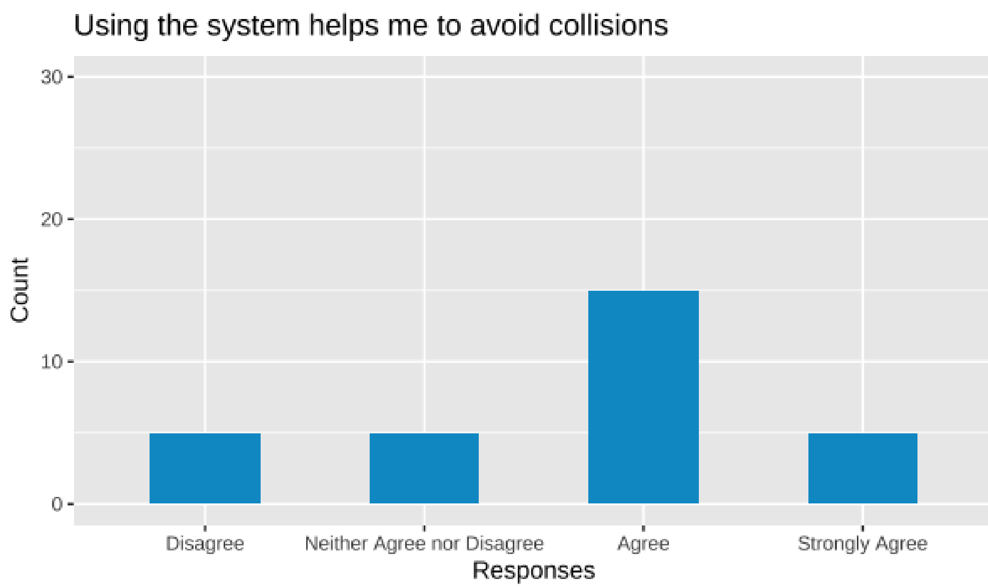

Figure 3.28: Self-reported functional use of LKA—experienced drivers

3.1.4 Trust/Willingness to Use

Most drivers indicated a preference to trust and use ADAS while driving. When asked if drivers would be comfortable with engaging in secondary tasks while driving with ADAS, most strongly disagreed, although a very small number of participants agreed. (Figures 3.29 to 3.36).

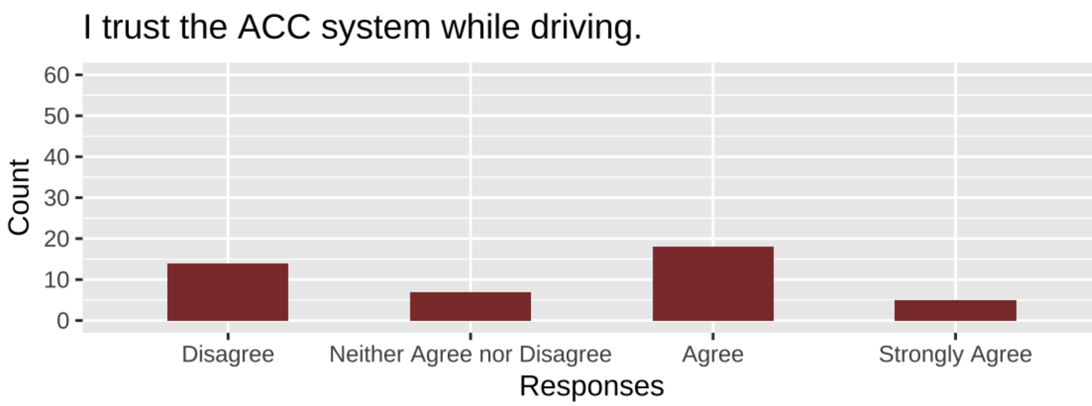

Figure 3.29: Self-reported trust in ADAS (ACC experienced)

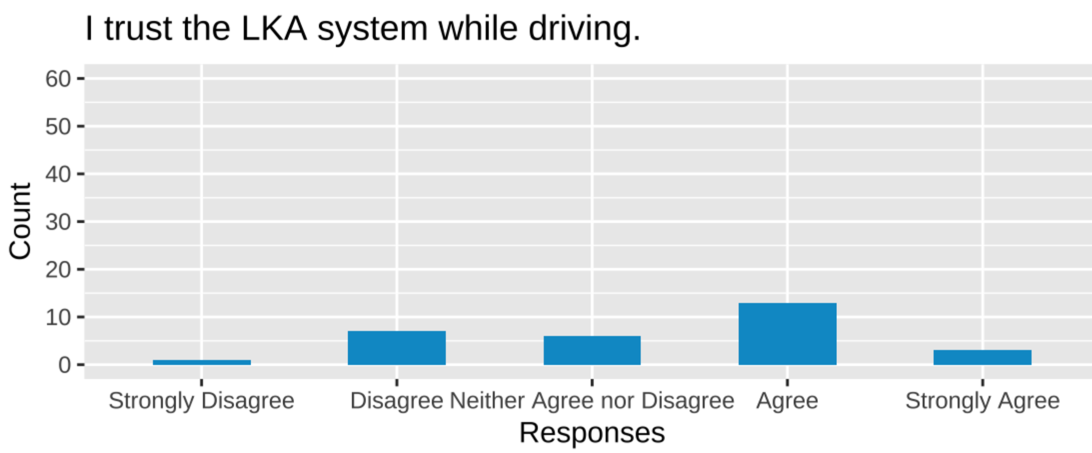

Figure 3.30: Self-reported trust in ADAS (LKA experienced)

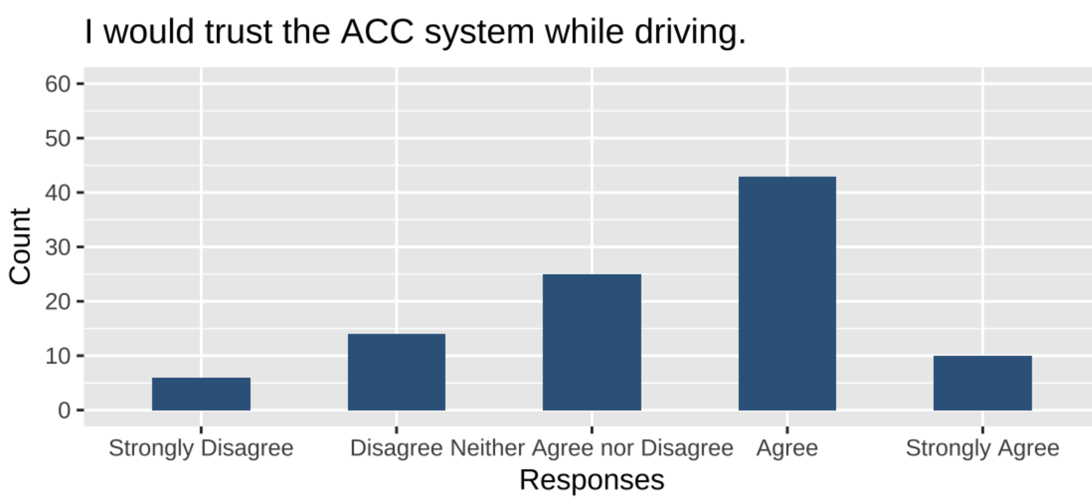

Figure 3.31: Self-reported trust in ADAS (ACC inexperienced)

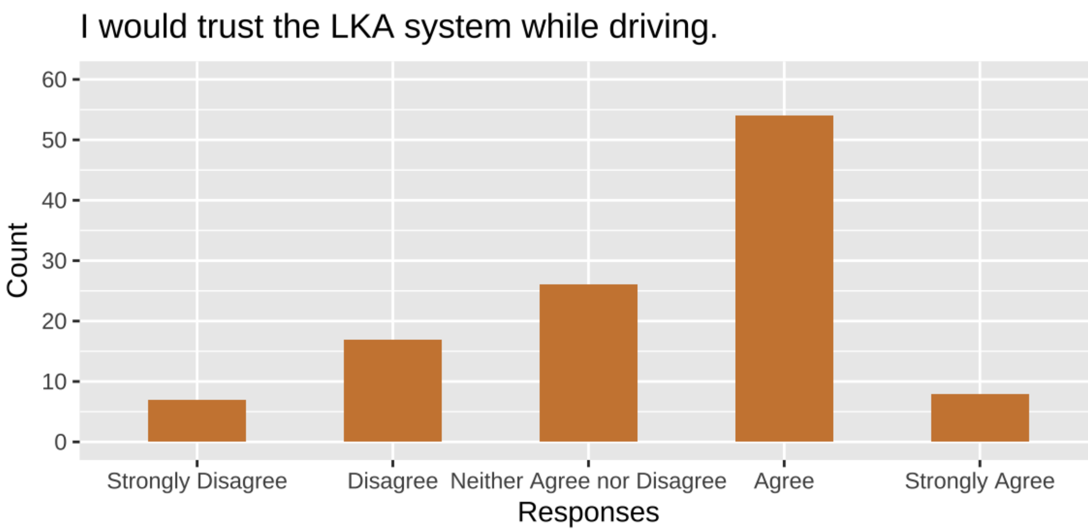

Figure 3.32: Self-reported trust in ADAS (LKA inexperienced)

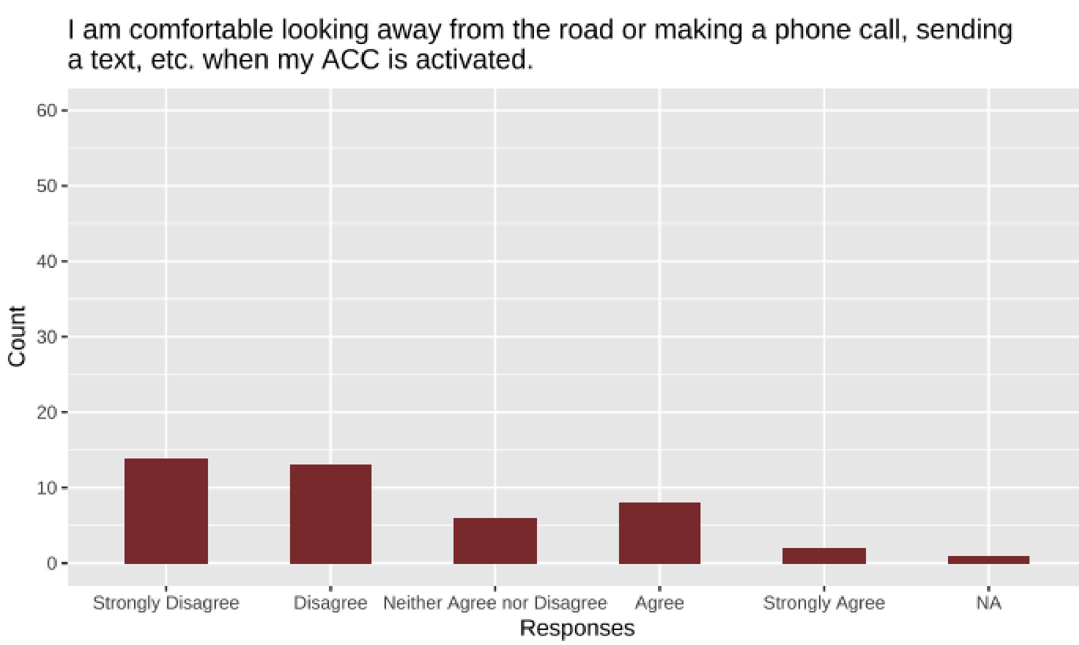

Figure 3.33: Willingness to engage in secondary tasks (ACC experienced)

