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Consumer Driving Automation System Education

A Learning and Retention Assessment

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EXECUTIVE SUMMARY

As driving automation systems become more prevalent in production vehicles, drivers will have increased opportunities to purchase and/or rent vehicles with these features. To achieve the potential safety benefits of driving automation systems, drivers must be informed of and fully understand the capabilities and limitations of these systems. Uninformed or misinformed drivers may be over-reliant on the automated features and engage in unsafe driving situations as a result. The inverse may also occur—drivers may not engage any of the automated systems if they are unfamiliar with the systems' capabilities or believe the systems to be unsafe or unsuited to their driving style.

Recognizing the large number of instructive resources available to consumers, this project sought to gain insight into the level of understanding that third-party vehicle owners/operators may obtain from a variety of training materials. Conditions were selected to discern what level and type of training materials are needed for someone buying a secondhand vehicle or renting a vehicle with these safety features. Is a review of the owner's manual or quick start guide found in the vehicle's glove compartment or online enough, or do drivers need to see videos or animations of the system features to help illustrate how those features work? If the vehicle is older and there are no longer videos available on the website of the original equipment manufacturer (OEM), could drivers look at videos on the MyCarDoesWhat.org website—a national campaign to help educate drivers on new vehicle safety technologies designed to help prevent crashes—and learn enough to operate the system technologies safely?

Test Conditions

Three training conditions were selected to explore the range of materials that drivers may access when trying to learn about driving automation system safety features:

1. Owner's manual only
2. Owner's manual and OEM website video or animation
3. Owner's manual and MyCarDoesWhat.org videos

In selecting these conditions, vehicles and associated websites were reviewed to identify the technologies and training materials available. Three vehicles, a 2015 Infiniti Q50, a 2016 Honda CR-V, and a 2015 Chevy Tahoe, were selected to represent a range of vehicle types/sizes, technologies, and price points (estimated average transaction price). Additionally, all three training conditions offered informational videos or animations with a differing degree of detail. Each training condition was tested with each vehicle for a total of nine possible testing scenarios.

Thirty-six participants were recruited for the study. An equal number of males and females were recruited from two age groups: 25–39 and 40–54 years old. Participants were balanced across the nine possible testing scenarios.

A two-part study was conducted to explore participants' ability to learn from existing training materials and to determine how well participants were able to retain what they learned. Participants took part in three assessments during this study:

1. Pre-Active Safety Exposure Assessment (Pre-Exposure)
2. Post-Active Safety Exposure Assessment (Post-Exposure)

3. Retention Safety Exposure Assessment (Retention)

Closed-ended questions were tallied and reported in the results section. Open-ended questions were placed in Excel spreadsheets and qualitatively analyzed by three researchers.

Summary of Results

Regardless of training condition or learning style, participants were able gain at least a rudimentary understanding about the operation and purposes of driving automation system technologies. However, participants were less sure of the specifics associated with the technologies (i.e., activation, alerts or warnings, and appropriate use). Participants were best able to articulate specifics associated with adaptive cruise control (ACC), most likely due to established mental models associated with ordinary cruise control. Those in the multimedia testing conditions reported feeling more familiar with the technologies than those in the owner's manual only condition. In addition to providing basic information, videos provided important contextual information about the technologies' operations that could not be obtained from review of the manual alone (e.g., what to expect when the automatic emergency braking [AEB; forward crash prevention] activates). Participants found the videos to be an entertaining and easier-to-understand alternative to the manual. Several indicated that they would refer to the video first to see how the technology worked and then refer to the manual to gain a more in-depth understanding. Videos with sound and additional details were preferred to the simpler animations. When taking into consideration participants' self-reported learning styles, average scores across all technologies were fairly comparable across styles.

Key Takeaways

Qualitative analysis included a review of participant comments that resulted in a list of key takeaways. The following represent some of the more concerning or informative takeaways based on participant comments.

ACC Takeaways

1. **Users need to understand that the purpose of ACC is not collision avoidance**. While users may grasp that ACC is a technology that can help maintain a safe distance and speed from a lead vehicle, they should not assume that equates to collision avoidance. Users should know that they must maintain proper attention to the road and not depend on ACC to prevent collisions.

2. **Users' understanding of the appropriate use of ACC needs to expand beyond thinking it is always appropriate on highways.** While many participants could name a variety of conditions under which it was appropriate or inappropriate to use ACC, several participants said simply that it was a system for use on the highway. Yet the owner's manuals for each of the vehicles in this study provided several specific conditions under which ACC is appropriate or inappropriate to use. For instance, most of the ACC systems covered in this study required, for appropriate use, good weather, straight roads, evenly flowing traffic, and a minimum speed threshold (e.g., 25 mph). If users do not understand the conditions under which the ACC sensors may not be able to monitor the vehicle ahead (e.g., curvy roads, adverse weather), they may use the system in unsafe conditions.

AEB Takeaways

1. **Users should understand the limits of AEB and remain alert to traffic ahead.** The vehicles in this study had AEB systems designed to assist the driver during risk of a collision; however, no system instructions stated that AEB would *prevent* a collision. Yet several users described AEB as something that would prevent accidents. Users need to know that they should remain alert and not count on AEB to prevent a collision.

2. **Users should know that AEB is typically active at certain speeds unless it has been turned off**. Several study participants thought AEB had to be activated. The fact that other systems in this study (i.e., ACC and lane departure warning/lane keeping assist [LDW/LKA]) must typically be turned on and activated may have led users to be confused and assume that AEB works the same way. It should be made clear to users that AEB is different. Unless a user has an AEB system that can be turned off, AEB is typically active above a certain speed threshold (e.g., 3 mph).

3. **Users should understand that while AEB has some limitations, it is a safety feature that should remain on in most cases.** Several study participants described the appropriate use of AEB similarly to other convenience features, such as ACC. For example, some described it as appropriate for highway use or not appropriate in heavy traffic. While users should know that AEB has some limitations (e.g., roads with sharp curves may impact detection capabilities) and should be knowledgeable of specific instances when it should not be used (e.g., one study vehicle noted it should not be used when towing a trailer), in most cases this safety feature should be left on to assist drivers in avoiding accidents.

LDW/LKA Takeaways

1. **Users need to understand that LDW and LKA are convenience features; they are not a substitute for alert driving.** While not a major issue, a few participants described the purpose of LDW and LKA as alerting drivers if they are falling asleep/drowsy or distracted (i.e., texting).

2. **Users need to understand whether their system provides LDW and LKA or just LDW.** Users need to know that some vehicles offer LDW and LKA together, while others only offer LDW. If a user only has LDW, it is important that they understand the feature will only provide warnings of a lane departure, not prevent it. In this study, 2 of the 12 participants who were exposed to materials for a vehicle that had only LDW described the feature as something that could prevent lane departure.

Cross-cutting Takeaways

1. **Users need to know where sensors (camera, radar, etc.) are located for each system and the basic purpose they serve so that they understand when these sensors may become inoperable.** While users may know that there is some sort of sensor being used for each technology, if they do not know where the sensors are located and their purpose, they may not understand when the system could become inoperable. While many participants were able to basically describe how sensors enabled these features to work (e.g., camera sensor reads the painted lines in LDW/LKA), there was some confusion for a few participants.

2. **Users can get confused between features; education/training materials need to clearly differentiate the functionality of each system.** Several participants confused the functionality of systems within the study and occasionally with other active safety features that were not part of the study. While it did not happen often, there were several participants who were confused and thought, for example, that LDW/LKA provided blind spot monitoring. Education and training materials should clearly differentiate between systems so that users do not depend on a system to assist them in ways that it will not.

3. **Users should be clear about which systems need to be activated (i.e., ACC and LDW/LKA) and which are active unless turned off (i.e., AEB).** A few participants appeared confused about whether or not a particular system needed to be activated or not. For instance, several participants thought ACC and LDW/LKA would automatically activate under certain conditions. A few users were unsure if AEB needed to be activated or not.

4. **Users need to understand how to activate/deactivate systems.** Several participants, when asked how to activate or deactivate a system, said only “press a button,” without providing details, such as where the button was located. Learning to activate/deactivate a system may simply be a function of spending time in the vehicle and becoming familiar with the location of the buttons/switches for each system, but it was of interest to the research team to note how many users, after reading/seeing educational materials, could not recall such details.

5. **Users need to know whether there is an alert and what the alert will sound/look/feel like for each system**. Every system on every vehicle had some type of alert. While many users understood that there were alerts and could basically describe them, others could not recall if there were alerts and/or could not describe them. Vehicle-specific multimedia materials may be useful in providing this information to users.

6. **Users should be clear on the conditions, such as speed, under which they can safely use each feature.** Several study participants were unclear about the conditions, such as speed, under which a system could be used. Making use conditions clear to participants through education/training is important so they know when it is appropriate to use a particular system. For example, AEB typically becomes operable at lower speeds (e.g., 3 mph), ACC becomes operable at moderate speeds (e.g., 25 mph), and LDW/LKA becomes operable at higher speeds (e.g., 40 mph).

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LIST OF ABBREVIATIONS AND SYMBOLS

ACC	adaptive cruise control
AEB	(forward) automatic emergency braking
ATP	estimated average transaction price
BSW	blind spot warning
DDT	dynamic driving task
FCW	forward collision warning
GDL	Graduated Driver Licensing
LDP	lane departure prevention
LDW	lane departure warning
LKA	lane keeping assist
MCDW	MyCarDoesWhat.org
MFA NDS	Mixed Function Automation Naturalistic Driving Study
NHTSA	National Highway Traffic Safety Administration
NSTSCE	National Surface Transportation Safety Center for Excellence
ODD	operational design domain
OEDR	object and event detection and response
PI	principal investigator
SUV	sport utility vehicle
VTTI	Virginia Tech Transportation Institute

CHAPTER 1. INTRODUCTION

As driving automation systems become more prevalent in production vehicles, drivers will have increased opportunities to purchase and/or rent vehicles with these features. To achieve the potential safety benefits of driving automation systems, drivers must be informed of and understand the capabilities and limitations of these automated systems. Uninformed or misinformed drivers may be over-reliant on the automated features and engage in unsafe driving situations as a result. The inverse may also occur: a driver may not engage any of the automated systems if they are unfamiliar with the systems' capabilities or believe the systems to be unsafe or not suited to their driving style.

For new car buyers, the amount of available training varies. Even though manufactures may provide dealerships with checklists of features to review upon sale of a new vehicle, a preliminary assessment of training provided to interested parties by dealerships conducted as part of a concurrent study found that the amount and quality of training provided varied by dealership. While some salespeople were familiar with new driving automation systems, others had difficulty determining whether the vehicle was even equipped with the technology.

A recent *New York Times* article indicated that original equipment manufacturers (OEMs) are beginning to distribute some or all of their vehicles' owner's manuals electronically. In addition to putting owner's manuals on their websites, they are using smartphone or tablet applications, or even video displays within the vehicle (Taub, 2016). However, consumers searching the internet for materials will find a wide range of information. Older manuals may not include instructions for an existing safety feature, while manuals for the current model year may include instructions for technologies not available in the driver's make and model.

A review of OEM or dealership websites indicates that video demonstrations of driving automation systems are widely available, varying from animated illustrations to more detailed "walk-throughs" of the vehicle and technology packages. Individuals seeking information through a web search will find that the quality of the available information varies greatly. For example, while official OEM-provided videos demonstrate the intended use of the driving automation system, the purpose of many third-party YouTube video demonstrations is to push the limits of the technologies toward misuse or even abuse. For example, dancing, playing cards, and dueling with light sabers while the vehicle is operational, as depicted in one video, are clearly not suggested by any OEM (Jukin Media, 2016). Moreover, these videos may (either intentionally or not) misrepresent the technology's capabilities (e.g., referring to the Tesla Autopilot system as "self-driving").

Recognizing the large number of instructive resources available to consumers, this project sought to gain insight into the level of understanding that third-party vehicle owners/operators may obtain from a variety of training materials. Conditions were selected to discern what level and type of training materials are needed for someone buying a secondhand vehicle or renting a vehicle with these safety features. Is a review of the owner's manual or quick start guide found in the vehicle's glove compartment or online enough, or do drivers need to see videos or animations of the system features to help illustrate how those features work? If the vehicle is older and there are no longer videos available on the OEM's website, could drivers look at the videos on the MyCarDoesWhat.org (MCDW) (National Safety Council & The University of Iowa, 2017) website—a national campaign to help educate drivers on new vehicle safety technologies designed to help prevent crashes— and learn enough to operate the system technologies safely? In this report, we discuss the two-session study that was conducted to explore participants' ability to learn from existing training materials and how well those participants were able to retain what they learned.

CHAPTER 2. BACKGROUND

A technology identification activity and a literature review were conducted to supplement previous research in this domain (e.g., Sullivan, Flannagan, Pradhan, & Bao, 2016; Trimble, Bishop, Morgan, & Blanco, 2014), and concurrent research efforts were leveraged in order to gain additional insights that could inform the experimental design or study procedures of the research being conducted (Trimble et al., 2014).

This project was completed in collaboration with the Naturalistic Study of Level 2 Driving Automation Functions (L2 NDS), which is currently being conducted by the Virginia Tech Transportation Institute (VTTI) for the National Highway Traffic Safety Administration (NHTSA). Completing the project in this manner provided an opportunity for both project teams to leverage resources to maximize their understanding of currently available vehicles equipped with automation functions that allow for hands-off and feet-off operations. Members of both research teams were also involved with the identification and review of OEM- and dealer-provided training materials and the development of the L2 NDS participant training, which was reviewed by OEM stakeholders prior to implementation.

DRIVING AUTOMATION SYSTEM IDENTIFICATION

Appendix A includes a table of vehicle makes and models that feature some type of lateral (lane centering or lane keeping) and longitudinal (adaptive cruise control [ACC] or forward automatic emergency braking [AEB]) automation. In terms of automation levels (SAE International, 2014), at the time of his project, 211 vehicles came factory-equipped with the capability of automating portions of lateral and/or longitudinal control (Level 1 automation), while 70 vehicles included the option for partial automation; i.e., both lateral automation and ACC capabilities (Level 2 automation; Table 1).

Table 1. SAE definitions for vehicle automation.

Level	Name	Narrative definition	Dynamic driving task (DDT)		DDT Fallback	Operational Design Domain (ODD)
			Sustained lateral and longitudinal vehicle motion control	Object and event detection and response (OEDR)		
Driver* performs part or all of the *DDT						
0	**No Driving Automation**	The performance by the *driver* of the entire *DDT*, even when enhanced by *active safety systems*.	*Driver*	*Driver*	*Driver*	n/a
1	**Driver Assistance**	The *sustained* and *ODD*-specific execution by a *driving automation system* of either the *lateral* or the *longitudinal vehicle motion control* subtask of the *DDT* (but not both simultaneously) with the expectation that the *driver* performs the remainder of the *DDT*.	*Driver* and *System*	*Driver*	*Driver*	Limited
2	**Partial Driving Automation**	The *sustained* and *ODD*-specific execution by a *driving automation system* of both the *lateral* and *longitudinal vehicle motion control* subtasks of the *DDT* with the expectation that the *driver* completes the *OEDR* subtask and *supervises* the *driving automation system*.	***System***	*Driver*	*Driver*	Limited
***Automated Driving System (ADS)*[4] ("*System*") performs the entire *DDT* (while engaged)**						
3	**Conditional Driving Automation**	The *sustained* and *ODD*-specific performance by an *ADS* of the entire *DDT* with the expectation that the *DDT fallback-ready user* is *receptive* to *ADS*-issued *requests to intervene*, as well as to *DDT performance-relevant system failures* in other *vehicle* systems, and will respond appropriately.	*System*	***System***	*Fallback-ready user (becomes the driver during fallback)*	Limited
4	**High Driving Automation**	The *sustained* and *ODD*-specific performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will respond to a *request to intervene*.	*System*	*System*	***System***	Limited
5	**Full Driving Automation**	The *sustained* and unconditional (i.e., not *ODD*-specific) performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will respond to a *request to intervene.*	*System*	*System*	*System*	**Unlimited**

TRAINING BEST PRACTICES

In completing this literature review, the research team built upon existing knowledge, focusing in particular on knowledge related to driving automation system technologies and driver training and engagement pedagogies, to identify effective strategies for providing information to consumers. This review considers best practices associated with training programs in general and teen driver training specifically, and concludes with a discussion of a training resource designed specifically to inform drivers about new car safety technologies.