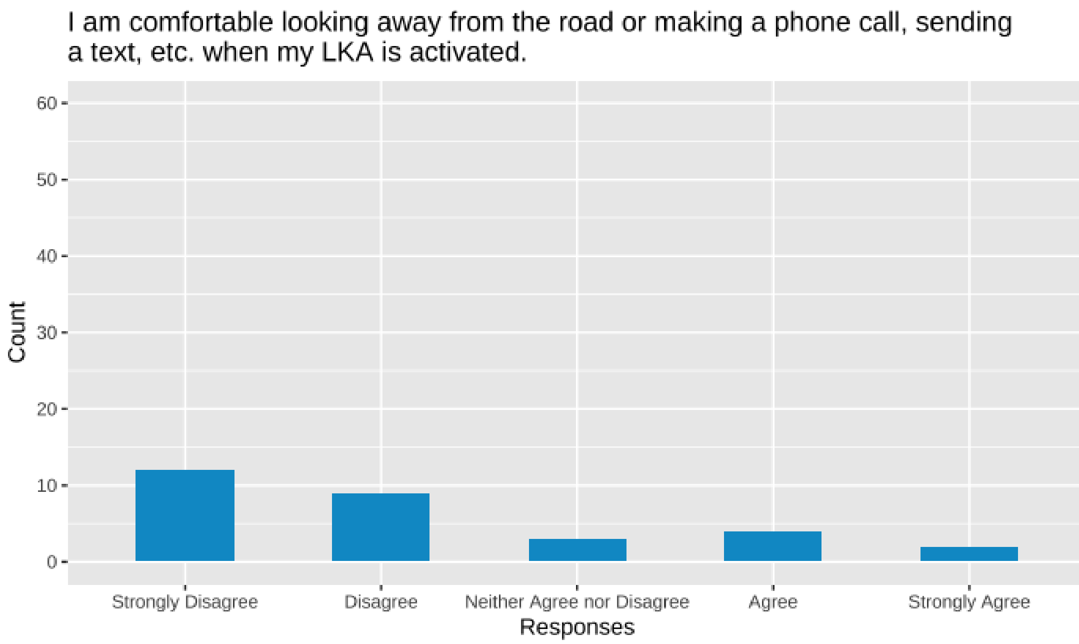

Figure 3.34: Willingness to engage in secondary tasks (LKA experienced)

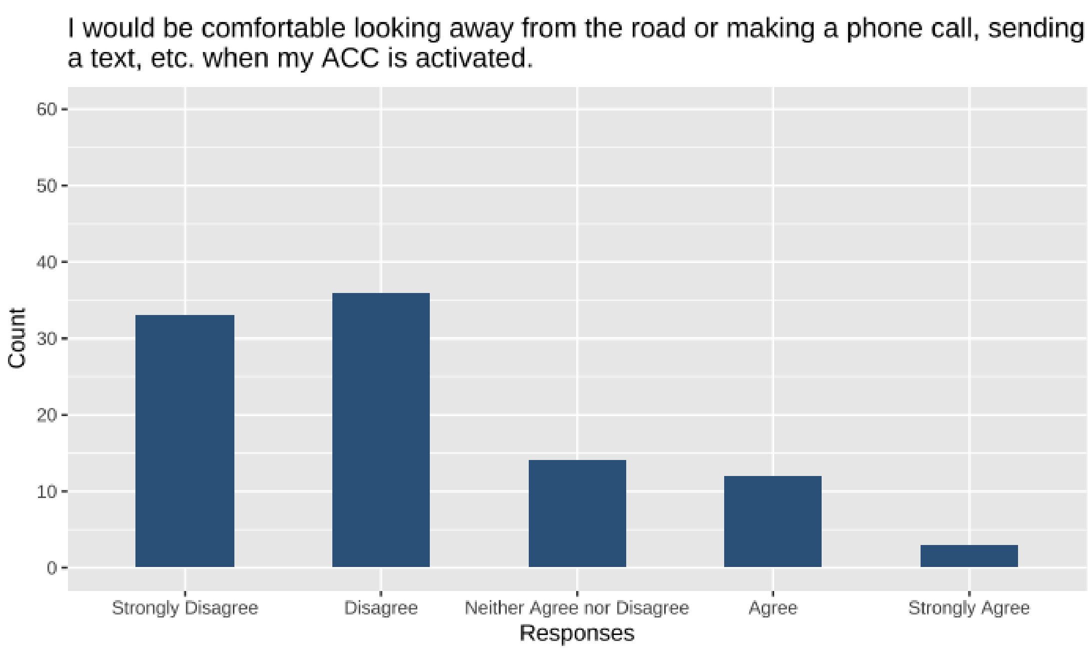

Figure 3.35: Willingness to engage in secondary tasks (ACC inexperienced)

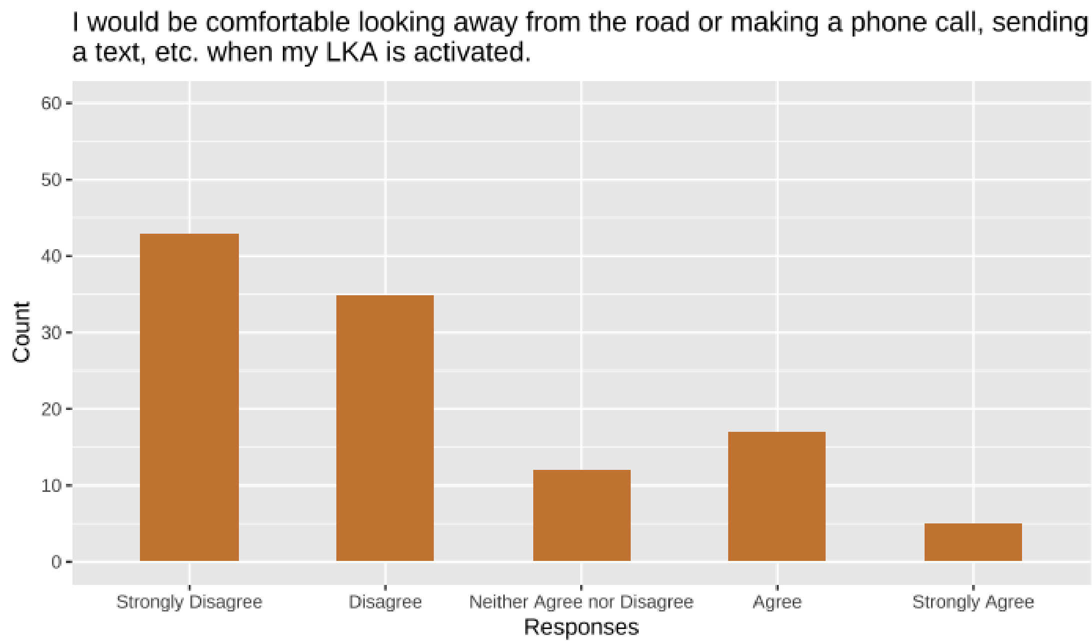

Figure 3.36: Willingness to engage in secondary tasks (LKA inexperienced)

3.2 Simulator Study—Improving Drivers' Knowledge of ADAS

3.2.1 Completeness and Accuracy of Mental Model

The analysis of the driver's knowledge and understanding of ACC were done by comparing pre and post scores for all participants and for groups. A two-way 3 (type of training method: M, S, or V) x 2 (condition type: pre or post training scores) mixed analysis of variance with repeated measures on the survey score variable was conducted. The analysis found a significant effect of condition type, but no main effect of training method. The main condition type yielded $F(1,21) = 30.951$, $p<.0001$ indicating a significant difference between pre-training ($M = 54.225$, $SD = 10.32$) and post-training ($M = 65.455$, $SD = 11.83$). This indicates that although there was a significant increase in knowledge due to training, the training type had no effect on the knowledge gain.

The pairwise comparisons for the main effect of condition type were corrected using a Bonferroni adjustment method. The test shows a statistically significant effect between the pre- and post-training survey specifically for the visualization group ($p=0.01$) and text-based group ($p=0.04$) only.

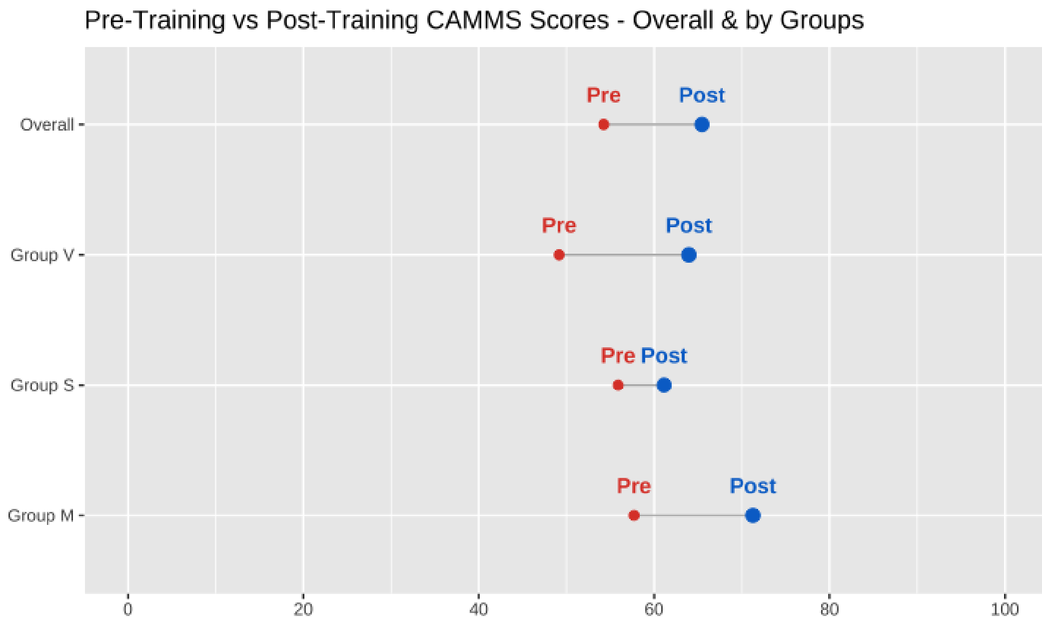

Figure 3.37: Pre-training and post-training scores for CAMMS

3.2.2 Trust Survey

As with the analysis of CAMMS, pre-training trust scores and post-training trust scores were compared for all participants and groups. A two-way 3 (type of training method: M, S, or V) x 2 (condition type: pre- or post-training scores) mixed analysis of variance with repeated measures on the trust score was conducted. The analysis found a significant effect of condition type ($F(1,21) = 6.137$, $p<.05$), but no main effect of training method.