Characteristics of Effective Training Programs

Several commonly used instructional design models may be used to design effective learning experiences, courses, and instructional content. These models include the Addie Model, SAM Model, Action Mapping, Merrill's First Principles of Instruction (Merrill, 2002), Guagné's Nine Events of Instruction, Bloom's Taxonomy, the Dick and Carey Model, Kemp's Instructional Design Model, and Kirkpatrick's Four Levels of Training (Instructional Design Central, n.d.).[1] Effective training programs seek to engage participants early on by providing a "What's in it for me?" rationale as quickly as possible (Knowles, 1996). Throughout the training, a blend of activities and learning styles should be accommodated (National Highway Institute, 2004). Most people learn best through an approach that incorporates a blend of activities that promote the three learning domains: cognitive (knowledge or a body of subject matter), affective (attitudes and beliefs), and behavioral (practical application; National Highway Institute, 2004, 2-1). Examples of activities in each of the domains include the following: cognitive domain (lectures, discussions), affective domain (values clarification exercises, normal group processes), and behavioral domain (role plays and simulations). Further, effective training takes into account the following different learning styles (National Highway Institute, 2004, 2-2):

1. Visual: learning by looking, seeing, viewing, and watching (e.g., readings, demonstrations)
2. Auditory: learning by listening, hearing, and speaking (e.g., lectures, stories, examples)
3. Kinesthetic: learning by experiencing, moving, and doing (e.g., practice demonstrations, writing/note-taking, simulations)

Through blended activities that appeal to the different learning domains and learning styles, key concepts should be repeated more than once, linking new content and skills to existing knowledge. Additionally, opportunities for practice and application of new concepts and skills should be encouraged. Moreover, learners should be provided with an evaluation of these new skills and feedback (National Highway Institute, 2004).

Teen Driver Training Best Practices

A previous effort completed a critical review of the current national and international literature and data sources pertaining to the training of teen drivers (Trimble, Baker, Schaudt, & Schrader, 2013). The research team considered this literature useful to this study, as teen drivers are new to

[1] Summaries of each of these models as well as links to additional information may be found at https://www.instructionaldesigncentral.com/instructionaldesignmodels

driving and require education and training, just as most drivers will be new to driving automation system technologies and will require some form of education and training. A review of national advocacy and safety associations and government institutes was supplemented with national and international studies of effective teen driving. The team then summarized available information from these resources, publications (journals, trade magazines, research organizations, electronic), and the internet in order to determine the best practices. Drawing upon the guidance provided in the Novice Teen Driver Education and Training Administrative Standards (National Driver Education Standards Project, 2009), the team identified areas of information which could be used to evaluate components of effective driver-training programs. Key characteristics of effective driver education programs are discussed below.

1. **Guardian involvement:** Activities related to increased guardian involvement have the potential to make the most difference in the education and Graduated Driver Licensing (GDL) process (Carney, McGehee, Lee, Reyes, & Raby, 2010; Foss, Masten, Goodwin, & OBrien, 2012; Lonero et al., 1995; Lonero & Mayhew, 2010; Preusser, Ferguson, & Williams, 1998; Simons-Morton et al., 2011; Thomas et al., 2012). Several existing resources provide guidance in developing such efforts. For example, Goodwin et al. (2013) draw attention to five nationally available programs that have been developed to encourage parental engagement: (1) Checkpoints, (2) Driving Skills for Life, (3) Road Ready Teens, (4) Teen Driver: A Family Guide to Teen Driver Safety, and (5) The Novice Driver's Road Map. Additionally, the Centers for Disease Control and Prevention's educational campaign, Parents Are the Key to Safe Teen Drivers, provides parents with tools and proven steps for reducing teen driving injuries and deaths (Centers for Disease Control and Prevention, 2013).

2. **Education and training:** While driver education programs alone have not been shown to significantly decrease crash risk, minimum requirements (such as those presented by the American Driver and Traffic Safety Education Association) should be met to ensure that all students are receiving basic instruction. Supplemental activities incorporated into basic education programs can be beneficial. For example, research has found that some teachers want updated materials, such as DVDs and hands-on experiences with heavy vehicles, to help novice teen drivers better understand the concepts associated with how to share the road with heavy vehicles, which in turn may be helpful in reducing future light vehicle/heavy vehicle interactions (Baker, Schaudt, Freed, & Toole, 2012). Other studies identified benefits associated with teen driving coach programs (Carney et al., 2010) and the use of simulated activities (Cullotta, 2013; Morgan, Tidwell, Medina, & Blanco, 2011; Thomas et al., 2012), and engagement (Thomas et al., 2012).

3. **Coordination with GDL:** GDL programs have been proven effective in reducing the crash risk for teen drivers, especially when GDL requirements are combined with parental or guardian involvement efforts. For example, in Oregon, researchers determined that the clearest safety improvements, those improvements in 16-year-old drivers in their first 6 months of licensure, occurred not only when the GDL restrictions were the greatest but also when parents reported the greatest

vigilance in supporting the restrictions (Raymond et al., 2007). Outreach efforts related to GDL enforcement are also recommended. These recommended efforts include the development of GDL-related outreach and educational materials, such as a law enforcement pocket guide, for use by judges, courts, and law enforcement agencies to ensure that GDL requirements are uniformly enforced. Additionally, vehicle decal programs, such as the one implemented in New Jersey, have been shown to result in significant programmatic benefits (Curry, Pfeiffer, Localio, & Durbin, 2012).

4. **Instructor qualification:** Instructors need to be qualified to teach and should have access to adequate training and resources to keep them up-to-date about driver education and training best practices. Training provides an opportunity for sharing information about teaching best practices, new technologies to aid in the instruction process (e.g., updated simulators), and topics of concern to agencies and instructors (e.g., new automobile technologies, such as ACC, lane assist, and advanced driving techniques). Training also serves as an opportunity to address concerns and share best practices regarding guardian involvement efforts and GDL coordination efforts. It is recommended that all instructors (1) take and pass state-approved practical and/or written tests; (2) obtain recertification every 2 years; and (3) fulfill continuing education requirements in driver-training-related topics.

A more recent project evaluated light-vehicle driver education programs targeting sharing the road with heavy vehicles (Baker, Schaudt, Joslin, Tidwell, & Bowman, 2014). As part of this effort, a case study was performed comparing a basic textbook-based component for sharing the road with heavy vehicles combined with a DVD to a textbook-based component combined with a hands-on truck experience developed by National Surface Transportation Safety Center for Excellence (NSTSCE) researchers. The results showed that both students and teachers found the supplemental DVD and hands-on demonstration to be helpful as well as preferable to just reading about sharing the road in textbooks.

Driving Automation Systems Training

Looking at how drivers learn about driving automation systems, Mehlenbacher, Wogalter, and Laughery (2002) investigated self-reported use of vehicle owner's manuals, finding that of the 58.9% drivers who reported having read the owner's manual of the vehicle they drove most often, the mean percentage of the manual reported read was 52.7%. They also found that people preferred owner's manuals to presentations (i.e., direct instruction from a live person, directly attached to the product, on the internet, on videocassette, or on CD/DVD) of the same product information. Since Mehlenbacher et al.'s study, learning material preferences have begun to shift. In a more recent study, McDonald et al. (2015, 2016) noted that, when asked what sources they would use if they found themselves in a situation in which they did not understand their vehicle's behavior, the most popular source for obtaining information was the internet (Google or other search engine; 57%) followed by contacting a local mechanic (52%), reading the owner's manual (50%), and contacting the dealership (48%).

Access to the vehicle owner's manual does not guarantee that drivers will refer to the manual or understand details associated with driving automation system technologies. Jenness et al. (2008) found that the most frequent methods for learning how to use ACC were the vehicle owner's manual (67%) and on-road experience (54%), where 15% reported on-road experience as the sole learning method. In a study of ACC-equipped vehicle owners, Larsson (2010) explored situations in which drivers reclaimed control of the vehicle, the extent of their understanding of system limitations, and whether or not the drivers forgot if the system was active. Although the vehicle owner's manual mentioned all of the following, 36 respondents were unaware of any system limitations, 31 reported mode errors, and one was not aware the system was ACC. Strand et al. (2011) also identified potential knowledge gaps associated with ACC systems.

Robinson et al. (2011) explored whether individuals understood what advanced crash warning systems (i.e., forward collision warning [FCW], lane departure warning [LDW], ACC, blind spot warning [BSW]) were present or operational in a vehicle and whether prior exposure to that vehicle's manual (or another vehicle's manual) affected that knowledge. Although participants were confident in their responses, they were not particularly accurate in assessing when a crash warning system was present (more than 40% of responses were incorrect) and demonstrated only slightly better accuracy when they read the appropriate vehicle owner's manual as opposed to no manual or another vehicle's manual.

Beggiato and Krems (2013) investigated how trust, acceptance, and mental model involvement were affected by divergent initial mental models of ACC (i.e., a correct ACC model, an incomplete and idealized model that omitted potential problems, and an incorrect model that included non-occurring problems). They found that users' mental models of the ACC converged toward the profile of the correct group, and that automation failures, if known beforehand, did not negatively affect trust and acceptance. Omitted problems, however, led to a constant decrease in trust and acceptance without recovery (Beggiato & Krems, 2013).

Stave and Strand (2015) also assessed the perspectives of end users on the purpose of driving automation systems, and identified two types of drivers (p. 6):

1. **Driver with a special interest in car technology:** Has patience to read through the owner's manual. Finds the car as a play-mate. Does often have prior experience. Prioritizes time to understand the car and therefore has more knowledge about it, often teaches others.

2. **Driver with less interest in car technology**: The car is primarily a means for transport. Has higher requirements in the learning of new car technology. Has less knowledge about the systems. Is less interested in spending time on learning the systems.

Stave and Strand (2015) further concluded that activities for learning could close the knowledge gap regarding the functioning of the technologies.

One resource that offers a variety of activities for learning is the MCDW campaign, which was launched in October 2015 to educate the driving public on new vehicle safety technologies and to encourage drivers to be more engaged and actively utilize defensive driving techniques when they are behind the wheel (National Safety Council & The University of Iowa, 2015, 2017). The

MCDW campaign resources incorporate social media as well as an interactive, research-driven website featuring instructional videos, short animations, illustrated guides and infographics, quizzes, and games. In developing these resources, the research team behind the campaign built upon the National Survey of Consumer Driving Safety Technologies (McDonald et al., 2015, 2016; Transportation and Vehicle Safety Research Program, 2015), which examined drivers' knowledge of vehicle safety systems, their understanding and use of defensive driving techniques, and effective messages and techniques for encouraging safer driver behavior. MCDW provides information on eight driving automation system technologies: back-up cameras, blind spot monitors, FCW, anti-lock braking systems, rear cross traffic alerts, ACC, AEB, and LDW.

While the MCDW campaign exists to provide drivers with an overview of existing technologies, individuals must actively seek out this information or be otherwise made aware of its availability. Such awareness is more likely among those engaged in driver safety and education programs than those seeking to purchase a vehicle from an OEM, dealer, or third party.

CHAPTER 3. METHODS

In designing this study, researchers considered the availability of driving automation system technologies on production vehicles and the range of training materials associated with these technologies, both those developed by the OEM and those developed by MCDW. Through this process, three technologies, three training conditions, and three vehicles were identified for this study.

SELECTION OF TECHNOLOGIES

To complement the activities undertaken in the NHTSA L2 NDS, a combination of longitudinal versus lateral features, as well as those which may be considered convenience features rather than safety-related, were explored. The following technologies were identified for inclusion in the study:

- ACC
- LDW and lane keeping assist (LKA)
- AEB

The first two technologies, ACC and LDW/LKA, were chosen based on their inclusion in the L2 NDS study. The third technology, AEB, was chosen based on the attention this technology has received in the media as a result of its inclusion in the Insurance Institute for Highway Safety's vehicle crashworthiness tests.

SELECTION OF TRAINING CONDITIONS

Conditions were selected to discern what level and type of training materials are needed for someone buying a secondhand vehicle or renting a vehicle with these safety features. Three training conditions were selected to explore the range of materials that people may access when trying to learn about driving automation system safety features:

1. Owner's manual only
2. Owner's manual and OEM website video or animation
3. Owner's manual and MCDW videos

In selecting these conditions, alternate educational materials (e.g., vehicle brochures) and combinations of materials (e.g., OEM video only) were also considered. However, these alternate materials often failed to provide adequate information about the technologies and appropriate use scenarios on their own.

The first condition included only the vehicle owner's manual. The vehicle owner's manual was used because it is an instructional guide to the vehicle and the technologies included in this study that should be readily available to drivers either in a vehicle or online. It was decided that the vehicle owner's manual would be included in the other two conditions as well, so researchers could understand if there is a benefit when supplemental materials, such as videos or animation, are provided above and beyond the owner's manual.

The second condition (i.e., vehicle owner's manual and OEM website video or animation) was used to explore whether reviewing supplemental videos or animation in addition to a user's manual improved participant understanding and retention of key information about features. Various types of video and animation were selected so that the research team could consider the differences in what multimedia format OEMs are using. When the research team was identifying vehicles to include in the study, an effort was made to include a vehicle with detailed website videos, a vehicle with basic website videos, and a vehicle with website animations.

The final condition included MCDW videos for the driving automation system features. The educational videos on this website were combined with the owner's manual to see if participants benefited in their understanding of the technologies after reviewing MCDW videos. For this condition, the MCDW videos were combined with every vehicle even if the vehicle did not offer all of the features described. This was the case with the 2015 Chevy Tahoe, which offered LDW but not LKA.

SELECTION OF VEHICLES

Vehicles and associated websites were reviewed to identify the technologies and training materials available. The three vehicles selected represent a range of vehicle types/sizes, technologies, and price points. Additionally, all three offered videos or animations with a differing degree of detail. Each is discussed below and presented in Table 2 (see also Appendix B). In terms of price point, researchers compared vehicle cost to the estimated average transaction price (ATP) for light vehicles in the United States as reported by Kelley Blue Book for December 2015 (i.e., $34,428). In this study, two vehicles cost more and one cost less than the ATP.

Table 2. Vehicle conditions.

Vehicles	Type/Size	Price Point	Video/Animation	Technologies
2015 Infiniti Q50	Midsize luxury	Above ATP	Detailed video	All
2016 Honda CR-V	Small SUV	Below ATP	Silent animation	All
2015 Chevy Tahoe	Large SUV	Above ATP	Brief video	All but LKA

The Infiniti Q50 was the first vehicle selected based on its inclusion in the L2 NDS project. Consequently, researchers had a solid understanding of the vehicle's active safety technologies, which included knowledge not only about how they worked but also what associated training materials were available to consumers. This midsize luxury vehicle was considered a higher price point vehicle (i.e., above ATP) with detailed instructional feature videos on its website.