The pairwise comparisons for the main effect of condition type were corrected using a Bonferroni adjustment method. The test shows a no significant effect between pre- and post-training trust surveys.

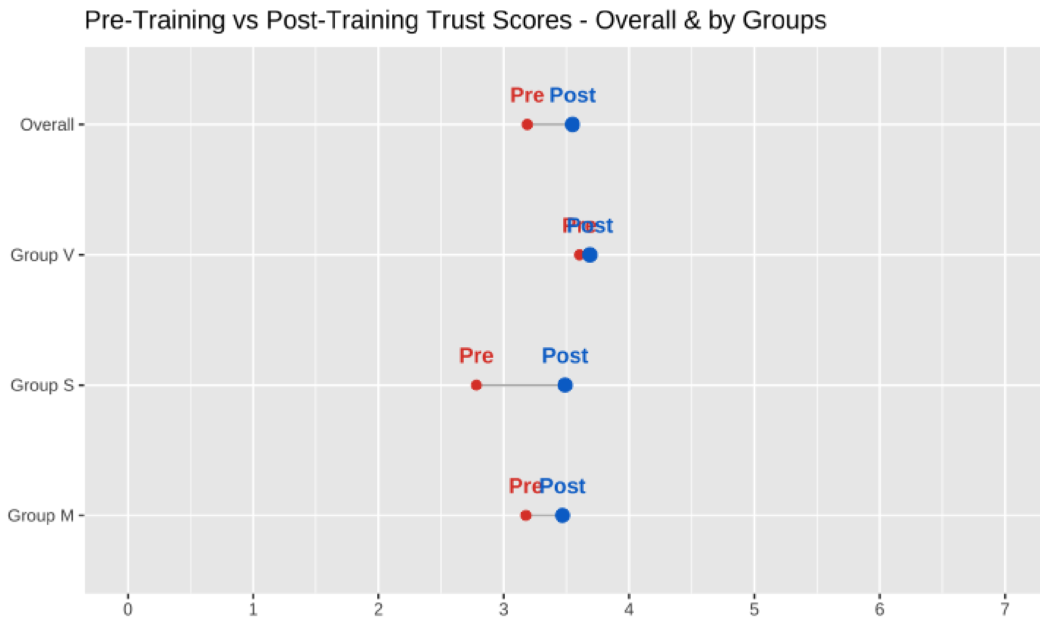

Figure 3.38: Pre-training and post-training scores for trust survey

3.2.3 Accuracy of Verbal Responses

The figure below describes the average accuracy of drivers' verbal responses to ACC questions while driving in the simulator. Participants in the Text Based (M = 0.85) and Visualization group (0.77) had higher mean accuracy than the Sham group (0.708). A one-way ANOVA was conducted and revealed no main effect of the training group on the accuracy of responses (F = 1.4863; p = 0.229, η2 = 0.02).

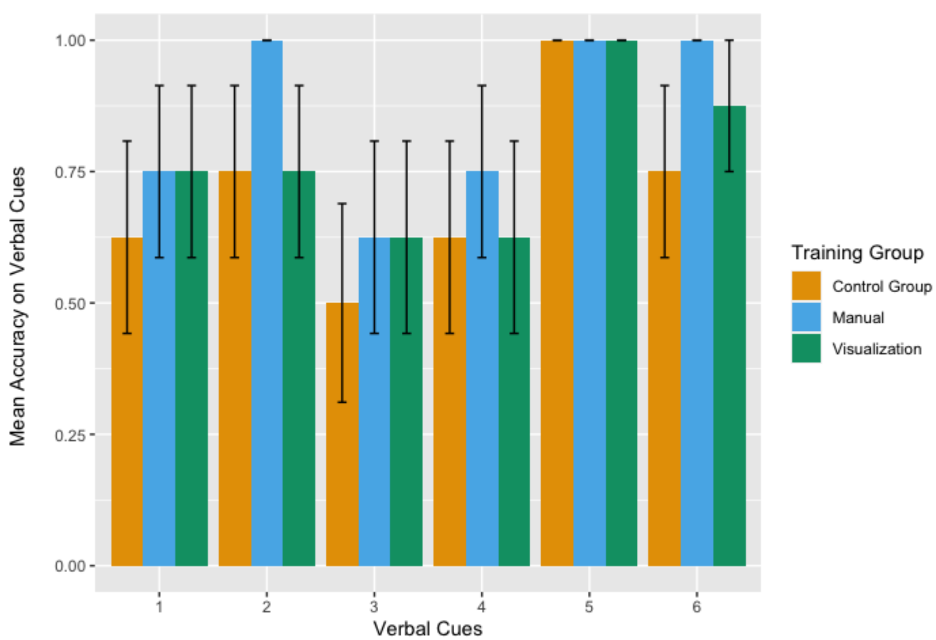

Figure 3.39: Verbal response accuracy

3.2.4 Accuracy of Manual Responses

The figure below described the average accuracy of drivers' manual responses to instruction throughout the drive. The Visualization group had a higher mean accuracy of manual responses (M = 0.775) than the Sham (0.75) or the Text-Based groups (M = 0.725), although a one-way ANOVA revealed no main effect of the training group on the scores (F = 0.2561; p = 0.776; η2 = 0.02).

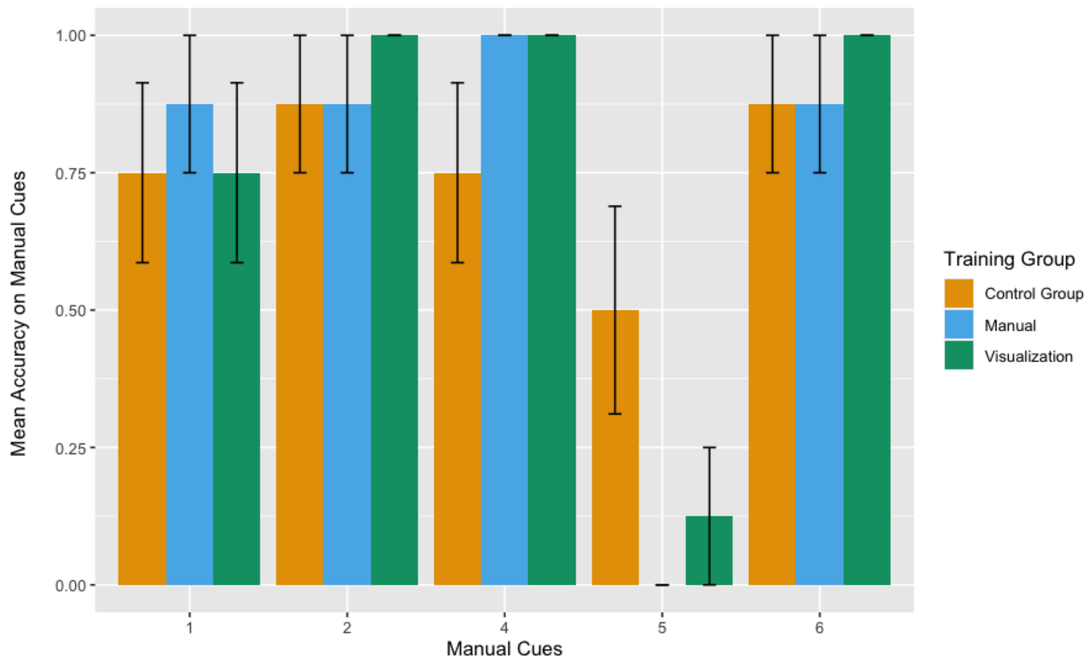

Figure 3.40: Manual response accuracy

3.2.5 Response Times for Manual Responses

Based on average scores, the control group had a higher mean time (M = 4.18s) as compared to the Visualization (M = 4.00) or Text-Based (M = 3.83s) groups. This indicates that they took longer to respond than the other two groups. A one-way ANOVA conducted indicated no main effect of the training group on the response times (F = 0.2821; p = 0.757; η2 = 0.03).

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4.0 Implementation and Technology Transfer

The findings of this research study may support or directly lead to the implementation of new standards or practices for driver training, licensing, and/or vehicle registration and inspection. The findings may also have implications for MassDOT's Highway Division, and local/state law enforcement and first responders.

As mentioned in the previous sections, one critical finding from this program of research, in terms of lessons learned, is the identification of the challenges of estimating what proportion of the commonwealth's vehicle fleet comprises of ADAS-equipped vehicles. The originally proposed method of identifying ADAS capabilities/features using vehicle's VINs was unsuccessful due to the opacity of the VIN with respect to ADAS features. Multiple conversations with stakeholders including members of the Auto Alliance and insurance companies ultimately led to the recognition that this is a recognized issue in the industry, and a non-trivial one. As an alternative, this researcher proposes a methodology for estimating ADAS prevalence by using vehicle registration data including year, make, model, and trim, and cross referencing it with a database created from publicly available information about vehicle features associated with model years and trim. While this is a potentially viable solution it is not an elegant or an efficient one. Vehicle models and trims and offerings change constantly, and updating and cross referencing such a database may not be sustainable. An important learning from this is thus to have a more concerted effort, perhaps as a joint effort between automakers and policy makers, to make information about vehicle's ADAS features more transparent.

This research also designed and evaluated a pilot approach to improving awareness of vehicle technologies via targeted training. There are significant translational opportunities for this particular outcome of this project, especially in terms of making this training available to specific stakeholders including driver education schools, vehicle registration and licensing authorities, and law enforcement authorities. Other potential recipients of this information for potential deployment of training could also include vehicle dealerships. This outcome holds most promise for potential technology transfer.

Such technology transfer can be implemented via a structured framework designed not just to deploy the interventional material but also to evaluate efficacy of the material and the efficacy of the process. This can include either a large, randomized control trial that includes bigger jurisdictions (counties, RMV zones, etc.) or multiple smaller multi-site trials conducted at multiple locations to ensure even representation of drivers as well as educators (trainers) and law enforcement officers. Another important dimension to be considered is the inclusion of different age groups for drivers, with a specific focus on newly licensed teen drivers, and another focus on senior drivers.

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5.0 Conclusions

Advanced Driver Assistance Systems are complex technically, functionally, and with respect to a driver's needed interaction with the systems. So, if a driver does not clearly or completely understand the functionality, capability, or limitations of the system, then the lack of clarity on driver responsibilities can increase the risk of using the system. Additionally, different automobile manufacturers have implemented different types and designs of ADAS, particularly in terms of the Human Machine Interface (HMI) and driver monitoring systems. Herein lie the critical human factor problems. These systems may elicit various unintended negative driving behaviors due to drivers' lack of a clear understanding of the systems. These behaviors could range from operational or control errors, to distraction, and to even more critical errors such as over-reliance on the systems and loss of vigilance. While some motor vehicle models may incorporate sophisticated driver monitoring technologies such as in-vehicle cameras to prevent driver misuse or error, other vehicle makes, and models have only rudimentary driver monitoring systems (such as steering sensors) or none at all.

The survey study was conducted to identify usage of ADAS, specifically, ACC and LKA among the drivers of Massachusetts. There were many similarities in the responses of ACC and LKA experienced users on their usage and training of these ADAS. The LKA survey of inexperienced users had the highest number of responses, followed by the ACC survey of inexperienced users. This indicates that although these features are being made available on a larger scale, most drivers do not have access to LKA in contrast to ACC. Almost half of the participants using ACC also used LKA. Most participants reported not receiving any training at the time of buying their car, and out of experienced LKA drivers, only 33% received training. This indicates that participants initially started using these cars without having complete or any knowledge of the safety systems available to them. Of the drivers that were offered training and completed the training, most reported being unsatisfied with the level of training provided.

Experienced users, in general, stated that they expected their understanding of ACC/LKA would increase with use and were confident of being skilled at using the system easily. Almost all participants were confident that their knowledge of the systems would improve with use. Participants were also certain that with an improved understanding of the system, they would be able to explain the system and its usage to others clearly. Over 50% of the experienced drivers trusted the system, although most also stated that they would not be distracted or engage in secondary tasks while driving with either system. Most of participants, experienced and inexperienced, did not strongly feel that LKA would increase safety, whereas the perceptions towards ACC remained inconclusive.

The simulator study aimed to identify an effective method of training and education of drivers. We used three different training methods and measured knowledge, understanding and trust towards ACC to quantify the change after training. The results demonstrate that there is an overall increase in knowledge and trust in ACC after training. Compared to participants of the control group (Group S), participants receiving relevant training material show improvement in knowledge, understanding and trust in ACC. The outcomes of this simulator study reinforce the importance of training in helping drivers create accurate mental models of ADAS technologies.

An outcome of the simulator study highlights the differences between the control and the experimental training methods, but not between the two experimental groups. The aim in developing the visualization method was to present information taken from user manuals in a manner that is less complicated and free of unnecessary text. The researchers expected the visualization method to be significantly better than the user manual method because the major drawback of referring to user manuals— sifting through dense owner's manuals to find relevant sections —was avoided. However, based on the results, both experimental groups were better than the control, but with no significant difference between them. One possible explanation of this result is that the text-based method, although derived from a user manual, did not overtly show the drawbacks of reading from a user manual. This also leads us to speculate that the text- based method could be provided as a quicker and more effective method of understanding more about ADAS technologies.

A secondary outcome of this study also highlights the similarities in drivers' responses to probing questions regarding state of ACC, despite there being significant differences in survey responses regarding knowledge between control and experimental groups. A potential explanation for this result could be that the questions asked were relatively straightforward, and a few simple glances toward the dashboard or information console would provide the answers. To properly measure real time knowledge, questions more specific and sensitive should be used.

This outcome is also reflected in drivers' responses to manual cues to instructions and their response times to complete the action. Although there was a significant difference in survey measures, this did not translate to improved responses and response times for experimental groups. It may be that the dependent variables in this study are not be the most sensitive or suitable for measuring mental models. Further work in this domain may focus more on noninvasively and efficiently measuring drivers' mental models.

If used properly by well-informed and attentive operators, advanced driver assistance systems have the potential to improve roadway safety for all road users. Many new passenger vehicles already include such systems, and automakers are anticipating that more advanced and fully automated systems may become available commercially within the next few years.

This research effort is therefore a critical first step to support the Commonwealth's understanding of how drivers are actively using ADAS technologies today, and the associated safety implications for roadway users. Level 2 systems, which require a human driver to actively "monitor the driving environment" and be prepared to take over the driving tasks, are not widely available yet, and their efficacy and safety should not be taken for granted. This research effort will assist MassDOT in documenting and understanding the challenges associated with Level 1 and Level 2 ADAS-equipped vehicles and how any identified safety risks may be mitigated through improvements to driver training, licensing, and/or vehicle registration and inspection processes.

The findings of this research study may support or directly lead to the implementation of new standards or practices for driver training, licensing, and/or vehicle registration and inspection. The findings may also have implications for MassDOT's Highway Division, local/state law enforcement and first responders, and ADAS/ADS technology developers.

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7.0 Appendices

7.1 Appendix A: ADAS Technology and Descriptions

ADAS Technology Name	What does it do? (NHTSA, MyCarDoesWhat, AAA)
Adaptive Cruise Control	Controls acceleration and/or braking to maintain a prescribed distance between it and a vehicle in front. May be able to come to a stop and continue.
Adaptive Headlights	Adapts to changing roadway conditions—such as curves—to better help illuminate the roadway along your path.
Anti-lock Braking Systems	Helps prevent wheels from locking up—possibly allowing the driver to steer to safety.
Automatic Crash Notification	Detects either that an air bag has deployed or that there's been a dramatic and sudden deceleration and connects to an emergency operator. Also sends basic information and location about the car, without any passenger or driver input.
Automatic Emergency Braking	Senses slow or stopped traffic ahead and urgently applies the brakes if the driver fails to respond.
Automatic Emergency Steering	Detects potential collision and automatically controls steering to avoid or lessen the severity of impact.
Automatic High Beams	Deactivates or orients headlamp beams automatically based on lighting, surroundings, and traffic.
Automatic Parallel Parking	Helps guide you into a parallel parking spot after searching and finding a viable option. Does not brake or monitor surroundings.
Back Up Warning	Alerts you of objects behind your car as you back out of spaces like driveways or parking spots.
Back Up Camera	Shows a wide view behind your car while in reverse, even at night.
Bicycle Detection	Alerts you of a potential collision with a bicyclist ahead.
Blind Spot Warning	Detects vehicles to rear in adjacent lanes while driving and alerts driver to their presence.
Brake Assist	Detects driver slamming the brakes and applies maximum force to the brakes to help make sure the car stops as quickly as possible.
Cruise Control	Allows you to maintain a constant vehicle speed without keeping your foot on the accelerator pedal
Curve Speed Warning	Uses GPS to warn driver when you're approaching a curve or exit on the road too quickly.
Driver Drowsiness Monitoring Systems	Alert you if you're drowsy and suggest you take a break when it's safe to do so.
Driver Monitoring Systems	Alert the driver when signs of drowsiness or distraction are detected.
Dynamic Brake Support and Crash Imminent Braking	Supplement the driver's braking in an effort to avoid the crash. If the driver does not take any action to avoid the crash, DBS and CIB automatically apply the vehicle's brakes to slow or stop the car, avoiding the crash or reducing its severity.
Dynamic Driving Assistance	Controls vehicle acceleration, braking, and steering. SAE standard definition of L2 Autonomous systems outlines this functionality.
Electronic Stability Control	Helps prevent drivers from losing control of the direction of your car due to a spin out or plow out. When effective, this also significantly reduces your risk of being in a rollover – one of the most dangerous types of single-vehicle crashes.
Forward Automatic Emergency Braking	Detects potential collisions while traveling forward and automatically applies brakes to avoid or lessen the severity of impact.
Forward Collision Warning	Detects impending collision while traveling forward and alerts driver.
Fully Automated Parking Assistance	Controls acceleration, braking, steering, and shifting during parking. May be capable of parallel and / or perpendicular parking.
High Speed Alert	Coordinates the car's position, via GPS, with a database of speed limit information to alert drivers if they're speeding.

Highway Pilot	Maintains vehicle’s lane position and following distance by automatically braking and accelerating as needed.
Hill Descent Control or Assist	Helps keep you at a steady speed when driving down a hill or other decline.
Hill Start Assist	Helps prevent roll-back when starting up again from a stopped position on an incline.
Intersection Assistant	Warns drivers of vehicles approaching from the sides at intersections, highway exits, or car parks and brakes the car if driver does not brake in time.
Lane Centering Assist	May gently steer you back into your lane if you begin to drift out of it.
Lane Departure Warning	Monitors vehicle's position within driving lane and alerts driver as the vehicle approaches or crosses lane markers.
Lane Keeping Assist	Controls steering to maintain vehicle within driving lane. May prevent vehicle from departing lane or continually center vehicle.
Night Vision	Aids driver vision at night by projecting enhanced images on instrument cluster or heads-up display.
Obstacle Detection	Uses sensors mounted in the front and or rear bumpers to determine the distance between the car and nearby objects. In some versions, it will brake the car automatically. Does not work in low visibility weather conditions.
Parking Obstruction Warning	Detects obstructions in close proximity to vehicle during parking maneuvers.
Parking Sensors	Alert you to the position of objects around your car as you park.
Pedestrian Automatic Emergency Braking	Provides automatic braking for vehicles when pedestrians are in front of the vehicle and the driver has not acted to avoid a crash.
Pedestrian Detection	Detects pedestrians in front of vehicle and alerts driver to their presence.
Push Start Button	Simplifies turning your car on and off using a key fob unique to you.
Rain Sensor	Detects rainfall and activates windshield wiper
Rear Cross Traffic Warning	Detects vehicles approaching from side and rear of vehicles while traveling in reverse and alerts driver.
Remote Parking	System parks vehicle without driver being physically present inside the vehicle. Automatically controls acceleration, braking, steering, and shifting.
Reverse Automatic Emergency Braking	Detects potential collision while traveling in reverse and automatically applies brakes to avoid or lessen the severity of impact.
Semi Automated Parking Assistance	Controls steering during parking. Does not accelerate, brake, or change gear position. May be capable of parallel and/or perpendicular parking.
Sideview Camera	Shows you an expanded view of a lane beside you when you use your turn signal or when you activate the feature manually.
Surround View Camera	Uses cameras located around vehicle to present view of surroundings
Temperature Warnings	Alert you when the outside temperature is detected to be at or below freezing, which can impact the conditions of roadways.
Tire Pressure Monitoring	Warns you if your tires are under- or over-inflated, helping increase your fuel economy and even potentially preventing a tire blowout. May not specify which tire needs attention.
Traction Control System	Helps your wheels gain traction on slippery surfaces.
Traffic Jam Assist	Automatically accelerates and brakes the vehicle with the flow of traffic and keeps vehicle between lane markings—even in curves.
Trailer Assistance	Assists driver during backing maneuvers with a trailer attached.
Vibrating Seat Warnings	Vibrate the driver’s seat bottom cushion if a crash risk is detected. Helps hearing impaired drivers.