Next, researchers reviewed a mix of vehicles from the Insurance Institute for Highway Safety's Top Safety list (e.g., Hyundai Tucson, Honda CR-V, Subaru Outback, Toyota Rav4, etc.) in order to find a vehicle with all three of the aforementioned technologies, a lower price point and size/type than the Infiniti, and with video or animation available about the technology. The Honda CR-V Touring was selected as the second vehicle because the three safety features were standard at that trim level, it varied in size/type and cost from the Infiniti, and the Honda website provided silent animations on the technologies of interest that were quite different from the Infiniti videos.

Finally, researchers identified a vehicle that would vary from the Infiniti Q50 and the Honda CR-V in terms of type/size, video/animation, and technology. The Chevy Tahoe was selected, as the Chevy website included briefer videos than the ones on the Infiniti website, and the type/size of the Tahoe was different from both the Infiniti Q50 and the Honda CR-V. Another reason the Chevy Tahoe was an important addition to the study is that the 2015 model offers LDW but not LKA. The research team was interested in determining whether Tahoe participants who viewed the MCDW video on LDW/LKA would understand and remember that LKA was not part of the Tahoe's feature package.

TEST PROCEDURES

Once the technologies, training, and vehicle conditions were determined, a two-part study was conducted to explore participants' ability to learn from existing training materials and to determine how well they were able to retain what they learned. This Test Procedures section provides information on the participants recruited for the study as well as the testing procedures.

Participants

Thirty-six participants were recruited for the study. An equal number of males and females were recruited from two age groups: 25–39 and 40–54 years old. Participants' education and income levels are provided in Figure 1. Only participants who indicated that they did not have experience driving vehicles with the key features being studied were recruited.

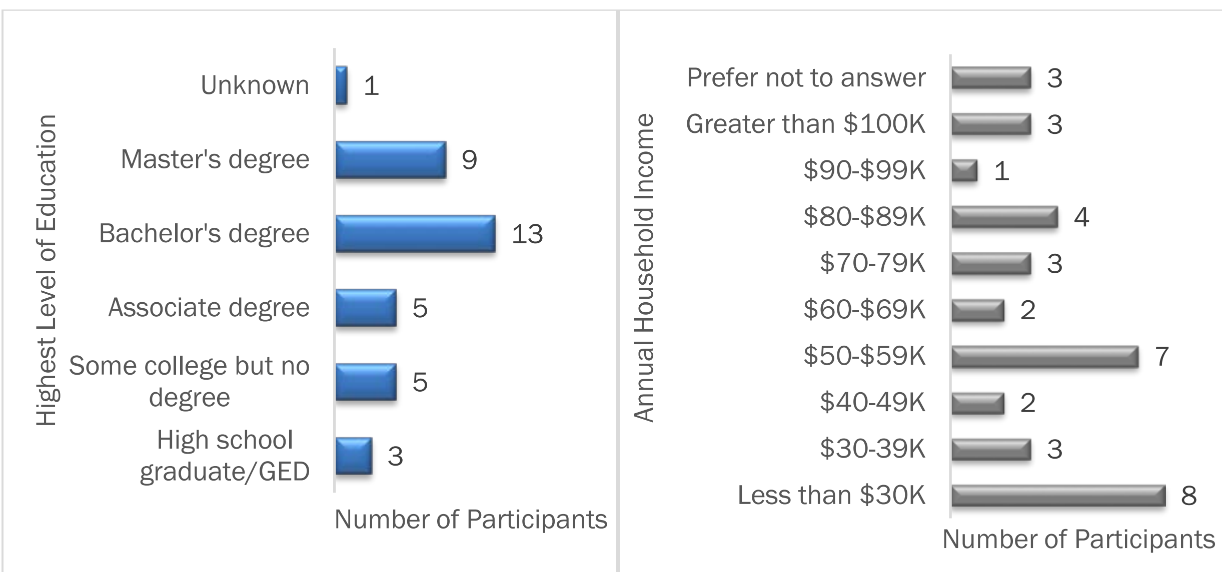

Figure 1. Bar chart. Participants' education and income.

Several steps were taken to protect participant privacy. The recruitment approach and associated materials were reviewed and approved by the Virginia Tech Institutional Review Board. In addition, the research team omitted participant names from interview audio files, and participant contact information was stored on password-protected computers accessible only to researchers.

Consent forms that included detail about the study were distributed to participants before the on-site interview. Participants also had the opportunity to read the information and ask questions upon arrival at VTTI for Session 1. Prior to the phone interview, participants were reminded about key points of the consent form, such as freedom to withdraw and use of an audio recorder.

Session 1: Technology and Information Exposure

During Session 1, participants came to VTTI and were given an assessment, both before and after exposure, to a combination of training materials that explained active safety technologies. Participants took part in the following activities during Session 1:

1. Pre-active safety technology exposure assessment
2. Active safety technology exposure
3. Post-exposure assessment

Pre-active Safety Technology Exposure Assessment

Prior to exposure to the training materials, participants were issued a pretest to determine their awareness of and experience with driver safety systems (see Appendix C). Despite the fact that participants indicated during recruitment that they did not have experience driving with the features being considered in this study, during the pretest a few participants said they did have experience with some features. The pre-active safety exposure assessment revealed that very few had knowledge of and/or experience with driving a vehicle with ACC, LDW, LKA, or AEB (Figure 2). Of those reporting experience with the technologies:

- One reported experience driving a vehicle with seven of the nine technologies: ACC, blind spot monitor, LDW, LKA, back-up warning, FCW, and AEB.

- One indicated experience driving a vehicle with a blind spot monitor, LDW, back-up warning, and pedestrian detection.

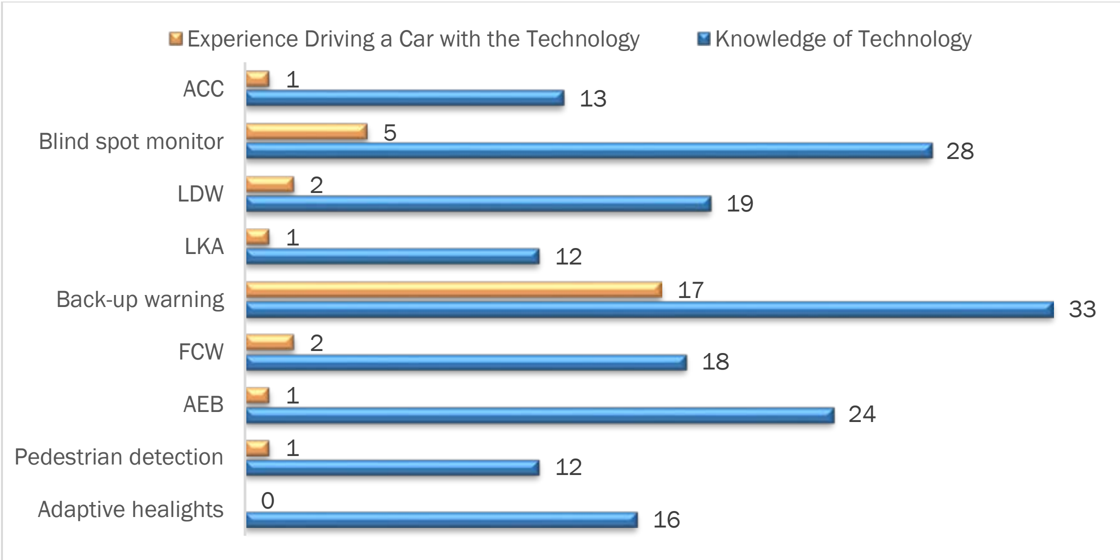

Figure 2. Bar chart. Participants' previous knowledge of experience with active safety features.

Additionally, participants were asked to complete a learning style self-assessment (National Highway Institute, 2004). This assessment was used during the analysis of the post-exposure questionnaire.

Four learning styles were identified (National Highway Institute, 2004; Pennsylvania Highway Education Assistance Agency, 2011):

1. Visual: learn by reading or seeing pictures; understand and remember things by sight.
2. Auditory: learn by listening; understand and remember things by hearing.
3. Kinesthetic: learn by touching and doing; understand and remember things through physical movement (i.e., hands-on activities).
4. Combination: no one learning style was preferred; two or more learning styles had the same score.

As learning style was not a screening factor, participants were not evenly distributed by learning style across vehicles (Figure 3) or across training conditions (Figure 4).

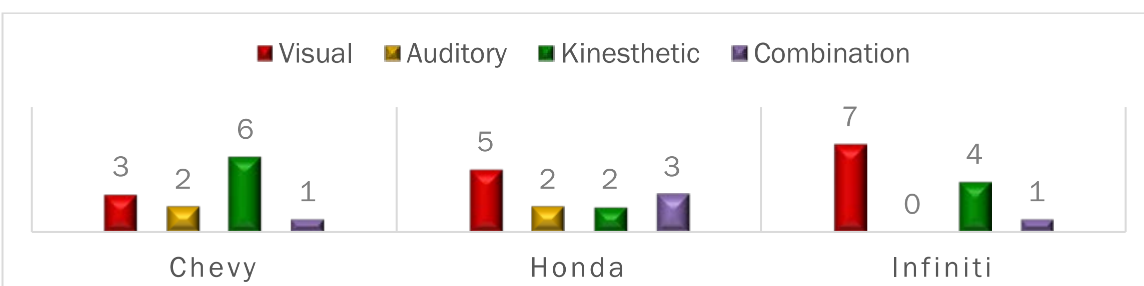

Figure 3. Bar chart. Participants' learning style by vehicle condition.

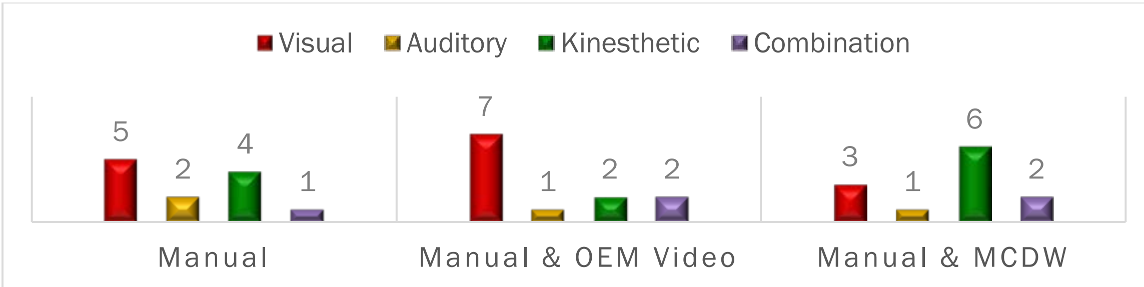

Figure 4. Bar chart. Participants' learning style by training condition.

Active Safety Technology Exposure

Each participant was presented with materials covering the three active safety technologies (i.e., ACC, LDW/LKA, and AEB). A technology table that included the names of the active safety technologies used by the manufacturer and/or MCDW (e.g., adaptive cruise control versus intelligent cruise control) was also provided. The type of educational/training materials participants were exposed to depended upon which vehicle (2015 Chevy Tahoe, 2016 Honda CR-V, or 2015 Infiniti Q50) and condition (i.e., manual only, manual and OEM videos, manual and MCDW videos) to which they were assigned, as shown in Table 3.

Table 3. Participant distribution among conditions.

Vehicle/Condition	Males (Younger)	Females (Younger)	Males (Older)	Females (Older)
Vehicle A manual only	1	1	1	1
Vehicle A manual and OEM videos	1	1	1	1
Vehicle A manual and MCDW videos	1	1	1	1
Vehicle B manual only	1	1	1	1
Vehicle B manual and OEM videos	1	1	1	1
Vehicle B manual and MCDW videos	1	1	1	1
Vehicle C manual only	1	1	1	1
Vehicle C manual and OEM videos	1	1	1	1
Vehicle C manual and MCDW videos	1	1	1	1

Participants were asked to review the materials as they would if they were reviewing them at home. All participants had 20 minutes to review the materials. This standard 20-minute review period ensured that all participants had equal exposure time to the educational/training materials.

Post-active Safety Technology Exposure

Following the active safety technology exposure, a post-exposure interview was conducted to explore participants' comprehension of the instructional materials (Appendix D). For each presented technology, participants were asked to explain the following.

1. What is the purpose of the [technology]?
2. How does the [technology] work?
3. How do you activate the [technology] (answer specific to vehicle model)?
4. How do you deactivate the [technology] (answer specific to vehicle model)?
5. Does the [technology] provide an alert or warning? If so, please describe.
6. When is it appropriate to use the [technology]?
7. Are there situations when you shouldn't use the [technology]? If so, please describe.
8. If you were placed in this vehicle, would you feel familiar enough with the feature to use it?
    a. If not, what information would you require to feel familiar enough with the feature to use it?
9. Would you be willing to pay (approximately $2,000) more for a technology package that included, among other features, the technologies you reviewed today?
    a. If yes, why?
    b. If no, why not?
10. If you could split apart the package and only purchase the features you want, which if any, would you buy?
    a. If only a few features, why these features and not the other(s)?
11. Can you rank order your preference for these features, with 1 being most preferred down to 3 being least preferred?
    a. Why did you rank them this way?

During recruitment, participants were scheduled for a follow-up phone call to occur approximately 2 weeks after the initial session. After the interview was completed, the researcher reminded the participant of the follow-up phone interview. Every effort was made to schedule the participant exactly 2 weeks after their on-site visit; however, in cases where participants were unable to meet on the 14^{th} day, they were scheduled as close to that date as possible (mean/median of 15 days; mode of 14 days).

Session 2: Retention Assessment

Session 2 involved a follow-up phone call approximately 2 weeks after the on-site exposure. During the phone call, participants were asked questions 1 through 7 from the list of questions above for each active safety technology presented (see Appendix E). Retention responses were compared to pre- and post-exposure responses.

In addition, participants were asked in the phone interview if they had sought additional instructional information regarding either the vehicles or the technologies presented after Session 1. Those who confirmed that they looked for additional information were asked where they looked, what type of information they looked for, and whether the information they found helped them to better understand the vehicle's features/how the active safety technologies work.

Participants were also asked basic demographic questions (i.e., education level, annual household income).

CHAPTER 4. DATA ANALYSIS PLAN

As described, participants took part in the following assessments during this study.

1. Pre-active Safety Exposure Assessment (Pre-Exposure)
2. Post-active Safety Exposure Assessment (Post-Exposure)
3. Retention Safety Exposure Assessment (Retention)

The assessments included a mix of closed-ended (demographic, learning style, and active safety technology) and open-ended (active safety technology) questions. In terms of the closed-ended questions, the demographic questions covered gender, age, education, and household income. Learning style self-assessment questions identified learners as visual, auditory, kinesthetic, or combination learners (more than one learning style). Closed-ended active safety technology questions were used to gauge pre-exposure knowledge and experience with various automated features, not just those included in the study.

Open-ended questions were asked at the pre-exposure, post-exposure, and retention stages of data collection to gauge knowledge before and after the technology exposure as well as knowledge retained approximately 2 weeks after exposure. The pre-exposure questionnaire, which asked participants about the purpose of each technology and how it works, included fewer questions than the post-exposure and retention interviews. A more extensive list of questions about the active safety technologies was asked via phone interview during the post-exposure and retention assessments (e.g., purpose, how it works, alerts, and activation/deactivation).