7.2 Appendix B: ADAS Technologies by Manufacturer

Manufacturer	Technology Name Given by Manufacturer	Safety Features Bundle Name	Categorization (Lateral, Longitudinal)	Alert/Warning or Control
Acura	Collision Mitigation Braking System (CMBS)	Acura Watch	Longitudinal	C
Acura	Forward Collision Warning System		Longitudinal	A
Acura	Adaptive Cruise Control with Low Speed Follow	Acura Watch	Longitudinal	C
Acura	Lane Keeping Assist System	Acura Watch	Lateral	C
Acura	Road Departure Mitigation (RDM) System	Acura Watch	Lateral	C
Acura	Blind Spot Information System		Lateral	A
Acura	Cross Traffic Monitor			A
Audi	Audi Pre Sense® Basic and City			A
Audi	Park Assist			C
Audi	Audi Adaptive Cruise Control w/Stop & Go		Longitudinal	C
Audi	Audi Side Assist			C
Audi	Rear Cross Traffic Assist			A
Audi	Audi Active Lane Assist		Lateral	C
BMW	Active Cruise Control with Stop & Go Function ACC	BMW ConnectedDrive	Longitudinal	C
BMW	Emergency Braking System		Longitudinal	C
BMW	Steering and Lane Guidance Assist		Lateral	C
BMW	Distance Control		Longitudinal	C
BMW	Lane-Change Warning & Lane-Change Assist		Lateral	A
Buick	Automatic Emergency Braking	Standard	Longitudinal	C
Buick	Enhanced Automatic Emergency Braking	Added on Feature	Longitudinal	C
Buick	Forward Collision Alert			A
Buick	Front Pedestrian Braking			C
Buick	Lane Change Alert with Side Blind Zone Alert		Lateral	A
Buick	Lane Keep Assist with Lane Departure Warning		Lateral	C
Buick	Rear Cross Traffic Alert			A
Cadillac	Adaptive Cruise Control - Advanced		Longitudinal	C
Cadillac	Automatic Emergency Braking		Longitudinal	C
Cadillac	Automatic Parking Assist with Braking.			C
Cadillac	Enhanced Automatic Emergency Braking	Added On	Longitudinal	C
Cadillac	Forward Collision Alert			A
Cadillac	Front Pedestrian Braking			C
Cadillac	Lane Change Alert with Side Blind Zone Alert		Lateral	A
Cadillac	Lane Keep Assist with Lane Departure Warning		Lateral	C

Manufacturer	Technology Name Given by Manufacturer	Safety Features Bundle Name	Categorization (Lateral, Longitudinal)	Alert/Warning or Control
Cadillac	Rear Cross Traffic Alert			A
Cadillac	Rear Pedestrian Alert			C
Cadillac	Reverse Automatic Braking			C
Cadillac	Super Cruise			C
Chevrolet	Automatic Emergency Braking		Longitudinal	C
Chevrolet	Forward Collision Alert			A
Chevrolet	Lane Change Alert with Side Blind Zone Alert			A
Chevrolet	Lane Departure Warning		Lateral	A
Chevrolet	Rear Cross Traffic Alert			A
Chrysler	Adaptive Cruise Control with Stop & Go	Advanced SafetyTec Group	Longitudinal	C
Chrysler	Blind Spot & RR Cross Path Detection	Advanced SafetyTec Group		A
Chrysler	Full Speed Forward Collision Warning Plus	Advanced SafetyTec Group		A
Chrysler	Lane Departure Warning Plus	Advanced SafetyTec Group	Lateral	A
Chrysler	LaneSense® Lane Departure Warning with Lane Keep Assist		Lateral	C
Chrysler	Parallel and Perpendicular Park Assist with Stop	Advanced SafetyTec Group		C
Dodge	Full-Speed Forward Collision Warning with Active Braking	Technology Group		A
Dodge	LANESENSE® Lane Departure Warning with Lane Keep Assist	Technology Group	Lateral	C
Dodge	Blind-Spot Indicator with Memory/Power/Heat Mirrors	Plus Group/Driver Convenience Group	Lateral	A
Dodge	Blind-Spot and Cross-Path Detection	Plus Group/Driver Convenience Group		A
Dodge	Rear Cross Path Detection	Collision Mitigation		A
Dodge	Available Adaptive Cruise Control with Stop	Technology Group	Longitudinal	C
Fiat	Full-Speed Forward Collision Warning with Active Braking			A
Fiat	Blind Spot Monitoring System		Lateral	A
Fiat	Rear Cross Path Detection			A
Fiat	LaneSense® Lane Departure Warning with Lane Keep Assist		Lateral	C
Fiat	Adaptive Cruise Control with Stop		Longitudinal	C
Ford	Pre Collision Alert with Emergency Braking	Ford Co-Pilot 360		C
Ford	BLIS with Cross Traffic Alert	Ford Co-Pilot 360	Lateral	A
Ford	Active Park Assist 2.0	Ford Co-Pilot 360		C

Manufacturer	Technology Name Given by Manufacturer	Safety Features Bundle Name	Categorization (Lateral, Longitudinal)	Alert/Warning or Control
Ford	Adaptive Cruise Control with Stop & Go	Ford Co-Pilot 360	Longitudinal	C
Ford	Lane Keeping System	Ford Co-Pilot 360	Lateral	C
GMC	Front Pedestrian Braking		Longitudinal	C
GMC	Forward Collision Alert			A
GMC	Lane Departure Warning		Lateral	A
GMC	Lane Keep Assist with Lane Departure Warning		Lateral	C
Honda	Collision Mitigation Braking System	Honda Sensing		C
Honda	Road Departure Mitigation System	Honda Sensing	Lateral	C
Honda	Adaptive Cruise Control	Honda Sensing	Longitudinal	C
Honda	Lane Keeping Assist System (LKAS)	Honda Sensing	Lateral	C
Honda	Blind Spot Information System	Honda Sensing	Lateral	A
Honda	Cross Traffic Monitor	Honda Sensing		A
Hyundai	Blind-Spot Collision-Avoidance Assist (BCA)			A
Hyundai	Rear Cross-Traffic Collision-Avoidance Assist (RCCA)			A
Hyundai	Forward Collision-Avoidance Assist with Pedestrian Detection (FCA-Ped)			A
Hyundai	Smart Cruise Control (SCC) with Stop & Go		Longitudinal	C
Hyundai	Lane Following Assist (LFA)			C
Hyundai	Lane Keeping Assist (LKA)		Lateral	C
Hyundai	Highway Drive Assist (HDA)	Premium Package	Lateral, Longitudinal	C
Infiniti	Forward Emergency Braking with Pedestrian Detection			C
Infiniti	Blind Spot Warning			A
Infiniti	Steering Assist		Lateral	C
Infiniti	Advanced Intelligent Cruise Control		Longitudinal	C
Infiniti	Lane Departure Warning		Lateral	A
Infiniti	Lane Departure Prevention		Lateral	C
Infiniti	Distance Control Assist		Longitudinal	C
Infiniti	PROPilot Assist	Luxe Package	Longitudinal	C
Jeep	Blind Spot Monitoring System (BSM)		Lateral	A
Jeep	LANESENSE® Lane Departure Warning with Lane Keep Assist			C
Jeep	Rear Cross Path (RCP)			A
Jeep	Forward Collision Warning w/ Mitigation (FCW)			A
Kia	Smart Cruise Control w/ Stop & Go		Longitudinal	C
Kia	Blind-Spot Collision Avoidance Assist-Rear		Lateral	C
Kia	Blind-Spot Collision Warning (BSW)	Kia DRIVE WiSE	Lateral	A
Kia	Rear Cross-Traffic Collision-Avoidance			A
Kia	Rear Cross Traffic Alert (RCTA)	Kia DRIVE WiSE		A

Manufacturer	Technology Name Given by Manufacturer	Safety Features Bundle Name	Categorization (Lateral, Longitudinal)	Alert/Warning or Control
Kia	Forward Collision-Avoidance Assistance with Pedestrian Detection			A
Kia	Forward Collision-Avoidance Assist-Junction Turning			A
Kia	Forward Collision Warning (FCW)	Kia DRIVE WiSE		A
Kia	Lane Departure Warning (LDW)	Kia DRIVE WiSE	Lateral	A
Kia	Lane Keeping Assist (LKA)	Kia DRIVE WiSE	Lateral	C
Kia	Lane Following Assist (LFA)	Kia DRIVE WiSE		C
Kia	Highway Driving Assist (HDA)	Kia DRIVE WiSE	Lateral, Longitudinal	C
Lexus	Blind Spot Monitor with Rear Cross-Traffic Alert and Intuitive Parking Assist with Auto Braking		Lateral	C
Lexus	Blind Spot Monitor with Rear Cross-Traffic Alert and Intuitive Parking Assist with Auto Braking, Rear Pedestrian Detection and Panoramic View Monitor		Lateral	C
Lexus	Intuitive Parking Assist with Auto Braking			C
Lincoln	Adaptive Cruise Control with Lane Centering		Lateral, Longitudinal	C
Lincoln	Adaptive Cruise Control with Stop and Go		Longitudinal	C
Lincoln	Intelligent Adaptive Cruise Control		Longitudinal	C
Lincoln	Lane Keeping System		Lateral	C
Lincoln	Blind Spot Information System		Lateral	A
Lincoln	Cross Traffic Alert		Warning System	A
Lincoln	Pre-Collision Assist with Pedestrian Detection			A
Lincoln	Active Park Assist			C
Land Rover	Adaptive Cruise Control		Longitudinal	C
Land Rover	Steering Assist		Lateral	C
Land Rover	Forward Alert			A
Land Rover	Autonomous Emergency Braking (AEB)		Longitudinal	C
Land Rover	Advanced Emergency Brake Assist (AEBA)		Longitudinal	C
Land Rover	Blind Spot Monitor System (BSM)		Lateral	A
Land Rover	Blind Spot Assist System		Lateral	C
Land Rover	Reverse Traffic Detection			A
Land Rover	Lane Departure Warning System		Lateral	A
Land Rover	Lane Keep Assist (LKA)		Lateral	C
Lexus	Pre-Collision System with Pedestrian Detection	Lexus Safety System+ 2.0		C
Lexus	Lane Tracing Assist	Lexus Safety System+ 2.0	Lateral	C