Closed-ended questions were tallied and are reported in the results section. Open-ended questions were placed in Excel spreadsheets and qualitatively analyzed by three researchers. Qualitative analysis steps included:

1. Analysis Preparation
    a. On-site and phone interview responses were transcribed.
    b. Vehicle specific spreadsheets with participant responses to pre-exposure, post-exposure, and retention (phone interview) questions were created.
    c. Rubric for scoring open-ended responses was developed.
2. Qualitative Scoring
    a. Participant responses were scored (double-blind scoring).
    b. Scoring was quality controlled (third researcher).
    c. Final scores were entered in database.
3. Qualitative Analysis
    a. Responses to questions that were not scored and justifications for answers (i.e., willingness to pay, preference for features) were reviewed and issues of concern or interest were noted and summarized in the results and takeaways sections.

Each state of the analysis process is described in more detail below.

ANALYSIS PREPARATION

The first step in preparing the data for analysis was transcription of the initial on-site interviews and follow-up phone interviews. A researcher transcribed participant responses to the interview questions and placed them in Excel spreadsheets. Separate spreadsheets were created for each vehicle and technology. For example, there was a spreadsheet created for responses to questions about ACC in the Infiniti Q50 and another spreadsheet for responses to questions about ACC in the Honda CR-V. A researcher also placed the open-ended responses from the pre-exposure questionnaire into the Excel spreadsheets to enable a comparison between what participants knew before and after their exposure via an examination of responses to key questions about the purpose of a technology and how it works.

Though the scoring for this study was based on the content from each vehicle owner’s manual, the technology descriptions and usage tips included on MCDW exemplify the types of information participants would have been exposed to during the study, what they were asked about during the interviews (e.g., a technology’s purpose and how it works), and what they were scored on during analysis (Appendix F).

A column was created within each spreadsheet with information from the vehicle owner’s manual that corresponded to the question participants were asked. For instance, information from the Infiniti Q50 owner’s manual regarding how ACC works was included in the Infiniti Q50 spreadsheet along with participant responses about ACC. Researchers referenced this information while scoring how well participants who viewed Infiniti Q50 materials answered the question “how does ACC work?” Researchers also highlighted what they thought was the most important information for participants to understand from the vehicle owner’s manual so that scoring could be as uniform as possible between researchers. For example, under ACC in the Infiniti Q50, researchers made a note that that one key point participants should understand about how ACC works is that it uses a sensor to detect vehicles ahead.

After transcription was completed and spreadsheets were organized with participant responses, manual information, and key points, researchers came up with an approach to scoring open-ended responses. The research team developed a simple approach adapted from scoring rubrics used in the field of education (Connecticut State Department of Education, n.d.), as shown in Table 4. Basically, a participant was given a “2” if they demonstrated a clear understanding, a “1” if they demonstrated a partial understanding, and a “0” if they had a very limited or no understanding (Connecticut State Department of Education, 2005).

Table 4. Coding rubric (Connecticut State Department of Education, n.d.).

Points	Requirements
2	Participant demonstrates a clear understanding of this aspect of the feature. • The response may contain minor errors that do not detract from a demonstration of understanding.
1	Participant demonstrates a partial understanding of this aspect of the feature. • The response contains some attributes of an appropriate response, but lacks convincing evidence that the participant clearly understands this aspect of the feature.
0	Participant demonstrates very limited or no understanding of this aspect of the feature. • The response is associated with the feature, but contains few attributes of an appropriate response. • There are significant omissions or errors that indicate a basic lack of understanding in regard to this aspect of the feature.

RESPONSE SCORING

After the scoring rubric was finalized, a researcher went through all the questions and corresponding answers and scored participants' responses. To provide as much opportunity as possible for participants to get a correct score, the researchers often referenced more than just the response that corresponded to a particular question. For instance, if a participant described the purpose of ACC in their response to the question about how ACC works, they were given credit for the correct response for the purpose question even though the response occurred later in the interview.

After the first researcher was done scoring each participant, the scoring was blacked out and a second researcher repeated the process. The second researcher used the same rubric to score participant responses. Throughout the scoring process, researchers discussed areas of uncertainty in the coding with the principal investigator (PI) and determined how they should be addressed.

When the second researcher was done scoring, a third researcher (the PI) reviewed the results and compared the scores. If there was a difference in the scoring, the PI made a final decision about what the score should be, consulting with the researchers who did the scoring as necessary. After all scoring was completed, each participant had a pre-exposure score, a post-exposure score, and a retention score. The difference between scores (e.g., knowledge gained or lost between assessments) was also calculated.

This scoring analysis was done with responses to the following questions under each technology except AEB.

1. What is the purpose of the [technology]?
2. How does the [technology] work?
3. How do you activate the [technology] (answer specific to vehicle model)?
4. How do you deactivate the [technology] (answer specific to vehicle model)?
5. Does the [technology] provide an alert or warning? If so, please describe.
6. When is it appropriate to use the [technology]?
7. Are there situations when you shouldn't use the [technology]? If so, please describe.

As described earlier, the pre-exposure only asked participants about the purpose of the technology and how it works. For this reason, some charts in the results section only compare post-exposure to retention because a pre-exposure score was not available.

Questions about when it is appropriate/not appropriate to use AEB were not scored since AEB is an emergency system that is not designed to be turned on/off. With few exceptions (e.g., when pulling a trailer), it is appropriate for the system to always be active to help prevent or reduce the severity of a crash. Researchers reviewed responses to this question to see if there was any misunderstanding of when it could be used. For instance, participants in some cases indicated that AEB was only for highway use.

QUALITATIVE ANALYSIS

Open-ended questions that were not scored were reviewed by a researcher to see if there was anything of interest or any notable trends in the data. For instance, participants were asked at the end of the phone interview if they had sought additional information after the on-site visit and if so, whether the information was helpful. There were also some questions from the initial interview that were not asked in the follow-up phone call. For example, participants were asked if they would feel familiar enough with the feature to use it and, if not, what they would require to feel familiar enough with the feature to use it. Researchers analyzed the responses to these questions and noted issues of concern, such as participants who indicated that they wanted to practice with AEB before using the system.

The method used to complete the qualitative analysis was an adaptation of framework analysis, a methodology developed in the 1980s at the National Center for Social Research in Britain (2012). This matrix-based approach allows researchers to manage and analyze qualitative data sets in a logical and thorough manner. Through this iterative approach, data are reduced through summarization and synthesis; however, links to original data are retained. The output allows for comprehensive and transparent data analysis. The National Centre for Social Research notes several advantages associated with the use of framework analysis (Ritchie, Spencer, & O'Conner, 2003). First, data are ordered in descriptive groupings (columns), which aids in question-focused analysis (e.g., "Are there situations when you shouldn't use ACC?"). Second, the matrix-based approach aids the search for explanation (looking across rows). This method has been used for previous VTTI-led research efforts, including the Human Factors Analysis of Level 2 and Level 3 Automated Vehicle Systems (Blanco et al., 2015).

Researchers also reviewed participant comments to identify issues of concern or interest. Particular focus was paid to misunderstandings that could pose a safety concern. For instance, some participants confused LDW and LKA with BSW. Issues of concern or interest are described in the results section under "Key Takeaways."

LIMITATIONS

As with any method, limitations exist. Qualitative analysis such as this is time- and labor-intensive. Researchers need to ensure that the focus remains on the process as opposed to the outcome. Additionally, when analyzing data, researchers should be reflexive and critical and should not force data into themes or categories (Ritchie et al., 2003).

Throughout the testing and scoring processes, researchers worked to keep the focus on the process as opposed to the outcome. During the interview sessions, participants were asked a consistent set of questions across all technologies. While not all questions lent themselves to scoring (e.g., when it is appropriate/not appropriate to use AEB), these questions did provide a means for researchers to see if participants understood key aspects of the technologies.

In an effort to minimize guesses or lead participants to particular responses, throughout the post-active safety technology exposure and retention assessments, follow-up questions were kept to a minimum and were sufficiently vague so as to prevent guessing (e.g., "How does the technology work?" versus "Is there a sensor that reads the line markings?"). Researchers sought to counter this possibility by scoring questions across closely related questions (e.g., purpose and how it works, appropriate and not appropriate) in case a key concept was noted in the complementary question. Further, participants were given opportunities to provide feedback on both the technologies and the training materials throughout the process. Still, it is possible that participants' full understanding of the technology may not have been expressed to the researcher.

While a hands-on component may have provided an additional learning opportunity for participants, such an opportunity was not available due to the timing of the participant interactions and the availability of vehicles with these advanced technologies.

Participants were self-selecting, having signed up to participate through VTTI's internal participant database. As such, these individuals may have had more interest, in general, in learning about new technologies than the average individual. Additionally, since the majority of participants had at least some college education, these individuals may have been more adept at understanding the training materials and technologies presented.

Though the study had a relatively small sample size, it was sufficient for the team to identify potential trends regarding preferred training materials and comprehension shortcomings. However, these findings cannot be generalized to the broader population based on this study alone.

CHAPTER 5. RESULTS

Although responses were scored by three researchers working separately, the scores presented throughout this chapter are based on qualitative assessments. No claims of statistical significance can be made based on these findings. However, findings are still useful in that they directed attention to trends in the data and opportunities for improved training materials. These trends and opportunities are discussed in the following chapter.

TECHNOLOGY UNDERSTANDING

Purpose and How It Works

Participants' post-active safety technology exposure scores and retention scores were compared to their pre-active safety technology exposure results for the questions:

1. What is the purpose of the [technology]?
2. How does the [technology] work?

As the answers to these two questions were so closely related, the questions were considered concomitantly. This approach allowed the researchers to obtain a better sense of the participants' understanding of the technology in question over time. Qualitative findings across all technologies suggest that learning occurred. Moreover, participants, as a group, obtained at least a partial understanding of key aspects associated with each technology which they generally maintained over a 2-week period (Figure 5). Of the presented technologies, participants were able to best explain and retain information related to ACC, likely due to established mental models associated with current cruise control technology. Participants demonstrated the most difficulty describing LDW/LKA, which will be discussed further.

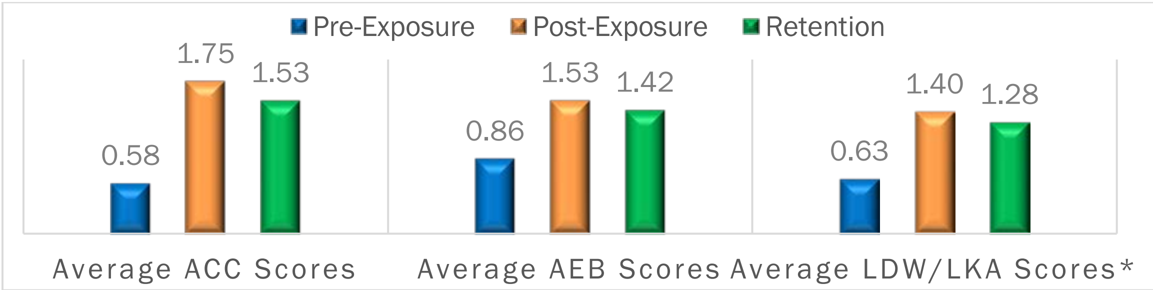

Figure 5. Bar chart. Average purpose and how-it-works scores for all participants. *Chevy Tahoe scores based only on LDW.

Looking at the average ACC purpose and how-it-works scores (Figure 6), those in the owner's manual only condition showed a slightly better understanding of the technology than those in either of the video conditions; however, the responses in all conditions reflect a near complete understanding of the technologies. The two video conditions resulted in the same average post-exposure score; however, the OEM video condition reflected slightly less retention than the MCDW condition. Due to the subjective nature of the scores, this difference should be considered slight and potentially due to the limited follow-up questions. Those in the MCDW condition also expressed a better pre-exposure understanding of ACC, which may have impacted retention.

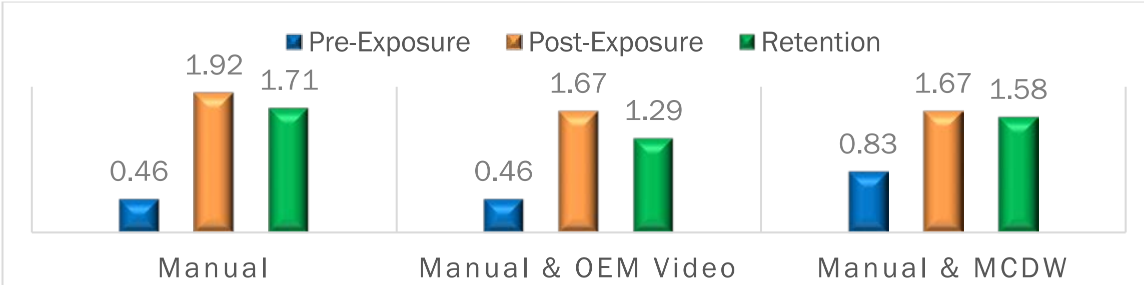

Figure 6. Bar chart. Average ACC scores by condition (purpose and how it works).

The post-exposure assessments were roughly the same across conditions for AEB (Figure 7). Even though some decrease in retention was expected, the average retention score for the manual condition improved slightly. When looking for a reason why this may have occurred, the researchers noted that more detailed responses were provided during the retention assessment than during the post-exposure assessment, perhaps as a result of the respondents having additional time to think about the information. The researchers caution against interpreting this as additional learning; rather, it should be considered a limitation of the research method.

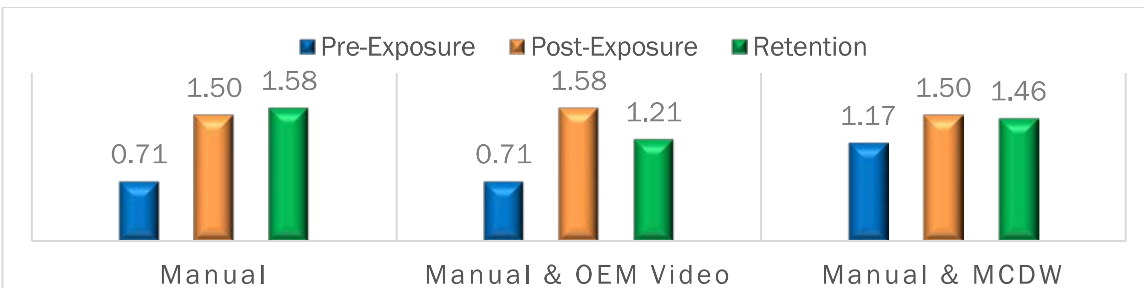

Figure 7. Bar chart. Average AEB scores by condition (purpose and how it works).

Across conditions, the average post-exposure and retention scores associated with the LDW/LKA systems were the lowest of the technologies reviewed (Figure 8). However, breaking the scores out by condition revealed that not all participants had difficulty understanding the purpose of the technologies and how they worked. Further, these findings help to illustrate the importance of clearly presented, technology-specific instructional materials.

As noted, the Chevy Tahoe was selected because it provided a point of comparison with the other two vehicles, offering LDW but not LKA. When comparing the average scores of those in the Chevy Tahoe condition to those in the Honda CR-V and Infiniti Q50 manual conditions, the scores were expected to be generally comparable. However, the scores and responses indicated that the participants in the Chevy Tahoe condition had a more difficult time grasping LDW's purpose or how it worked, while those in the Honda CR-V and Infiniti Q50 manual conditions expressed an almost complete understanding of the systems.