Manufacturer	Technology Name Given by Manufacturer	Safety Features Bundle Name	Categorization (Lateral, Longitudinal)	Alert/Warning or Control
Lexus	Lane Departure Alert with Steering Assist	Lexus Safety System+ 2.0	Lateral	C
Lexus	All-Speed Dynamic Radar Cruise Control	Lexus Safety System+ 2.0	Longitudinal	C
Lexus	Blind Spot Monitor with Rear Cross-Traffic Alert		Lateral	A
Mazda	Lane-Keep Assist System (LAS)	Mazda i-ACTIVSENSE	Lateral	C
Mazda	Lane Departure Avoidance	Mazda i-ACTIVSENSE	Lateral	A
Mazda	Lane Trace	Mazda i-ACTIVSENSE	Lateral	C
Mazda	Blind Spot Monitoring (BMS)	Mazda i-ACTIVSENSE	Lateral	A
Mazda	Rear Cross Traffic Alert (RCTA)	Mazda i-ACTIVSENSE		A
Mazda	Mazda Radar Cruise Control (MRCC)	Mazda i-ACTIVSENSE	Longitudinal	C
Mazda	Lane Departure Warning System (LDWS)	Mazda i-ACTIVSENSE	Lateral	A
Mazda	Forward Obstruction Warning (FOW)	Mazda i-ACTIVSENSE		A
Mercedes Benz	Blind Spot Assist		Lateral	A
Mercedes Benz	Active Parking Assist			C
Mercedes Benz	Active Distance Assist DISTRONIC		Longitudinal	C
Mercedes Benz	Active Steering Assist		Lateral	C
Mercedes Benz	Active Blind Spot Assist		Lateral	A
Mercedes Benz	Active Lane Keeping Assist		Lateral	C
Mercedes Benz	Active Brake Assist with Cross-Traffic Function			C
Mercedes Benz	Active Stop-and-Go Assist		Lateral, Longitudinal	C
Mini	Daytime pedestrian collision mitigation			A
Mitsubishi	Forward Collision Mitigation with Pedestrian Detection			A
Mitsubishi	Lane Departure Warning			A
Mitsubishi	Adaptive Cruise Control		Longitudinal	C
Mitsubishi	Rear Cross Traffic Alert			A
Mitsubishi	Blind Spot Warning and Lane Change Assist		Lateral	A
Nissan	ProPILOT	ProPILOT	Lateral, Longitudinal	C
Nissan	Rear Automatic Breaking		Longitudinal	A
Nissan	Lane Departure Warning		Lateral	A
Nissan	Blind Spot Warning		Lateral	A
Nissan	Intelligent Blind Spot Intervention (I-BSI)		Lateral	C
Nissan	Intelligent Lane Intervention (LI)		Lateral	C
Nissan	Rear Cross Traffic Alert			A
Nissan	Intelligent Emergency Braking			C
Ram Trucks	Blind Spot Monitoring (BSM)		Lateral	A

Manufacturer	Technology Name Given by Manufacturer	Safety Features Bundle Name	Categorization (Lateral, Longitudinal)	Alert/Warning or Control
Ram Trucks	Forward Collision Warning with Mitigation			A
Subaru	Advanced Adaptive Cruise Control	EyeSight	Longitudinal	C
Subaru	Lane Centering Function	EyeSight	Lateral	C
Subaru	Lane Departure Prevention Function	EyeSight	Lateral	C
Subaru	Rear Cross-Traffic Alert			A
Subaru	Blind-Spot Detection and Lane Change Assist			C
Subaru	Lane Departure Warning	EyeSight	Lateral	A
Tesla	Autosteer+	Autopilot		C
Tesla	Lane Assist	Autopilot	Lateral	C
Tesla	Lane Departure Avoidance	Autopilot	Lateral	C
Tesla	Emergency Lane Departure Avoidance	Autopilot	Lateral	C
Tesla	Blind Spot Collision Warning Chime	Autopilot	Lateral	A
Tesla	Forward Collision Warning	Autopilot		A
Tesla	Automatic Emergency Braking	Autopilot	Longitudinal	C
Tesla	Traffic-Aware Cruise Control	Autopilot	Longitudinal	C
Tesla	Autosteer	Autopilot	Longitudinal	C
Tesla	Auto Lane Change	Autopilot	Lateral	C
Tesla	Autopark	Autopilot		C
Toyota	Pre-Collision System with Pedestrian Detection (PCS w/PD)	Toyota Safety Sense		C
Toyota	Dynamic Radar Cruise Control (DRCC)	Toyota Safety Sense	Longitudinal	C
Toyota	Lane centering function	Toyota Safety Sense	Lateral	C
Toyota	LTA (Lane Tracing Assist)	Toyota Safety Sense	Lateral	C
Toyota	Lane Departure Alert function	Toyota Safety Sense	Lateral	A
Toyota	Steering Assist function	Toyota Safety Sense	Lateral	C
Toyota	BSM (Blind Spot Monitor)	Toyota Safety Sense	Lateral	A
Toyota	RCTA (Rear Cross Traffic Alert)	Toyota Safety Sense		A
Toyota	Parking Support Brake function (rear-crossing vehicles)	Toyota Safety Sense	Longitudinal	A
Toyota	Intelligent Clearance Sonar (ICS) with Intelligent Parking Assist (IPA)	Toyota Safety Sense		C
Volkswagen	Travel Assist	IQ.DRIVE - Standard	Lateral, Longitudinal	C
Volkswagen	Lane Assist	IQ.DRIVE - Standard	Lateral	C
Volkswagen	Front Assist	IQ.DRIVE - Standard		C
Volkswagen	Park Assist			C
Volkswagen	Adaptive Cruise Control	IQ.DRIVE - Standard	Longitudinal	C
Volkswagen	Blind Spot Monitor (Side Assist)	IQ.DRIVE - Standard	Lateral	A

Manufacturer	Technology Name Given by Manufacturer	Safety Features Bundle Name	Categorization (Lateral, Longitudinal)	Alert/Warning or Control
Volkswagen	Rear Traffic Alert	IQ.DRIVE - Standard		A
Volkswagen	Forward Collision Warning	Added On		A
Volkswagen	Autonomous Emergency Braking (Front Assist)	Added On		C
Volvo	Adaptive Cruise Control	Pilot Assist	Longitudinal	C
Volvo	Pilot Assist	Pilot Assist	Longitudinal	C
Volvo	Steering assistance	Pilot Assist		C
Volvo	Collision risk warning from driver support	Pilot Assist		A
Volvo	Lane Keeping Aid	Pilot Assist	Lateral	C
Volvo	Blind Spot Information (BLIS)	Pilot Assist	Lateral	A
Volvo	Cross Traffic Alert	Pilot Assist		A
Volvo	Park Assist Pilot	Pilot Assist		C

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7.3 Appendix C: Driver Monitoring Systems

Manufacturer	Technology Name	What does it do?	Safety Bundle/Suite
Aura	Drowsiness Detection Technology	This system can monitor a vehicle's movements and detect a driver who's dozing off. The sleepy driver is given a warning sound and a coffee cup graphic. Some systems alert the driver by jiggling the seat.	
BMW	Attention Assist	This analyzes driving behavior in the first few minutes of your ride and assesses your personal driving techniques, identifies certain steering corrections that indicate drowsiness and fatigue while considering external factors, including road conditions, crosswinds, and driver's interaction with vehicle controls. Sends an alert that suggests the driver take a break from driving if it determines that change in driving behavior is due to fatigue.	
Cadillac	Driver Attention Monitor	When Super Cruise is engaged, the Driver Attention Camera, located on top of the steering column, focuses on your attention to the road ahead. It works with infrared lights to track head position to determine where you are looking. In the event of an unresponsive driver, the vehicle will come to a controlled stop, activate the hazard lights, and contact OnStar Emergency Services.	
Honda	Driver Attention Monitor	This continually monitors and assesses driver behavior behind the wheel to help determine if the driver is becoming inattentive—and then if so, to warn the driver to take a break. The system uses input from the Electric Power Steering (EPS) to measure both the frequency and severity of the driver's steering inputs to gauge their level of awareness with four gradients.	
Ford	Lane Keeping System	The system has three modes: Lane-Keeping Aid applies steering torque to direct you back to the center of the lane, Lane-Keeping Alert warns you through steering wheel vibrations that simulate driving over a rumble strip, and Driver Alert sends out warnings in the message center when it detects repeated lane drifts—a reminder to pull over and take a break.	Ford Co-Piolpt 360
Hyundai	Driver Attention Warning	This helps detect patterns of fatigue or distraction. This feature alerts the driver with an audible cue and pop-up message,notifying the driver of possible fatigue and suggesting a break from driving.	
Jaguar	Driver Condition Monitor	Driver Condition Monitor detects if the driver is starting to feel drowsy and gives an early warning when the driver needs to take a break.	Incontrol Driver Assistance
Kia	Driver Attention Warning (DAW)	DAW is designed to alert the driver if it detects certain inattentive driving and, in certain situations, can give a warning signal to take a break from driving. A message, "Consider taking a break," appears on the LCD display and a warning sounds to suggest the driver to take a break when the driver's attention level is below one bar	
Land Rover	Driver Condition	The driver condition monitor feature evaluates driving technique for signs of fatigue. The instrument panel displays a white icon if it is determined that the driver is fatigued. The instrument panel also emits a chime.	
Lincoln	Driver Alert System	If the system detects that your reduced driving alertness is below a certain threshold, the system alerts you using a tone and a message in the cluster display.	

Manufacturer	Technology Name	What does it do?	Safety Bundle/Suite
Mazda	Driver Attention Alert	The system comes into play at speeds above 65 km/h and begins to “learn” the driver’s habits, watching inputs and the vehicle’s movements in the early stages before fatigue is a factor. Later, if the system detects changes in vehicle behavior that suggest the driver may be losing concentration, it will suggest a rest stop by sounding a chime and displaying a warning in the Multi-Information Display	i-ACTIVSENSE
Mercedes Benz	ATTENTION ASSIST®	This continuously monitors up to 70 parameters of driving behavior, and can automatically alert the driver with both visual and audible warnings if it detects signs of drowsiness on long trips.	
MINI	Fatigue alert	The system can detect decreasing alertness or fatigue of the driver during long, monotonous trips, for instance on highways. In this situation, it is recommended that the driver take a break	
Nissan	Intelligent Driver Alertness	While driving at a high speed (60 kph/37 mph or higher), if the system determines that driver attention is reduced based on the steering behavior, the system generates an audible chime and a message to prompt the driver to take a break.	
Suburu	EyeSight Assist Monitor	The operating status of the EyeSight system is projected on the lower part of the windshield. This allows the driver to remain aware of warnings and displayed information without taking their eyes off the surrounding driving environment	EyeSight
Toyota	Vehicle sway warning function	When the system determines that the vehicle is swaying while the vehicle sway warning function is operating, a buzzer sounds and a warning message urging the driver to rest and the symbol shown in the illustration (Coffee cup) are simultaneously displayed on the multi-informational display.	Toyota Saftey Sense
Volkswagen	Emergency Assist	As soon as the sensors detect no steering, braking or acceleration activity on the part of the driver, the system activates various escalation stages. Initially, the system attempts to wake the driver by steering jerks and finally an emergency stop is initiated. The hazard warning flashers are activated automatically and the car completes some slight steering maneuvers to draw the attention of other road users to the hazardous situation. ACC prevents collisions with the traffic ahead. Finally, the system brakes the vehicle continuously to a standstill.	IQ.DRIVE – Standard
Volvo	Driver Alert Control	The Driver Alert Control (DAC) function is designed to help alert the driver to erratic behavior, e.g. if the driver is distracted or showing signs of fatigue.	

7.4 Appendix D: Driver Survey

Eligible Participants—Inexperienced Drivers will receive this survey after Screening Survey and Informed Consent.

Inexperienced Drivers

Adaptive Cruise Control (ACC)

On the following screens, you will be given descriptions of different types of advanced vehicle safety technologies. Please read the technology descriptions carefully to evaluate whether your vehicle is equipped with that technology.

1st screen: ACC description—"Adaptive Cruise Control (ACC) is a technology that automatically keeps your vehicle speed at a speed that you have pre-selected and also automatically follows another vehicle at a distance that you have pre-selected."