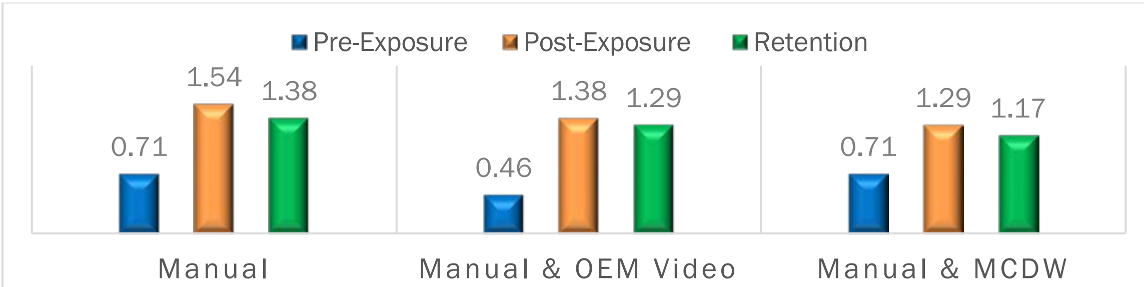

Figure 8. Bar chart. Average LDW/LKA scores* by condition (purpose and how it works). *Chevy Tahoe scores based only on LDW.

Activation and Deactivation

The next questions explored participants' understanding of how technology should be activated and deactivated. Again, these questions were considered in tandem as they are so closely related.

It is important to note that for these questions and the following questions, participants' scores are based on characteristics associated with the vehicle; therefore, while the MCDW videos can help illustrate how a technology works and its purpose, the MCDW resources cannot be expected to provide details specific to each individual vehicle make and mode.

Those in the ACC conditions again demonstrated the greatest understanding (Figure 9) and those in the AEB condition the least (Figure 10). Reviewing the responses, it became clear that participants did not fully understand that AEB was an active safety system and, as such, did not need to be activated each time it might be needed or wanted, which points to another point of confusion—the need to distinguish between when systems are available (i.e., enabled) and when they are on (i.e., activated). Participants' inability to distinguish between enabled and active is reflected in the scores across all the technologies. For example, the Infiniti Q50's LDP (i.e., LKA) feature can be enabled or disabled by completing the following steps:

1. Push the MENU button and touch [Driver Assistance] on the lower display.
2. Touch [Lane Assist].
3. Touch [Lane Departure Prevention] to enable or disable the system.

However, it is activated in the following manner:

> To turn on the LDP system, push the dynamic driver assistance switch on the steering wheel after starting the engine. [Image provided] The driver assist system lane indicator (green) will illuminate in the vehicle information display. Push the dynamic driver assistance switch again to turn off the LDP system. The driver assist system lane indicator (green) will turn off. (Infiniti USA, 2015, p. 5-36)

When scoring the Infiniti LDW/LKA, individuals were given two points if they indicated that the system was activated by pushing the dynamic driver assistance switch on the steering wheel after starting the engine (i.e., push the switch/button on the steering wheel). Responses ranged from variations of "pressing a button" to "going into the menu screen and selecting LDP." Those who read the manual did slightly better than those in the other conditions (Figure 11). Again, MCDW cannot be expected to address the specifics associated with each vehicle.

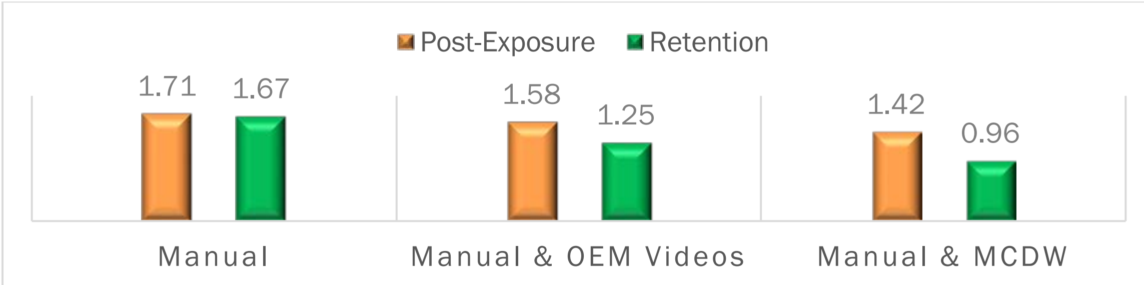

Figure 9. Bar chart. Average ACC scores by condition (activation and deactivation).

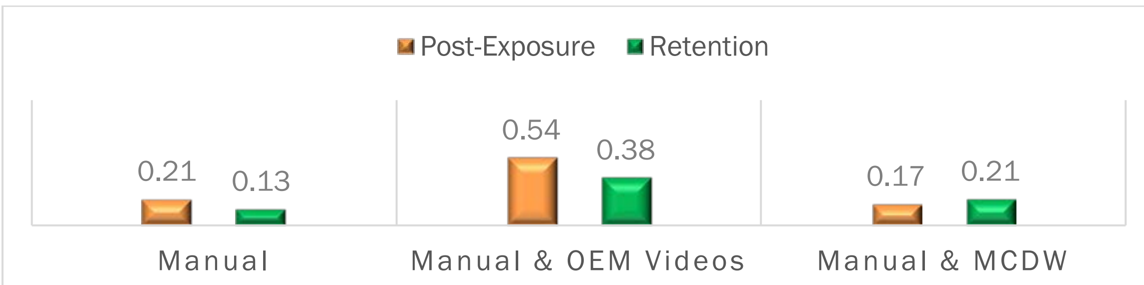

Figure 10. Bar chart. Average AEB scores by condition (activation and deactivation).

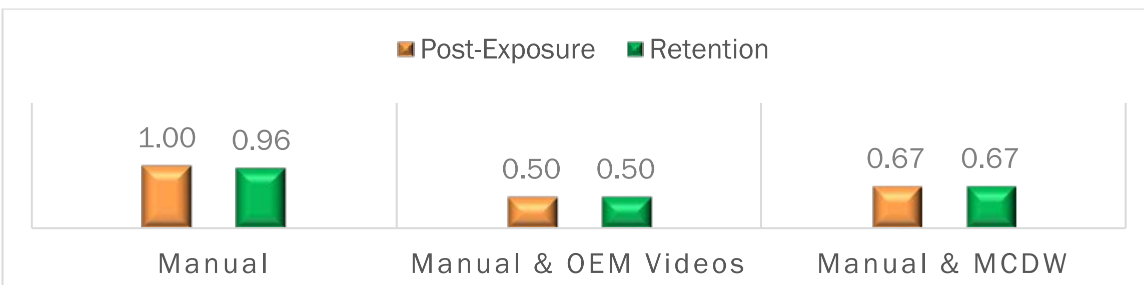

Figure 11. Bar chart. Average LDW/LKA scores* by condition (activation and deactivation). *Chevy Tahoe scores based only on LDW.

Alert or Warning

Next, participants were asked if the system provided an alert or warning. If they indicated an alert was provided, they were then asked to describe it. In most instances individuals knew whether or not there was an alert or warning; however, they were often unsure of its specific characteristics (e.g., if ACC cannot apply sufficient braking, six red lights flash on the windshield and eight beeps sound from the front, or both sides of Safety Alert Seat pulse five times). Additionally, participants often guessed or assumed that an alert/warning was present based on their knowledge of an alert associated with one of the other technologies in question.

The average scores for all alerts/warnings (ACC, AEB, and LDW/LKA) combined were fairly consistent across training conditions (Figure 12).

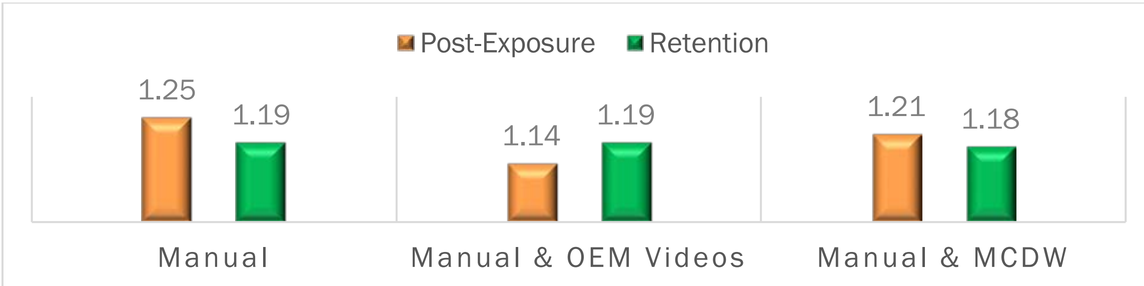

Figure 12. Bar chart. Average alert scores (all technologies). *Chevy Tahoe scores based only on LDW.

Appropriate and Inappropriate Use

Participants were asked when it was appropriate to use the technologies and if there were situations when the technologies should not be used. Across technologies, participants again had the easiest time explaining when it was appropriate to use ACC. Those with the manual demonstrated the greatest understanding, as they had the full time available to them to study and review the numerous scenarios that the vehicle owner's manuals caution against.

When discussing the appropriate times to use ACC, participants focused on highway conditions, good weather, and straight roads. Bad weather, bad road conditions, and curvy roads were identified as inappropriate times to use the system (Figure 13).

Figure 13. Word cloud. Participants' perceptions of when it is appropriate and inappropriate use ACC.

In regard to AEB, researchers wanted to see if participants understood that, unless the vehicle has an AEB system that can be turned off, the AEB system should always be active above a certain speed threshold. While participants did note that it could be used any time, they also noted a number of other conditions when it was appropriate and inappropriate to use the system (Figure 14).

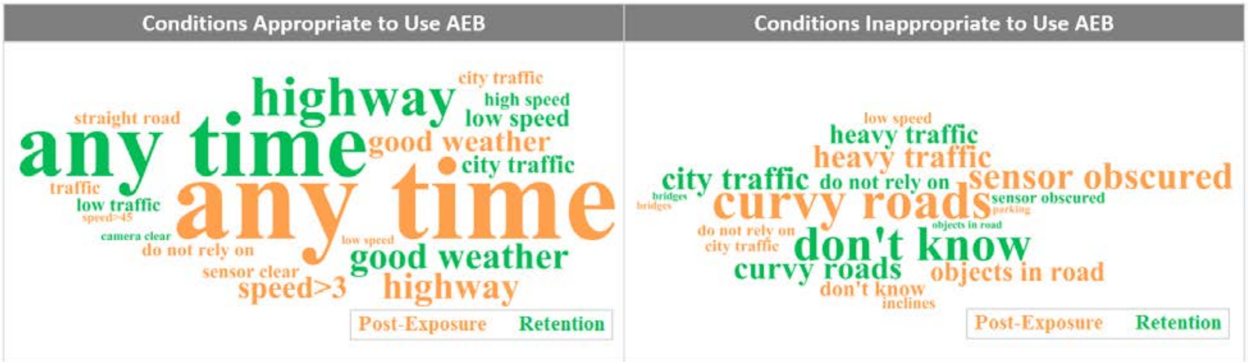

Figure 14. Word cloud. Participants' perceptions of when it is inappropriate to use AEB.

Participants generally had clear perceptions of when it was and was not appropriate to use the LDW/LKA systems (Figure 15). Researchers looked to see if participants indicated that the systems needed to be able to read the lane lines and that the roads needed to be relatively straight. For the most part, participants noted road conditions that would meet the requirements (highways) while also noting conditions when the lines would be obscured either generally or specifically (e.g., bad weather).

Figure 15. Word cloud. Participants' perceptions of when it is appropriate to use LDW/LKA.

Familiarity with Technology

Participants were asked if they were driving the vehicle whether they would feel familiar enough with the technology to use it. If they indicated that they did not feel familiar enough to use the technology or if they qualified their response (i.e., yes, but…), they were asked what information they would require to feel familiar enough with the technology to use it. Most frequently, across technologies, participants responded that they would like to have hands-on practice using the technologies. Participants also noted that they would read the manual again or have the manual on hand, or prefer a demo (either in person or video). A few simply noted that they were not ready to rely on the technologies either due to driving style preferences or safety concerns.

While hands-on practice is a practical request for ACC and LDW/LKA technologies, practice with the AEB system is not practical (or safe). When describing AEB systems, videos are beneficial in that they can provide drivers with a better idea of what they might experience should the system activate. In looking at the responses, those in the multimedia (i.e., video) conditions expressed the greatest sense of certainty and familiarity with the driving automation systems (Figure 16, Figure 17, Figure 18).

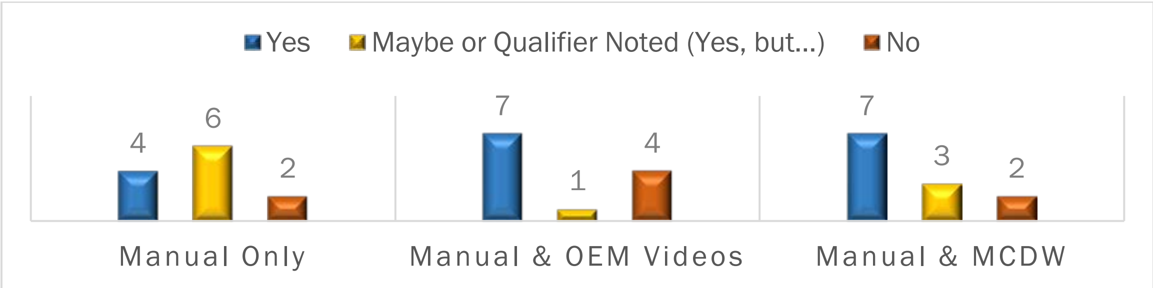

Figure 16. Bar chart. Participants' perceived familiarity with ACC.

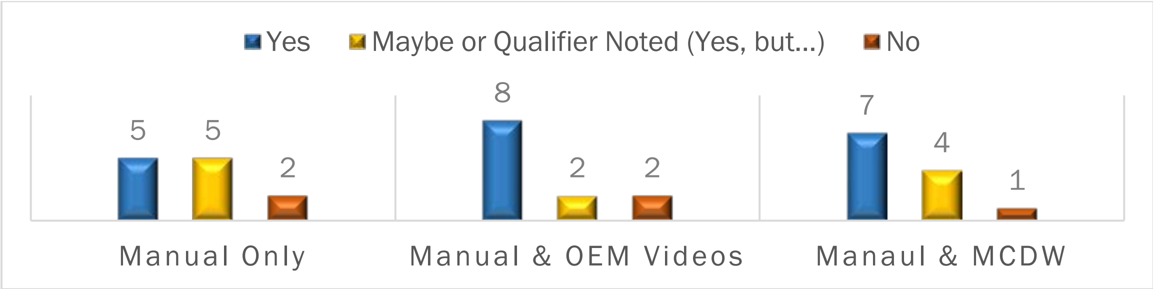

Figure 17. Bar chart. Participants' perceived familiarity with AEB.