Q 1. To the best of your knowledge, is your vehicle equipped to use **ACC** while driving?

1. Yes 2. No

(If YES, then go to Q C1—Survey for Experienced Drivers If NO, skip to Q A1—Survey for Inexperienced Drivers)

Q A 1. How often do you use Cruise Control while driving?

1. Frequently 2. Often 3. Sometimes 4. Rarely 5. Never

Q A. 2. If your vehicle had ACC would you use this system while driving?

1. Yes 2. No

Q A 3. How often would you use the ACC?

1. Frequently 2. Often 3. Sometimes 4. Rarely 5. Never

(Display this Question if answered NEVER for Q A 3)

Q A 3.1. You indicated that you would not use your ACC system for highway and in-town driving. Please check all that apply to indicate why you would not use the technology.

1. I don't understand it.
2. I don't trust it.
3. I think it is dangerous.
4. It makes me nervous/anxious.
5. It is annoying. It doesn't work.
6. It is distracting.
7. I don't need/want it.

Q A 4. On a scale of 1 = Strongly Disagree to 5 = Strongly Agree how much do you agree with each statement:

4. 1 I would be comfortable looking away from the road or making a phone call, sending a text, etc. when my ACC is activated
4. 2 I would trust the ACC system for in-town or highway driving.
4. 3 I would feel apprehensive about using the ACC system for in-town or highway driving.
4. 4 I would expect that using the system would increase my driving safety

Q A 5. On a scale of 1 = Strongly Disagree to 5 = Strongly Agree how much do you agree with each statement:

5. 1 I think the ACC system is annoying for driving on the highway and in-town driving.
5. 2 I think the ACC system reduces stress during highway and in-town driving.
5. 3 I think using the ACC in-town system for highway and in-town driving requires a lot of mental effort.
5. 4 I think using the ACC highway system for highway and in-town driving is distracting.
5. 5 I think using the ACC highway system for highway and in-town driving is easy to learn.
5. 6 I think using the ACC system for highway/interstate or in-town driving makes me feel safer.
5. 7 I think using the ACC in-town system for highway and in-town driving increases the risk of a crash.

Q A 6. On a scale of 1 = Strongly Disagree to 5 = Strongly Agree how much do you agree with these statements:

I am willing to use the system…

6. 1 ...in urban environments (30 mph +).
6. 2 ...in rural environments (45 mph +).
6. 3 ...in highway environments (55 mph +).
6. 4 ...in highly congested situations.

Q A 7. When do you think you can use ACC? (Select all you think applies)

1. When one lane marking is present
2. When both lane markings are present
3. Travelling at a speed below 25mph
4. Travelling at a speed above 25mph
5. Travelling at a speed below 90mph
6. Travelling at a speed above 90mph
7. When ACC is being used
8. When there is a vehicle in front of your vehicle
9. When there is no vehicle in front of your vehicle
10. I don't know

Q A 8. When do you think you cannot use ACC? (Select all you think applies)

1. When one lane marking is present
2. When both lane markings are present
3. Travelling at a speed below 25mph
4. Travelling at a speed above 25mph
5. Travelling at a speed below 90mph
6. Travelling at a speed above 90mph
7. When ACC is being used
8. When there is a vehicle in front of your vehicle
9. When there is no vehicle in front of your vehicle
10. I don't know

Q A 9. Please select all roadway environments where you think it would be appropriate to use ACC.

1. Divided highways and roadways
2. Carpool/HOV Lanes
3. Roundabouts and traffic circles
4. Toll roads
5. Gravel Roads
6. Parking lots
7. Local roads and streets
8. Residential streets

Q A 10. Please select all situations from the following where you think ACC may not work as expected.

1. Extremely hot or cold temperatures
2. Clear sunny days
3. Dusk and dawn
4. Heavy rain or snow
5. Poor tire traction
6. Sensors are obstructed
7. Windy roads
8. Straight roads
9. Roads with poor lane markings
10. Roads with no lane markings
11. Roads with clearly visible lane markings
12. Work Zones
13. Toll plazas

Q A 11. On a scale of 1 = Strongly Disagree to 5 = Strongly Agree how much do you agree with these statements:

I expect using the system would…

11. 1 …enable me to adjust to the traffic conditions more efficiently and keep a safer distance from the leading vehicle
11. 2 …improve my driving performance
11. 3 …help me to avoid collisions

Q A 12. Next time you buy or lease a car, will you want it to have an ACC system?

1. Yes	2. Probably yes	
3. Not sure	4. Probably not	5. No

Lane Keeping Assist (LKA)

On the following screens, you will be given descriptions of different types of advanced vehicle safety technologies. Please read the technology descriptions carefully to evaluate whether your vehicle is equipped with that technology.

1st screen: LKA description—“Lane Keeping Assist (LKA) is a technology that alerts you when you move out of your lane. It also gently steers you back into your lane if you begin to drift out of it.”

Q 1. To the best of your knowledge, is your vehicle equipped with **LKA**?

1. Yes 2. No

(If YES, then go to Q D1 - Survey for Experienced Drivers If NO, skip to QB 1 - Survey for Inexperienced Drivers)

Q B 1. If your vehicle had LKA would you use this system for driving?

1. Yes 2. No

Q B 2. How often would you use the LKA?

1. Frequently 2. Often 3. Sometimes 4. Rarely 5. Never

(Display this Question if answered NEVER for Q B 2)

Q B 2.1. You indicated that you would not use your LKA system for highway and in-town driving. Please check all that apply to indicate why you would not use the technology.

1. I don't understand it.
2. I don't trust it.
3. I think it is dangerous.
4. It makes me nervous/anxious.
5. It is annoying. It doesn’t work.
6. It is distracting.
7. I don't need/want it.
8. Other, please explain.

Q B 3. On a scale of 1 = Strongly Disagree to 5 = Strongly Agree how much do you agree with each statement:

3. 1 I would be comfortable looking away from the road or making a phone call, sending a text, etc. when my LKA is activated
3. 2 I would trust the LKA system for in-town or highway driving.
3. 3 I would feel apprehensive about using the LKA system for in-town or highway driving.
3. 4 I would expect that using the system would increase my driving safety

Q B 4. On a scale of 1 = Strongly Disagree to 5 = Strongly Agree how much do you agree with each statement:

4. 1 I think using the LKA system while driving is annoying.
4. 2 I think using the LKA system while driving reduces stress.
4. 3 I think using the LKA system while driving requires a lot of mental effort.
4. 4 I think using the LKA system while driving is distracting.
4. 5 I think using the LKA system while driving is easy to learn.
4. 6 I think using the LKA system while driving makes me feel safer.
4. 7 I think using the LKA system while driving increases the risk of a crash.

Q B 5. On a scale of 1 = Strongly Disagree to 5 = Strongly Agree how much do you agree with these statements:

I am willing to use the system…

5. 1 ...in urban environments (30 mph +).
5. 2 ...in rural environments (45 mph +).
5. 3 ...in highway environments (55 mph +).
5. 4 ...in highly congested situations.

Q B 6. When do you think you can use LKA? (Select all you think applies)

1. When one lane marking is present
2. When both lane markings are present
3. Travelling at a speed below 40mph
4. Travelling at a speed above 40mph
5. Travelling at a speed below 90mph
6. Travelling at a speed above 90mph
7. When driving on curved roads
8. When driving on straight roads
9. I don't know

Q B 7. When do you think you cannot use LKA? (Select all you think applies)

1. When one lane marking is present
2. When both lane markings are present
3. Travelling at a speed below 40mph
4. Travelling at a speed above 40mph
5. Travelling at a speed below 90mph
6. Travelling at a speed above 90mph
7. When driving on curved roads
8. When driving on straight roads
9. I don't know

Q B 8. Please select all roadway environments where you think it would be appropriate to use LKA.

1. Divided highways and roadways
2. Carpool/HOV Lanes
3. Roundabouts and traffic circles
4. Toll roads
5. Gravel Roads
6. Parking lots
7. Local roads and streets
8. Residential streets

Q B 9. Please select all situations from the following where you think LKA may not work as expected.

1. Extremely hot or cold temperatures
2. Clear sunny days
3. Dusk and dawn
4. Heavy rain or snow
5. Poor tire traction
6. Sensors are obstructed
7. Windy roads
8. Straight roads
9. Roads with poor lane markings
10. Roads with no lane markings
11. Roads with clearly visible lane markings
12. Work Zones
13. Toll plazas

Q B 10. On a scale of 1 = Strongly Disagree to 5 = Strongly Agree how much do you agree with these statements:

I expect using the system would…

10. 1 …enable me to adjust to the traffic conditions more efficiently and keep a safer distance from the leading vehicle
10. 2 …improve my driving performance
10. 3 …help me to avoid collisions

Q B 11. Next time you buy or lease a car, will you want it to have an LKA system?

1. Yes 2. Probably yes
3. Not sure 4. Probably not 5. No

Eligible Participants—Experienced drivers will receive this survey after Screening Survey and Informed Consent.

Experienced Drivers
Adaptive Cruise Control (ACC)

On the following screens, you will be given descriptions of different types of advanced vehicle safety technologies. Please read the technology descriptions carefully to evaluate whether your vehicle is equipped with that technology.

1st screen: ACC description—"Adaptive Cruise Control (ACC) is a technology that automatically keeps your vehicle speed at a speed that you have pre-selected, and also automatically follows another vehicle at a distance that you have pre-selected."

Q 1. To the best of your knowledge, is your vehicle equipped to use **ACC** while driving?

1. Yes 2. No

(If YES, then go to Q C1—Survey for Experienced Drivers. If NO, skip to Q A1—Survey for Inexperienced Drivers)

Q C 1. How often do you use Cruise Control while driving?

1. Frequently 2. Often 3. Sometimes 4. Rarely 5. Never

Q C 2. Is this the first vehicle you have owned that is equipped with an ACC system?

1. Yes 2. No

Q C 3. Before you purchased your vehicle, did you understand how ACC works?

1. Yes 2. No

Q C 4. How often do you use ACC while driving?

1. Frequently 2. Often 3. Sometimes 4. Rarely 5. Never

Q C 5. When you purchased your vehicle, was there any training offered by someone at the dealership regarding the use of the ACC?
By training, we mean that someone showed you or described to you how the system operates. This may or may not have included a test drive using the technology.

1. Yes 2. No

Q C 5. Did you complete the training?

1. Yes 2. No

Q C 6. Please rate your satisfaction with the training you received at the dealership.

Scale from 1 to 10 (Very Unsatisfied to Very Satisfied)

Q C 7. After your training at the dealership concluded, did you still have questions or uncertainties about the operation of the system?

1. Yes 2. No

Q C 8. Have you used any of the following to get information about your ACC system? Check all that apply.