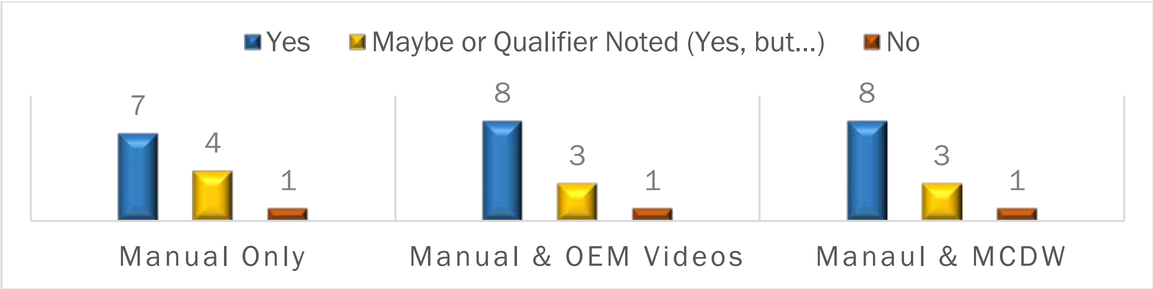

Figure 18. Bar chart. Participants' perceived familiarity with LDW/LKA*.
***Chevy Tahoe scores based only on LDW.**

Training Material Feedback

For each technology, participants were asked to provide feedback on the training materials. The feedback was grouped as it relates to the manuals (Figure 19), the OEM videos (Figure 20), and MCDW (Figure 21).

Participants found that the owner's manual did a good job of laying out specific technology details and diagrams of how the technology worked. Several noted that they would look at the video for a general overview of the technology but then look to the manual for specific details.

To improve design and layout of the manual, some participants suggested that materials should be easier to read and understand and be less repetitive. Specific suggestions included more clearly differentiating between technologies (for example, through color-coded sections) while also proving better descriptions of how systems interact with each other. Further, when discussing limitations, participants suggested providing a clearer differentiation between warnings about conditions in which the system **may not** work, or work as well, versus conditions where the system **will not** operate. Participants tended to get caught up in details (e.g., not recommended for use on steel bridges) and miss key points (e.g., must be able to read the lane lines).

Videos were found to be an entertaining and easier-to-understand alternative to the owner's manual. Several participants indicated that they would refer to the video first to see how the technology worked and then refer to the manual to gain a more in-depth understanding. Videos with sound and additional details were preferred to the simpler animations.

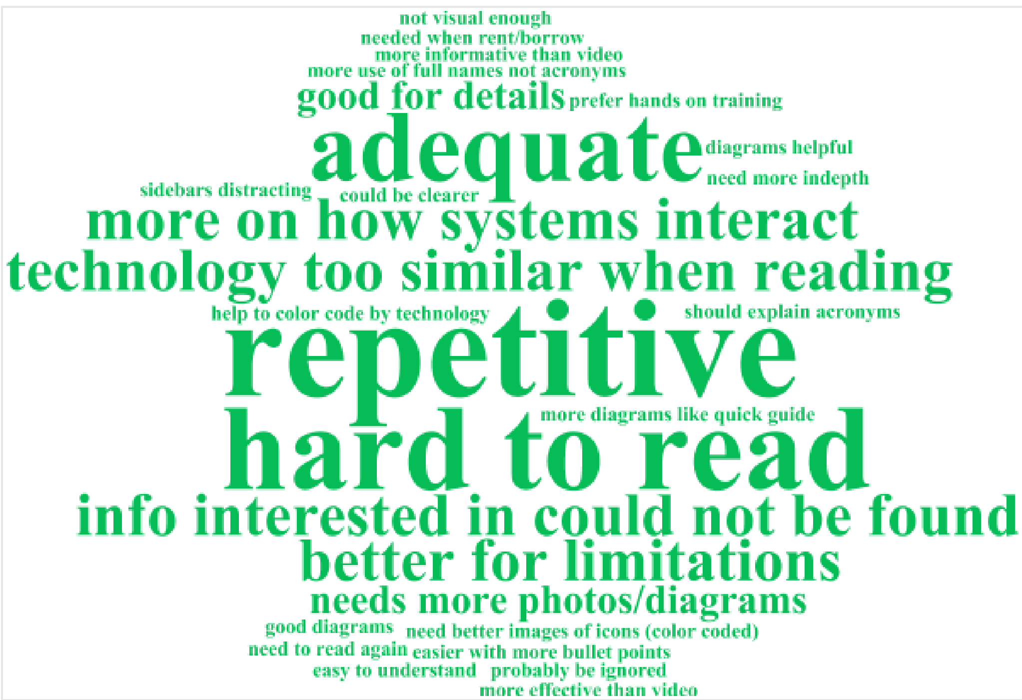

Figure 19. Word cloud. Participants' feedback on the manuals.

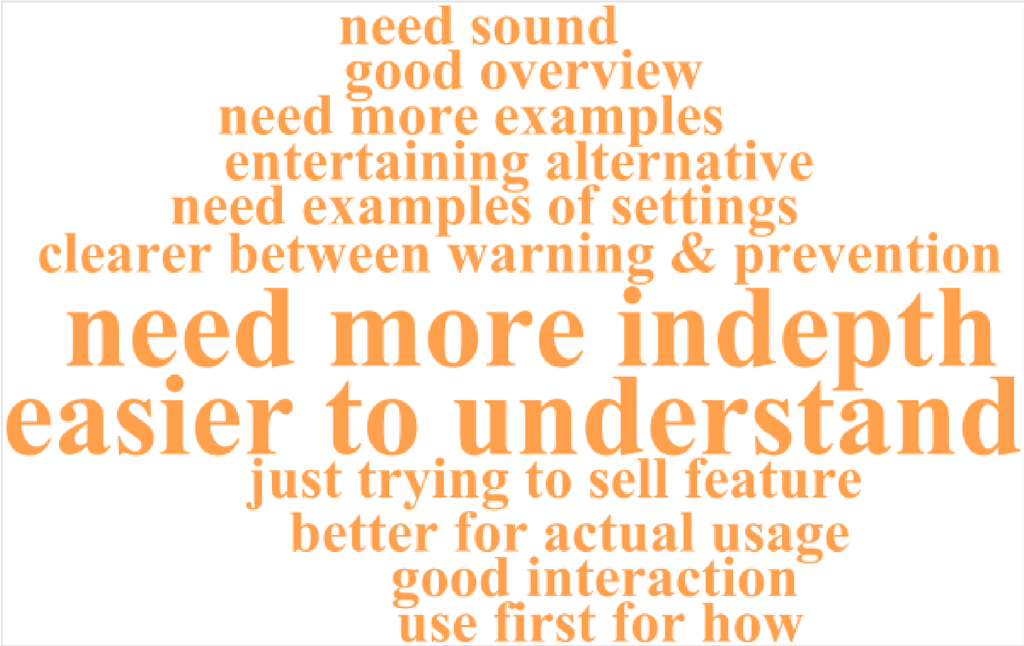

Figure 20. Word cloud. Participants' feedback on OEM videos.

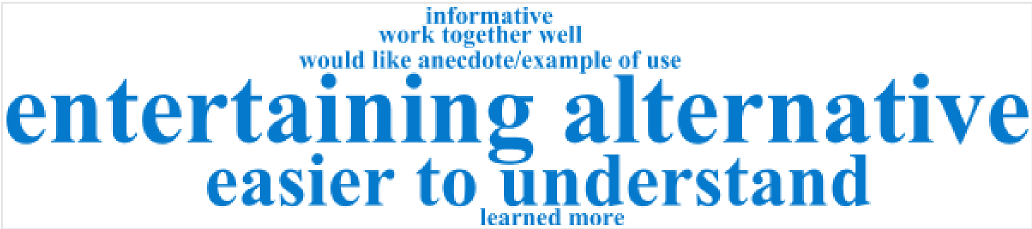

Figure 21. Word cloud. Participants' feedback on MCDW.

TECHNOLOGY PREFERENCES

The post-exposure assessment concluded with a number of questions designed to elicit feedback regarding participants' technology preferences.

Willingness to Pay

First, participants were asked if they would be willing to pay approximately $2,000 more for a vehicle equipped with a technology package that included, among other features, the technologies they reviewed during the session. The majority of the participants were unwilling to pay more for the technology package (Figure 22). Participants who were willing to pay for the technology package primarily noted the safety benefits associated with the technologies. Those who were not willing to pay for the technologies stated a variety of reasons, from cost, to incompatibility with current driving styles (i.e., prefer to be in control), to a belief that the technologies should be standard on new vehicles (Figure 23).

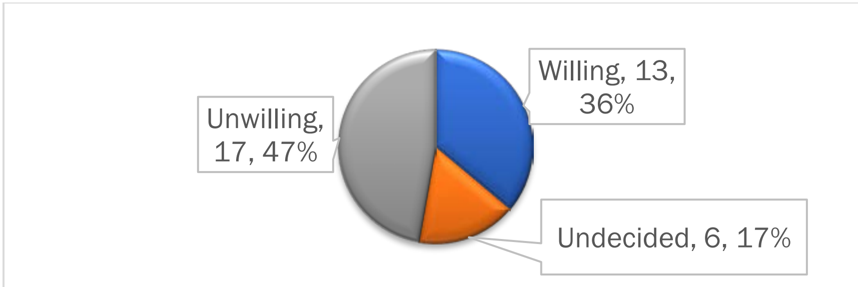

Figure 22. Pie chart. Participants' willingness to pay for technology package.

Figure 23. Word cloud. Reasons why participants would not be willing to pay for technologies.

Preferred Technologies

To follow-up, participants were asked which technologies they would want if they could split the technology package apart and select only the features they would buy. For this question, participants were allowed to select more than one technology (Figure 24). The majority of participants (20) indicated that they wanted the AEB system. Three participants indicated that they would not want any of these features.

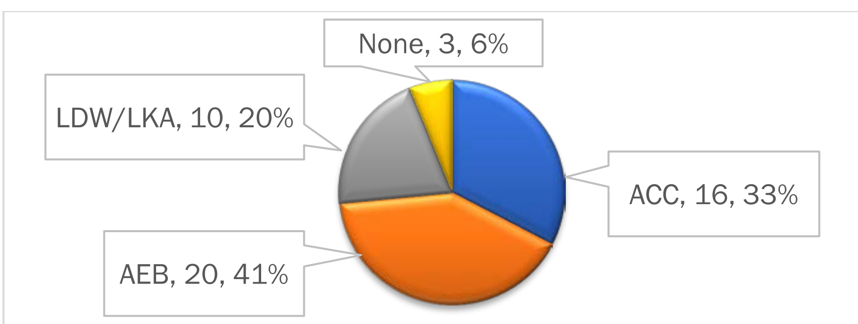

Figure 24. Pie Chart. Participants' individual technology preferences, rank ordered.

As a final exercise, participants were asked to rank order their preferences for the technologies, with 1 being most preferred to 3 being least preferred (Figure 25). Those in the owner's manual condition tended to favor ACC over AEB, while the inverse was true for those in the multimedia conditions. Regardless of training condition, LDW/LKA was predominantly participants' second or third choice.

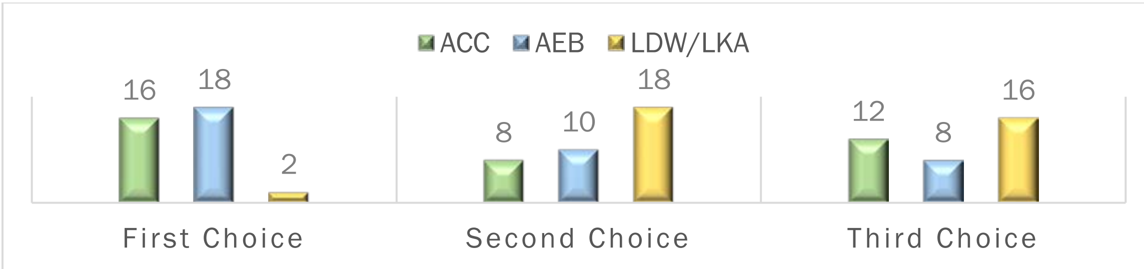

Figure 25. Bar chart. Participants' rank-ordered preferences (all training conditions).

When asked why they ranked the technologies the way they did, the justifications given in Table 5 were provided (grouped according to general theme).

Table 5. Participants' justifications for technology preference rankings.

Justification	ACC	AEB	LDW
Deemed useful to participants' own driving conditions/habits	20	3	5
Deemed not useful to participants' own driving conditions/habits	7	4	10
Concerned could alter participants' own attention to driving	0	1	0
Afraid other drivers would not be as attentive while driving	4	3	4
Deemed feature as important for safety	2	15	4
Not sure the feature is ready for use because of limitations	1	8	3
Believe the feature should be standard	0	1	0

LEARNING STYLE

As noted, participants were asked to complete a learning style self-assessment. Participants' average scores across all technologies were fairly comparable across learning styles (owner's manual versus multimedia; Figure 26).

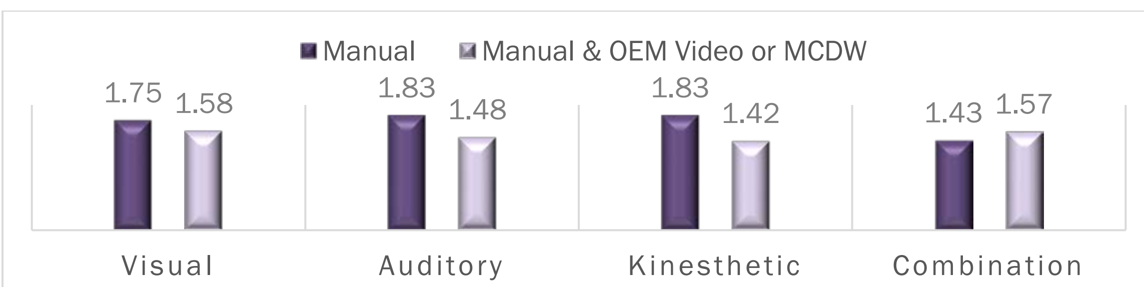

Figure 26. Bar chart. Average scores for all technologies by learning style (manual vs. manual and OEM video or MCDW).

SUMMARY OF RESULTS

Regardless of training condition or learning style, participants were able gain at least a rudimentary understanding of how the driving automation system technologies worked and their purposes. However, participants were less sure of the specifics associated with the technologies (i.e., activation, alerts/warnings, and appropriate use). Participants were best able to articulate specifics associated with ACC, most likely due to established mental models associated with ordinary cruise control. Those in the multimedia conditions reported feeling more familiar with the technologies than those in the owner's manual only condition. In addition to providing basic information, videos provided important contextual information about the technologies' operations that could not be obtained from review of the manual alone. Participants found the videos to be an entertaining and easier-to-understand alternative to the manual. Several indicated that they would refer to the video first to see how the technology worked and then refer to the manual to gain a more in-depth understanding. Videos with sound and additional details were preferred to the simpler animations.

CHAPTER 6. TAKEAWAYS AND FUTURE RESEARCH

In this chapter, takeaways from participants' comments are discussed. Participants' comments were reviewed to find anything informative or concerning that arose across vehicle types and conditions. For instance, several participants across vehicle types and conditions thought that ACC was a technology that would help users avoid collisions, whereas ACC is instead designed to help a user maintain a safe following distance and speed; it is not a collision avoidance system. For illustration purposes, each takeaway includes participant comments. The list is not inclusive of every takeaway, but rather represents some of the more concerning or informative comments made by participants.

ACC TAKEAWAYS

1. **Users need to understand that the purpose of ACC is not collision avoidance**. While users may grasp that ACC is a technology that can help maintain a safe distance and speed from a lead vehicle, they should not assume that equates to collision avoidance. Users should know that they must maintain proper attention to the road and not depend on ACC to prevent collisions.

    - **Example comment regarding the purpose of ACC**: To keep the car from hitting a car in front of you while maintaining a safe speed. I think it's about a preset speed. And you have 1, 2, or 3 seconds.

2. **User understanding of the appropriate use of ACC needs to expand beyond thinking it is always appropriate on highways.** While many participants could name a variety of conditions under which ACC use is appropriate or inappropriate, several participants said simply that it was a system for use on the highway. Yet the owner's manuals for each of the vehicles used in this study provided several specific conditions defining when ACC is appropriate or inappropriate to use. For instance, most of the ACC systems covered in this study require, for appropriate use, good weather, straight roads, evenly flowing traffic, and a minimum speed threshold (e.g., 25 mph). If users do not understand the conditions under which sensors may not be able to monitor the vehicle ahead (e.g., curvy roads, adverse weather), they may use the system in unsafe conditions.

    - **Example comment regarding appropriate ACC usage**: On a highway.

AEB TAKEAWAYS

1. **Users should understand the limits of AEB and remain alert to traffic ahead.** The vehicles in this study had AEB systems designed to assist the driver when there is a risk of a collision; none of the system manuals or videos stated that AEB would prevent a collision. Yet several users described AEB as something that would prevent accidents. Users need to know that they should remain alert and not count on AEB to prevent a collision; rather, they should consider AEB an accident avoidance system.

- **Example comment regarding the purpose of AEB:** To stop the vehicle if the driver is distracted. To prevent crash based off driver reaction time.

2. **Users should know that AEB is typically active at certain speeds unless it has been turned off**. Several study participants thought AEB had to be activated. The fact that other systems in this study (i.e., ACC and LDW/LKA) typically must be turned on and activated may have led users to be confused and think that AEB worked the same way. It should be made clear to users that AEB is different. Unless a user has an AEB system that can be turned off, AEB is typically active above a certain speed threshold (e.g., 3 mph).

   - **Example comment regarding how to activate AEB**: Button - kind of like cruise control. Another system you have to engage.

3. **Users should understand that while AEB has some limitations, it is a safety feature that should remain on in most cases.** Several study participants described the appropriate use of AEB similarly to other convenience features, such as ACC. For example, some described it as appropriate for highway use or not appropriate in heavy traffic. While users should know that AEB has some limitations (e.g., roads with sharp curves may impact detection capabilities) and should be knowledgeable of specific instances when it should not be used (e.g., one study vehicle noted it should not be used when towing a trailer), in most cases this safety feature should be left on to assist drivers in avoiding accidents.

   - **Example comment regarding when AEB is appropriate to use**: Same conditions as ACC - straight or slightly curving roads, good weather, between 45 and 90 mph
   - **Example comment regarding when AEB is inappropriate to use:** Same as not using ACC, windy roads, steep grades, hills, curves, thick traffic, stop and go sort of ordeals.

LDW/LKA TAKEAWAYS

1. **Users need to understand that LDW and LKA are convenience features; they are not a substitute for alert driving.** While not a major issue, a few participants described the purpose of LDW and LKA as alerting drivers if they are falling asleep/drowsy or distracted (i.e., texting).

   - **Example comment regarding the purpose of LDW/LKA**: Keep you alert as to where you’re at in the road. If you deviate from the lane that you’re going in to keep you from possibly falling asleep or hitting an animal.

2. **Users need to understand if their system provides LDW and LKA or just LDW.** Users need to know that some vehicles offer LDW and LKA together, while others only offer LDW. If a user only has LDW, it is important that they understand the feature will only provide a warning of a lane departure, not prevent it. In this study, 2

of the 12 participants who were exposed to materials for a vehicle that had only LDW described the feature as something that could prevent lane departure.

- **Example comment regarding purpose of LDW**: To prevent you from crossing over the line - suppose it's to prevent you from going into oncoming traffic.

CROSS-CUTTING TAKEAWAYS

1. **Users need to know where sensors (camera, radar, etc.) are located for each system and the basic purpose they serve so they understand when those sensors may become inoperable.** While users may know there is some sort of sensor being used for each technology, if they do not know where the sensors are located and their purpose, they may not understand when the system could become inoperable. While many participants were able to basically describe how sensors enabled these features to work (i.e., camera sensor reads the painted lines in LDW/LKA), there was some confusion for a few participants.

    - **Example comment regarding how ACC works**: I don't remember if it was the one with the camera on the rear-view mirror or if was just the radar thing, the sensor thing that you set the minimum gap that you want and the sensor senses if you're within that gap and then it decelerates if you're within the gap.
    - **Example comment regarding how AEB works:** Not sure, don't know.
    - **Example comment regarding how LDW/LKA works:** Didn't pick up on that - believe it again senses some sort of radar - ahead of you - may use structures or objects that it's following or parallel to let you know when you're shifting around these somewhat stable objects.

2. **Users can get confused between features; education/training materials need to clearly differentiate the functionality of each system.** Several participants confused the functionality of systems within the study and occasionally with other active safety features that were not part of the study. While it did not happen often, there were several participants who were confused and thought, for example, that LDW/LKA provided blind spot monitoring. Education and training materials should clearly differentiate between systems so that users do not depend on a system to assist them in ways that it will not.

    - **Example comment regarding how AEB works:** Works at speeds above 3 mph and warns the driver of any obstacles ahead or behind when backing or driving in an area. If there are any people or objects it will give a visual stimulus on the screen.
    - **Example comment regarding the purpose of LDW/LKA**: LDW - will essentially warn you if there's a car in your blind spot or a car that you're going to get in front of or hit. LKA - tries to keep you in the middle of your lane.

3. **Users should be clear about which systems need to be activated (i.e., ACC and LDW/LKA) and which are active unless turned off (i.e., AEB).** A few participants appeared confused about whether or not a particular system needed to be activated or not. For instance, several participants thought ACC and LDW/LKA would automatically activate under certain conditions. A few AEB users were unsure if their AEB needed to be activated or not.

    - **Example comment regarding ACC activation**: Automatically activated at speeds above 50 mph and below 90 mph.
    - **Example comment regarding AEB activation**: Going to assume there's a button that says activate or deactivate. Don't think automatic.
    - **Example comment regarding LDW/LKA activation:** Similar to the forward braking it just is on and is activated when the car registers that it needs to be used. It's kind of like an air bag - you don't turn on/off, just always there.

4. **Users need to understand how to activate/deactivate systems.** Several participants, when asked how to activate or deactivate a system, said only "press a button," without providing details as to where the button was located. Learning to activate/deactivate a system may be simply a function of spending time in the vehicle and becoming familiar with the location of the buttons/switches for each system, but it was of interest to the research team to note how many users, after reading/seeing educational materials, could not recall such details.

    - **Example comment regarding how to activate ACC**: You press a button. Where is it? I don't remember. And then a light comes on.
    - **Example comment regarding how to deactivate ACC**: However you cut it on do the opposite. No, I don't know. No point in lying, I don't know.
    - **Example comment regarding how to activate AEB**: Honestly not sure - assuming on steering wheel or on the keypad, console pad. Thinking on steering wheel as well.
    - **Example comment regarding how to deactivate AEB:** I want to say maybe there's a control like kind of where your blinkers are, but that might be the other one. I think there's a button somewhere.
    - **Example comment regarding how to activate LDW/LKA:** Not even sure – I'll just say a button on the dashboard or something
    - **Example comment regarding how to deactivate LDW/LKA:** Don't remember.

5. **Users need to know there is an alert and what the alert will sound/look/feel like for each system**. Every system on every vehicle had some type of alert. While many users understood that there were alerts and could basically describe them, others could not recall if there were alerts and/or could not describe them. Vehicle-specific multimedia materials may be useful in providing this information to users.

    - **Example comment regarding if ACC has an alert and its description**: Don't believe - just slows down automatically.

- **Example comment regarding if AEB has an alert and its description:** When the car stops that ought to get your attention. Don't remember if it had a beep or lights or whatever.
- **Example comment regarding if LDW/LKA has an alert and its description**: Yes, I'm sure it does but I don't remember what it is.

6. **Users should be clear on conditions, such as speed, when they can safely use each feature.** Several study participants were unclear about the conditions, such as speed, when a system could be used. Making use conditions clear to participants through education/training is important so they know when it is appropriate to use a particular system. For example, AEB typically becomes operable at lower speeds (e.g., 3 mph), ACC becomes operable at moderate speeds (e.g., 25 mph), and LDW/LKA becomes operable at higher speeds (e.g., 40 mph).

    - **Example comment regarding when it is appropriate to use ACC:** Above a certain speed – 45 mph
    - **Example comment regarding when it is appropriate to use AEB:** Speeds over 45 mph
    - **Example comment regarding when it is appropriate to use LDW/LKA:** Same-over 25 mph, not curvy roads, good weather.

FUTURE RESEARCH

The findings of this study confirm previous studies suggesting that drivers do not rely on their owner's manuals for information about how their vehicles work (Mehlenbacher et al., 2002), and moreover, when they do, they often fail to fully comprehend specific system details (Jenness et al., 2008; Mehlenbacher et al., 2002; Strand et al., 2011). In-vehicle training materials, such as embedded center-stack videos provided jointly with owner's manuals, would allow drivers to view examples of system operations (e.g., activation and deactivation, alert or warning activation) as well as descriptions of system functionality (e.g., the identification of system critical sensor locations) from the perspective of the driver's seat. In addition, the use of in-vehicle training alternatives would fit the needs of both those who are interested in their vehicle and willing to invest time reading about it and those less interested in spending time learning about their vehicles by providing alternative learning activities for features (Stave & Strand, 2015). Vehicle-embedded training systems have the value of being specific to the vehicle design itself and are advantageous in that they remain with the vehicle over its entire lifecycle with multiple owners. Future research is needed to evaluate vehicle-embedded training options that allow drivers to become familiarized with the driving automation system and driver-vehicle interface, whether they are novices or long-time users looking to understand the benefits of using advanced features.

APPENDIX A. COMMERCIALLY AVAILABLE VEHICLES WITH LATERAL AND LONGITUDANAL AUTOMATION CAPABILITIES

Table 6. Table of lateral and longitudinal features available (green cells) or not available (grey cells) by vehicle make and model for the 2017 model year.

Vehicle		Lateral Features		Longitudinal Features	
Make*	**Model**	**Lane Centering**	**Lane Keeping**	**Adaptive Cruise Control**	**Forward Emergency Braking**
Acura	ILX	green	green	green	green
Acura	MDX	green	green	green	green
Acura	RDX	green	green	green	green
Acura	RLX	green	green	green	green
Acura	TLX	green	green	green	green
Audi	A3 Cabriolet	green	green	green	green
Audi	A3 Sedan	green	green	green	green
Audi	A3 Sportback e-tron®	green	green	green	green
Audi	A4	green	grey	green	green
Audi	A4 allroad®	grey	grey	green	green
Audi	A5 Sport	grey	grey	green	grey
Audi	A5 Sport Cabriolet	grey	grey	green	grey
Audi	A6	green	grey	green	grey
Audi	A7	grey	grey	green	grey
Audi	A8	grey	grey	green	grey
Audi	Q5	grey	grey	green	grey
Audi	Q7	green	grey	green	green
Audi	S3	grey	green	green	green
Audi	SQ5	grey	grey	green	grey
Audi	TT Coupe	green	grey	grey	grey
BMW	2 Series	grey	grey	grey	green
BMW	3 Series	grey	grey	green	green
BMW	4 Series	grey	grey	grey	green
BMW	5 Series	grey	grey	green	green
BMW	6 Series	grey	grey	green	green
BMW	7 Series	green	green	green	green
BMW	i3	grey	grey	grey	green
BMW	i8	grey	grey	grey	green
BMW	M Series	grey	grey	grey	green

Vehicle		Lateral Features		Longitudinal Features	
Make*	Model	Lane Centering	Lane Keeping	Adaptive Cruise Control	Forward Emergency Braking
BMW	X1				
BMW	X3				
BMW	X4				
BMW	X5				
BMW	X6				
Buick	Envision				
Buick	LaCrosse				
Buick	Regal				
Cadillac	ATS				
Cadillac	CT6				
Cadillac	CTS				
Cadillac	CTS-V				
Cadillac	Escalade / ESV				
Cadillac	XT5 Crossover				
Cadillac	XTS				
Chevrolet	Cruze				
Chevrolet	Equinox				
Chevrolet	Express Passenger				
Chevrolet	Impala				
Chevrolet	Malibu				
Chevrolet	Silverado 1500				
Chevrolet	Suburban				
Chevrolet	Tahoe				
Chevrolet	Volt				
Chrysler	200				
Chrysler	300				
Chrysler	Pacifica				
Dodge	Charger				
Dodge	Durango				
Fiat	500X				
Ford	C-MAX				
Ford	Edge				
Ford	Escape				
Ford	Expedition				

Vehicle		Lateral Features		Longitudinal Features	
Make*	Model	Lane Centering	Lane Keeping	Adaptive Cruise Control	Forward Emergency Braking
Ford	Explorer				
Ford	F-150				
Ford	Flex				
Ford	Focus				
Ford	Fusion				
Ford	Taurus				
Genesis	G80				
Genesis	G90				
Genesis	Genesis				
GMC	Acadia				
GMC	Sierra 1500				
GMC	Yukon				
GMC	Yukon XL				
Honda	Accord Hybrid				
Honda	Accord Sedan				
Honda	Civic Sedan				
Honda	Clarity Fuel Cell				
Honda	CR-V				
Honda	CR-Z				
Honda	Fit				
Honda	Fit Ev				
Honda	HR-V				
Honda	Odyssey				
Honda	Pilot				
Honda	Ridgeline				
Hyundai	Accent				
Hyundai	Azera				
Hyundai	Elantra				
Hyundai	Genesis Coupe				
Hyundai	Santa Fe				
Hyundai	Sonata				
Hyundai	Tuscon				
Infiniti	Q50				
Infiniti	Q60				

Vehicle		Lateral Features		Longitudinal Features	
Make*	**Model**	**Lane Centering**	**Lane Keeping**	**Adaptive Cruise Control**	**Forward Emergency Braking**
Infiniti	Q70				
Infiniti	QX30				
Infiniti	QX50				
Infiniti	QX60				
Infiniti	QX70				
Infiniti	QX80				
Jaguar	F-PACE				
Jaguar	XE				
Jaguar	XF				
Jeep	Cherokee				
Jeep	Grand Cherokee				
Jeep	Renegade				
Kia	Cadenza				
Kia	Forte				
Kia	K900				
Kia	Optima				
Kia	Sedona				
Kia	Sorento				
Kia	Sportage				
Land Rover	Discovery Sport				
Land Rover	LR4				
Land Rover	Range Rover				
Lexus	CT Hybrid				
Lexus	ES				
Lexus	F / F Sport				
Lexus	GS				
Lexus	GX				
Lexus	IS				
Lexus	LFA				
Lexus	LS				
Lexus	LX				
Lexus	NX				
Lexus	NX Hybrid				
Lexus	RC				

Vehicle		Lateral Features		Longitudinal Features	
Make*	**Model**	**Lane Centering**	**Lane Keeping**	**Adaptive Cruise Control**	**Forward Emergency Braking**
Lexus	RX				
Lexus	RX Hybrid				
Lincoln	Continental				
Lincoln	MKC				
Lincoln	MKS				
Lincoln	MKT				
Lincoln	MKX				
Lincoln	MKZ				
Mazda	CX-5				
Mazda	CX-9				
Mazda	Mazda CX-3				
Mazda	Mazda3				
Mazda	Mazda6				
Mercedes-Benz	B-Class Electric Drive				
Mercedes-Benz	C-Class				
Mercedes-Benz	CLS				
Mercedes-Benz	E-Class				
Mercedes-Benz	G-Class				
Mercedes-Benz	GLA				
Mercedes-Benz	GLC				
Mercedes-Benz	GLE Coupe				
Mercedes-Benz	GLE SUV				
Mercedes-Benz	GLS				
Mercedes-Benz	S-Class				
Mercedes-Benz	SL Roadster				
Mercedes-Benz	SLC Roadster				
Mini	Clubman				
Mini	Convertible				
Mini	Countryman				
Mini	Hardtop				
Mitsubishi	Outlander				
Mitsubishi	Outlander Sport				
Nissan	Altima				

Vehicle		Lateral Features		Longitudinal Features	
Make*	**Model**	**Lane Centering**	**Lane Keeping**	**Adaptive Cruise Control**	**Forward Emergency Braking**
Nissan	Armada				
Nissan	Maxima				
Nissan	Murano				
Nissan	Pathfinder				
Nissan	Rogue				
Nissan	Sentra				
Porsche	718				
Porsche	911				
Porsche	Cayenne				
Porsche	Macan				
Porsche	Panamera				
Subaru	Crosstrek				
Subaru	Forester				
Subaru	Impreza				
Subaru	Legacy				
Subaru	Outback				
Subaru	WRX				
Tesla	Model S				
Tesla	Model X				
Toyota	Avalon				
Toyota	Camry				
Toyota	Corolla				
Toyota	Corolla iM				
Toyota	Highlander				
Toyota	Land Cruiser				
Toyota	Mirai				
Toyota	Prius				
Toyota	Prius c				
Toyota	Prius Prime				
Toyota	Prius v				
Toyota	RAV4				
Toyota	Sienna				
Toyota	Yaris				
Toyota	Yaris iA				

Vehicle		Lateral Features		Longitudinal Features	
Make*	Model	Lane Centering	Lane Keeping	Adaptive Cruise Control	Forward Emergency Braking
Volkswagen	Golf				
Volkswagen	Golf GTI				
Volkswagen	Golf SportWagen				
Volkswagen	Jetta				
Volkswagen	Passat				
Volkswagen	Touareg				
Volvo	S60				
Volvo	S90				
Volvo	V60				
Volvo	V90				
Volvo	XC60				
Volvo	XC90				
Volvo	XC90				

*Note: Where applicable, the first entry in the table for each manufacturer contains a hyperlink to the manufacturer's description of their available safety technologies.