1. Internet or online forums (Google or other type of search)
2. Online video (YouTube, Google video, etc.)
3. Learning by trial and error
4. Local mechanic
5. Dealership Manufacturer or Manufacturer's website
6. Government safety website (National Highway Traffic and Safety Administration, safercar.gov, etc.)
7. Books
8. Brochures or pamphlets
9. Social media (Facebook, Twitter, etc.)
10. Owner's manual
11. Friends or family
12. None of the above—I have not sought out information

Q C 9. On a scale of 1 = Strongly Disagree to 5 = Strongly Agree, how much do you agree with this statement:

“I expect that after using the system my interaction with the system will be clear and understandable.”

Q C 10. On a scale of 1 = Strongly Disagree to 5 = Strongly Agree how much do you agree with this statement:

"I expect that it will be easy for me to become skillful at understanding and using the system"

Q C 11. Do you have a better understanding of how ACC works now that you have driven with it for a period of time?

1. Yes 2. No

Q C 12. Have you ever been confused or not understood why your ACC system behaved the way it did?

1. Yes 2. No

Q C 13. I can explain to others how to use Adaptive Control Cruise for driving.

1. Strongly Disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly Agree

Q C 14. On a scale of 1= Strongly Disagree to 5 = Strongly Agree how much do you agree with each statement:

14. 1 I am comfortable looking away from the road or making a phone call, sending a text, etc. when my ACC is activated.
14. 2 I trust the ACC system while driving.
14. 3 I feel apprehensive about using the ACC system while driving.
14. 4 I expect that using the system would increase my driving safety

Q C 15. On a scale of 1 = Strongly Disagree to 5 = Strongly Agree how much do you agree with each statement:

15. 1 I think using the ACC system while driving is annoying.
15. 2 I think using the ACC system while driving reduces stress.
15. 3 I think using the ACC system while driving requires a lot of mental effort.
15. 4 I think using the ACC system while driving is distracting.
15. 5 I think using the ACC system while driving is easy to learn.
15. 6 I think using the ACC system while driving makes me feel safer.
15. 7 I think using the ACC system while driving increases the risk of a crash.

Q C 16. On a scale of 1 = Strongly Disagree to 5 = Strongly Agree how much do you agree with these statements:

I am willing to use the system…

16. 1 ...in urban environments (30 km/h +).
16. 2 ...in rural environments (45 km/h +).
16. 3 ...in highway environments (55 km/h +).
16. 4 ...in highly congested situations.

Q C 17. I change the ACC distance settings (short, medium, long).

1. Frequently 2. Often 3. Sometimes 4. Rarely 5. Never

Q C 18. I use the ACC when it is raining, snowing, or sleeting.

1. Frequently 2. Often 3. Sometimes 4. Rarely 5. Never

Q C 19. Please select the appropriate option to complete each statement.

19.1 When travelling at higher speeds, I tend to...
19.2 When travelling at lower speeds, I tend to...
19.3 When there is less traffic present, I tend to...
19.4 When there is heavy traffic present, I tend to...

a. Increase my distance setting (e.g., travel further away from the vehicle ahead).
b. Decrease my distance setting (e.g., travel closer to the vehicle ahead).
c. I do not change my distance setting in this situation.
d. Not sure

Q C 20. When can you use ACC? (Select all that apply)

1. When one lane marking is present
2. When both lane markings are present
3. Travelling at a speed below 25mph
4. Travelling at a speed above 25mph
5. Travelling at a speed below 90mph
6. Travelling at a speed above 90mph
7. When ACC is being used
8. When there is a vehicle in front of your vehicle
9. When there is no vehicle in front of your vehicle
10. I don't know

Q C 21. When can you not use ACC? (Select all that apply)

1. When one lane marking is present
2. When both lane markings are present
3. Travelling at a speed below 25mph
4. Travelling at a speed above 25mph
5. Travelling at a speed below 90mph
6. Travelling at a speed above 90mph
7. When ACC is being used
8. When there is a vehicle in front of your vehicle
9. When there is no vehicle in front of your vehicle
10. I don't know

Q C 22. Please select all roadway environments where it would be appropriate to use ACC.

1. Divided highways and roadways
2. Carpool/HOV Lanes
3. Roundabouts and traffic circles
4. Toll roads
5. Gravel Roads
6. Parking lots
7. Local roads and streets
8. Residential streets

Q C 23. Please select all situations from the following where ACC may not work as expected.

1. Extremely hot or cold temperatures
2. Clear sunny days
3. Dusk and dawn
4. Heavy rain or snow
5. Poor tire traction
6. Sensors are obstructed
7. Windy roads
8. Straight roads
9. Roads with poor lane markings
10. Roads with no lane markings
11. Roads with clearly visible lane markings
12. Work Zones
13. Toll plazas

Q C 24. On a scale of 1 = Strongly Disagree to 5 = Strongly Agree how much do you agree with these statements:

Using the system…

24. 1 ...enables me to adjust to the traffic conditions more efficiently and keep a safer distance from the leading vehicle.
24. 2 ...improves my driving performance.
24. 3 ...helps me to avoid collisions.

Q C 25. Next time you buy or lease a car, will you want it to have an ACC system?

1. Yes 2. Probably yes
3. Not sure 4. Probably not 5. No

Lane Keeping Assist (LKA)

On the following screens, you will be given descriptions of different types of advanced vehicle safety technologies. Please read the technology descriptions carefully to evaluate whether your vehicle is equipped with that technology.

1st screen: LKA description—"Lane Keeping Assist (LKA) is a technology that alerts you when you move out of your lane. It also gently steers you back into your lane if you begin to drift out of it."

Q 1. To the best of your knowledge, is your vehicle equipped with **LKA**?

1. Yes 2. No

(If YES, then go to Q D1—Survey for Experienced Drivers If NO, skip to Q B1—Survey for Inexperienced Drivers)

Q D 1. Is this the first vehicle you have owned that is equipped with an LKA system?

1. Yes 2. No

Q D 2. Before you purchased your vehicle, did you understand how LKA works?

1. Yes 2. No

Q D 3. How often do you use your LKA system while driving?

1. Frequently 2. Often 3. Sometimes 4. Rarely 5. Never

Q D 4. When you purchased your vehicle, was there any training offered by someone at the dealership regarding the use of the LKA?
By training, we mean that someone showed you or described to you how the system operates. This may or may not have included a test drive using the technology.

1. Yes 2. No

Q D 5. Did you complete the training?

1. Yes 2. No

Q D 6. Please rate your satisfaction with the training you received at the dealership.

Scale from 1 to 10 (Very Unsatisfied to Very Satisfied)

Q D 7. After your training at the dealership concluded, did you still have questions or uncertainties about the operation of the system?

1. Yes 2. No 3. Not Sure

Q D 8. Have you used any of the following to get information about your LKA system? Check all that apply.

1. Internet or Online forums (Google or other type of search)
2. Online video (YouTube, Google video, etc.)
3. Learning by trial and error
4. Local mechanic
5. Dealership Manufacturer or Manufacturer's website
6. Government safety website (National Highway Traffic and Safety Administration, safercar.gov, etc.)
7. Books
8. Brochures or pamphlets
9. Social media (Facebook, Twitter, etc.)
10. Owner's manual
11. Friends or family
12. None of the above—I have not sought out information

Q D 9. On a scale of 1 = Strongly Disagree to 5 = Strongly Agree how much do you agree with this statement:

“I expect that after using the system my interaction with the system will be clear and understandable”

Q D 10. On a scale of 1 = Strongly Disagree to 5 = Strongly Agree how much do you agree with this statement:

“I expect that it will be easy for me to become skillful at understanding and using the system”

Q D 11. Do you have a better understanding of how LKA works now that you have driven with it for a period of time?

1. Yes 2. No

Q D 12. Have you ever been confused or not understood why your LKA system behaved the way it did?

1. Yes 2. No

Q D 13. I can explain to others how to use LKA for driving.

1. Strongly Disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly Agree

Q D 14. On a scale of 1 = Strongly Disagree to 5 = Strongly Agree how much do you agree with each statement:

14. 1 I am comfortable looking away from the road or making a phone call, sending a text, etc. when my LKA is activated
14. 2 I trust the LKA system for driving.
14. 3 I feel apprehensive about using the LKA system for driving.
14. 4 I expect that using the system would increase my driving safety

Q D 15. On a scale of 1 = Strongly Disagree to 5 = Strongly Agree how much do you agree with this statement:

15. 1 I think using the LKA system while driving is annoying.
15. 2 I think using the LKA system while driving reduces stress.
15. 3 I think using the LKA system while driving requires a lot of mental effort.
15. 4 I think using the LKA system while driving is distracting.
15. 5 I think using the LKA system while driving is easy to learn.

15. 6 I think using the LKA system while driving makes me feel safer.
15. 7 I think using the LKA system while driving increases the risk of a crash.

Q D 16. On a scale of 1 = Strongly Disagree to 5 = Strongly Agree how much do you agree with these statements:

I am willing to use the system…

16. 1 ...in urban environments (30 km/h +).
16. 2 ...in rural environments (45 km/h +).
16. 3 ...in highway environments (55 km/h +).
16. 4 ...in highly congested situations.

Q D 17. I use the LKA when it is raining, snowing, or sleeting.

1. Frequently 2. Often 3. Sometimes 4. Rarely 5. Never

Q D 18. When can you use LKA? (Select all that apply)

1. When one lane marking is present
2. When both lane markings are present
3. Travelling at a speed below 40mph
4. Travelling at a speed above 40mph
5. Travelling at a speed below 90mph
6. Travelling at a speed above 90mph
7. When driving on curved roads
8. When driving on straight roads
9. I don't know

Q D 19. When can you not use LKA? (Select all that apply)

1. When one lane marking is present
2. When both lane markings are present
3. Travelling at a speed below 40mph
4. Travelling at a speed above 40mph
5. Travelling at a speed below 90mph
6. Travelling at a speed above 90mph
7. When driving on curved roads
8. When driving on straight roads
9. I don't know

Q D 20. Please select all roadway environments where it would be appropriate to use LKA.

1. Divided highways and roadways
2. Carpool/HOV Lanes
3. Straight Roads
4. Toll roads
5. Gravel Roads
6. Parking lots
7. Local roads and streets
8. Residential streets

Q D 21. Please select all situations from the following where LKA may not work as expected.

1. Extremely hot or cold temperatures
2. Clear sunny days
3. Dusk and dawn
4. Heavy rain or snow
5. Poor tire traction
6. Sensors are obstructed
7. Windy roads
8. Straight roads
9. Roads with poor lane markings
10. Roads with no lane markings
11. Roads with clearly visible lane markings
12. Work Zones
13. Toll plazas

Q D 22. On a scale of 1 = Strongly Disagree to 5 = Strongly Agree how much do you agree with these statements:

Using the system…

1. …enables me to adjust to the traffic conditions more efficiently and keep my car in the center of the lane.
2. …improves my driving performance.
3. …helps me to stray off lane.

Q D 22. Next time you buy or lease a car, will you want it to have an LKA system?

1.Yes	2. Probably yes	
3. Not sure	4. Probably not	5. No