APPENDIX B. SUMMARY OF MATERIALS

2015 CHEVY TAHOE MATERIALS

Manuals

Getting to Know Your 2015 Tahoe/Suburban (Chevrolet, 2015b)
2015 Chevrolet Tahoe/Suburban Owner Manual (Chevrolet, 2015a)

Video Transcripts

Adaptive Cruise Control (0:28) [Video]
The available Adaptive Cruise Control on the Tahoe uses radar to detect a vehicle ahead and automatically adjusts your speed to maintain a selected following gap time. If while using cruise control the radar detects a slower vehicle ahead within the gap time, the system can reduce the speed of the vehicle to match the gap time. When no traffic is detected the system will accelerate the vehicle back to the previously set speed.

Forward Collision Alert & Front Automatic Braking (0:35) [Video]
Available Forward Collision Alert on the 2015 Tahoe uses a camera or radar to help prevent front collisions. It activates at speeds above 25 MPH and will alert the driver with visual and either safety alert seat vibrations or audio cues. With available Front Automatic Braking on the 2015 Tahoe, if the driver does not react quickly enough or if the traffic conditions suddenly change the system can automatically apply the brakes in certain situations.
Lane Departure Warning (0:20) [Video]

Available Lane Departure Warning on the Tahoe uses a camera mounted behind the inside rearview mirror to alert drivers if they drift out of the lane without using a turn signal. The technology activates at speeds above 35 MPH.

2016 HONDA CR-V

Manuals
2016 CR-V Owner's Guide (Honda Motor Co., 2016a)
2016 CR-V Owner’s Manual (Honda Motor Co., 2016b)

Videos
Available at: http://automobiles.honda.com/sensing/
Scroll down to each technology to watch silent animations

- Lane Departure Warning
- Lane Keeping Assist
- Adaptive Cruise Control
- Collision Mitigation Braking System

2015 INFINITI Q50

Manuals

2015 Infiniti Q50 Quick Reference Guide (Infiniti USA, 2015)
2015 Infiniti Q50 Owner's Manual (Infiniti USA, 2015)

Videos
Intelligent Cruise Control (Full-Speed Range)

- Available at: http://www.infinitiownersinfo.mobi/Home/Topic/2015/Q50Sedan/739

Lane Departure Warning (LDW) and Lane Departure Prevention (LDP) Systems

- Available at: http://www.infinitiownersinfo.mobi/Home/Topic/2015/Q50Sedan/822

Predictive Forward Collision Warning and Forward Emergency Braking System

- Available at: http://www.infinitiownersinfo.mobi/Home/Topic/2015/Q50Sedan/909

MYCARDOESWHAT.ORG

Adaptive Cruise Control

- Available at: https://www.youtube.com/watch?v=z_8rlKsqQLg

Lane Departure Warning and Lane Keeping Assist

- Available at: https://www.youtube.com/watch?v=PapY5MOtW_0

Automatic Emergency Braking

- Available at: https://www.youtube.com/watch?v=2WPGhoHkgE8

APPENDIX C. PRE-ACTIVE SAFETY TECHNOLOGY EXPOSURE ASSESSMENT

Please answer the following questions:

1. What is your age: ____

2. What is your gender:
   - ☐ Male
   - ☐ Female

3. How many miles do you drive in a typical week? ________

Directions: For the following questions in each List, please place a check mark in all of the boxes that describe you.*

List A

- ☐ 1. I often ask that verbal instructions be repeated.
- ☐ 2. I typically watch a speaker's facial expressions and body language.
- ☐ 3. I like to take notes to review later.
- ☐ 4. I remember best by writing things down several times or drawing pictures and diagrams.
- ☐ 5. I am a good speller.
- ☐ 6. I often turn the volume of the radio or TV up really loud.
- ☐ 7. I often get lost when given verbal directions.
- ☐ 8. I prefer information to be presented visually (e.g., on flip charts, overheads, whiteboards, etc.)
- ☐ 9. I am skillful at making graphs, charts, and other visual displays.
- ☐ 10. I can understand and follow directions on maps.
- ☐ 11. I believe the best way to remember something is to picture it in my head.
- ☐ 12. I follow written instructions better than verbal instructions.
- ☐ 13. I am good at solving jigsaw puzzles.
- ☐ 14. I often get the words to songs wrong.
- ☐ 15. I am good at the visual arts.

List B

- ☐ 1. I follow verbal direction better than written ones.
- ☐ 2. I would rather listen to a lecture on a subject than read about it in a textbook.
- ☐ 3. I understand better when I read aloud.
- ☐ 4. I struggle to keep notes neat.
- ☐ 5. I prefer to listen to the radio than read a newspaper.
- ☐ 6. I frequently sing, hum, or whistle to myself.
- ☐ 7. I dislike reading from a computer screen.
- ☐ 8. When presented with two similar sounds, I can tell if the sounds are the same or different.
- ☐ 9. I require explanations of diagrams, graphs, or maps.
- ☐ 10. I enjoy talking to others.
- ☐ 11. I often talk to myself.
- ☐ 12. I often use musical jingles to learn things.

- ☐ 13. I would rather listen to music than view a piece of artwork.
- ☐ 14. I often use my finger as a pointer when reading.
- ☐ 15. I like to tell jokes, stories, and use analogies to demonstrate a point.

List C

- ☐ 1. I often reach out to touch things.
- ☐ 2. I collect things.
- ☐ 3. I often find myself talking fast and using my hands to communicate what I want to say.
- ☐ 4. I seem to constantly fidget (e.g., I tap my pen or play with the things in my pockets).
- ☐ 5. I am good at sports.
- ☐ 6. I like to take things apart and put them back together.
- ☐ 7. I prefer to stand while working.
- ☐ 8. I like to have music playing in the background while I am working.
- ☐ 9. I enjoy working with my hands and making things.
- ☐ 10. I often eat, smoke, or chew gum while working or studying.
- ☐ 11. I think I learn best through movement and by exploring my surroundings.
- ☐ 12. Some people might consider me hyperactive.
- ☐ 13. I am good at finding my way around.
- ☐ 14. I am comfortable touching people as a sign of friendship (e.g. hugging, shaking hands, etc.)
- ☐ 15. I prefer doing things rather than watching a demonstration or reading about it.

*Adapted from NIH (2004).

Directions: Please read the following list of automated features. Have you heard about any of the following automated features? Please place a check mark in the box next to feature(s) you have heard about:

- ☐ Adaptive Cruise Control
- ☐ Blind Spot Monitor
- ☐ Lane Departure Warning
- ☐ Lane Keeping Assist
- ☐ Back-up Warning
- ☐ Forward Collision Warning
- ☐ Automatic Emergency Braking (also known as Forward Crash Prevention)
- ☐ Pedestrian Detection
- ☐ Adaptive Headlights

Directions: Please read the following list of automated features. Do you have experience driving a vehicle with any of the following automated features? Please place a check mark in the box next to feature(s) you have used:

- ☐ Adaptive Cruise Control
- ☐ Blind Spot Monitor
- ☐ Lane Departure Warning
- ☐ Lane Keeping Assist
- ☐ Back-up Warning
- ☐ Forward Collision Warning

- Automatic Emergency Braking (also known as Forward Crash Prevention)
- Pedestrian Detection
- Adaptive Headlights

Directions: For the following questions, please write in your responses.

1. What is the purpose of adaptive cruise control?
2. How does adaptive cruise control work?
3. What is the purpose of automatic emergency braking (also known as forward crash prevention)?
4. How does automatic emergency braking (also known as forward crash prevention) work?
5. What is the purpose of lane departure warning?
6. How does lane departure warning work?
7. What is the purpose of lane keeping assist?
8. How does lane keeping assist work?

APPENDIX D. POST-ACTIVE SAFETY TECHNOLOGY EXPOSURE ASSESSMENT

Note to interviewer: The questions below are primary prompts, secondary prompts may be asked as long as they don't stray from this line of questioning.

Session One: On-Site Interview

For each presented technology for the (vehicle), participants will be asked to explain:

- What is the purpose of (technology)?
- How does (technology) work?
- How do you activate or deactivate (technology) in the (vehicle)?
- Does the (technology) provide you with an alert or warning? If so, please describe.
- When is it appropriate to use (technology)?
- Are there situations when you shouldn't use (technology)? If so, please describe.
- If you were placed in this vehicle, would you feel familiar enough with (technology) to use it?
    a. If not, what information would you require to feel familiar enough with the feature to use it?
- Think a moment about the materials you were given to review about (technology). Do you have any comments about the (technology) materials that you'd like to share?

After all technologies have been covered, ask question(s):

1. Would you be willing to pay (estimated cost of technology package for vehicle) more for a technology package that included, among other features, the technologies you reviewed today?
    a. If yes, why?
    b. If no, why not?

2. If you could split apart the package and only purchase the features you want, which if any would you buy?
    a. If only a few features, why these features and not the other(s)?

3. Can you rank order your preference for these features, with 1 being most preferred down to 3 being least preferred?
    a. Why did you rank them this way

Session Two: Follow-Up Phone Interview

Reminder of Informed Consent Form Information:

- This interview will take a maximum of 20 minutes.
- The interview is being audio recorded. Though audio recordings may be transcribed, names will not be transcribed and your name will not be associated with any comments you make.
- You are free to withdraw at any time for any reason and are free to refrain from answering any questions you'd rather not answer.
- Do you have any questions before we begin?

Directions: For each presented technology for the (vehicle), participants will be asked to explain:

1. What is the purpose of (technology)?
2. How does (technology) work?
3. How do you activate or deactivate (technology) in the (vehicle)?
4. Does the (technology) provide you with an alert or warning? If so, please describe.
5. When is it appropriate to use (technology)?
6. Are there situations when you shouldn't use (technology)? If so, please describe.

After all technologies have been covered, ask question(s):

1. Since participating in session one, have you sought additional instructional information regarding the (vehicle) or (technology) we presented to you?
    - If yes, where did you look?
    - Did the information help you to better understand the (technology)? If so, please describe.

I have a couple of demographic questions and then we'll be done.

1. What is the highest level of education you have completed? Please stop me when I get to the appropriate level.

    - ☐ Less than High School
    - ☐ High School/GED
    - ☐ Some College
    - ☐ 2-year College Degree
    - ☐ 4-year College Degree
    - ☐ Master's Degree
    - ☐ Doctoral Degree
    - ☐ Professional Degree (JD, MD)
    - ☐ Prefer not to answer

2. What is your combined annual household income? Please stop me when I get to the appropriate income range.

- ☐ Less than 30,000
- ☐ 30,000 - 39,999
- ☐ 40,000 - 49,999
- ☐ 50,000 - 59,999
- ☐ 60,000 - 69,999
- ☐ 70,000 - 79,999
- ☐ 80,000 - 89,999
- ☐ 90,000 – 99,999
- ☐ 100,000 or more
- ☐ Prefer not to answer

Thank you so much for your participation in our study, we really appreciate your time and input.

APPENDIX E. TIPS FOR COMMON SAFETY TECHNOLOGIES AND FEATURES

The following technology descriptions and usage tips are from the MyCarDoesWhat.org website Though the scoring for this study was based on the content from each owner's manual, these descriptions exemplify the types of information participants would have been exposed to during the study, what they were asked about during the interviews (e.g., technology purpose and how it works), and what they were scored on during analysis.

Adaptive Cruise Control (ACC)
Not only maintains your set speed, but your following distance as well; provides some limited braking.

- Be aware that ACC may not work effectively in certain types of weather conditions. Some examples of these include heavy fog or rain; having dirt, snow or ice covering the sensors; or when the roadways are slippery. These systems also may not work in tunnels.
- ACC allows you to spend less energy maintaining your following distance with the cars in front of you. You should use this opportunity to pay more attention to the traffic mix, including cars ahead of you and in adjacent lanes.
- Check your owner's manual to see if your ACC is capable of slowing your car to a stop, or if you need to stop on your own.

Automatic Emergency Braking (AEB)
This feature can sense slow or stopped traffic ahead and urgently apply the brakes if the driver fails to respond.

- Automatic emergency braking relies on sensors that may be blocked by dirt, ice or snow. So, be sure to clear any build-up off your feature's sensors or windshield before trips.
- Not sure where your automatic emergency braking's sensors are located? You can always check your owner's manual or with your dealership.
- Some automatic emergency braking features are vulnerable to glare from sunrise/sunset. You shouldn't rely on this feature exclusively during those times – or at any other time.

Lane Departure Warning (LDW)
Lane departure warning systems alert you if you're drifting out of your lane using visual, vibration or sound warnings.

- This feature relies on lane markings to operate. This feature is not designed to work on unpaved roads or roads without lane markings.
- If the roadway is covered with snow, leaves, fog or debris, the lane departure warning may not be able to detect the lane markings on the road.
- Using your turn signal will override the lane departure warning.

Lane Keeping Assist (LKA)
May gently steer you back into your lane if you begin to drift out of it.

- This feature relies on painted lane markings to operate. This feature is not designed to work with markers that are faded, covered, in disrepair, or are overly complicated.
- If the roadway is covered with snow, leaves, fog or debris, the lane keeping assist may not be able to detect the lane markings on the road.
- Turning your wheel will override this feature after it activates.

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