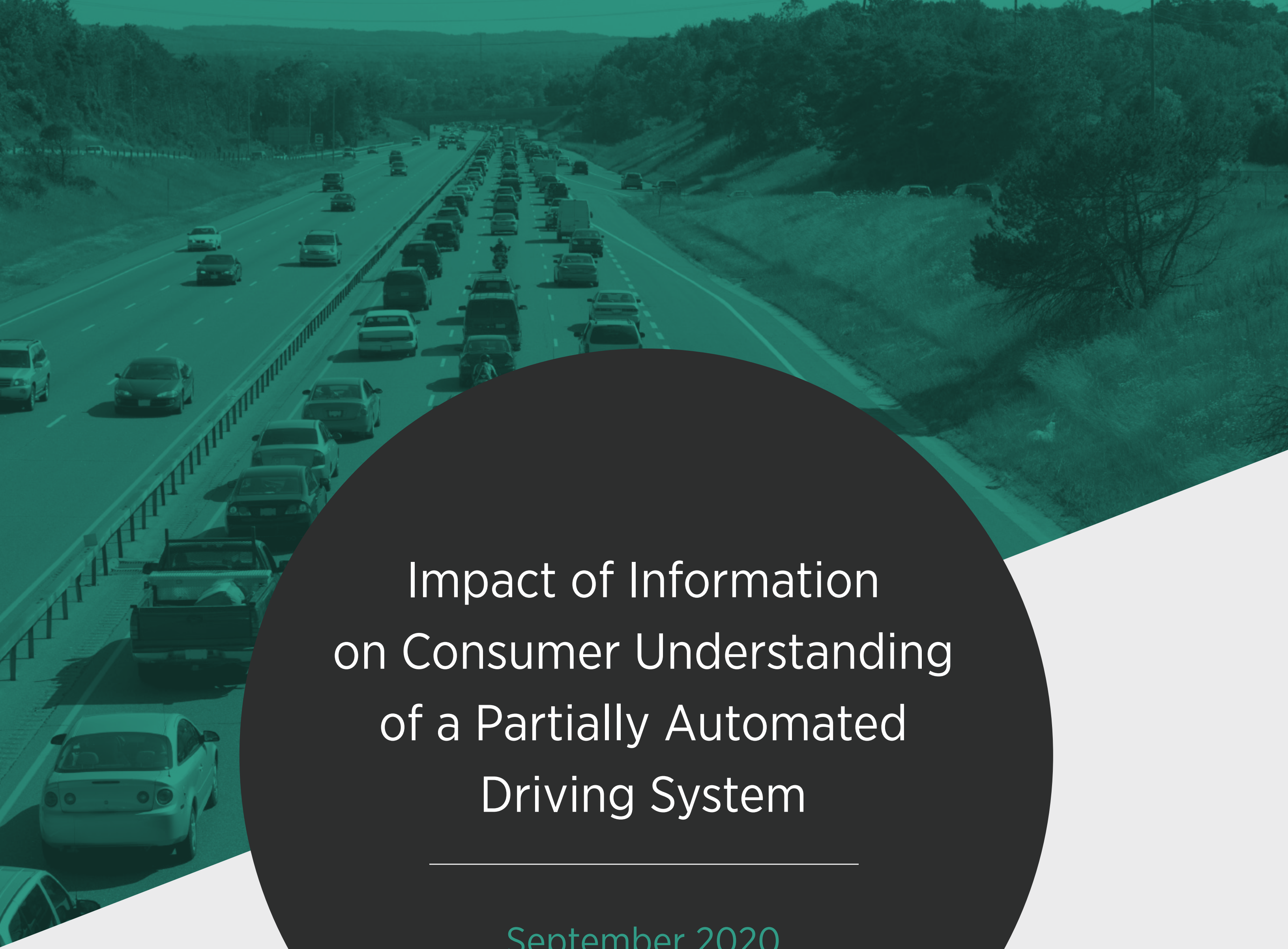

# Impact of Information on Consumer Understanding of a Partially Automated Driving System

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AAA Foundation for Traffic Safety

## Title

Impact of Information on Consumer Understanding of a Partially Automated Driving System

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## Authors

Jeremiah Singer & James W. Jenness

*Westat*

## Foreword

Recent advances in technology have made it possible for some vehicles, under certain circumstances, to control their speed and direction for an extended period of time without any input from the driver. These partially automated driving systems may give the impression that the car can "drive by itself," however, no vehicle available to consumers currently is designed to be used without an attentive driver who is ready and able to retake control of the vehicle at any time. Thus, it is imperative that drivers properly understand the capabilities and limitations of the technology in their vehicles.

This report describes the results of an experimental study designed to investigate how seemingly small differences in marketing and training materials can influence consumers' initial understanding and expectations of a partially automated driving system. The information provided in this report should be of interest to automobile manufacturers and dealers, consumer advocates, driver training professionals, and drivers of new vehicles with advanced technologies.

C. Y. David Yang, Ph.D.

Executive Director
AAA Foundation for Traffic Safety

## About the Sponsor

AAA Foundation for Traffic Safety
607 14th Street, NW, Suite 201
Washington, D.C. 20005
202-638-5944
www.aaafoundation.org

Founded in 1947, the AAA Foundation for Traffic Safety in Washington, D.C., is a nonprofit, publicly supported charitable research and education organization dedicated to saving lives by preventing traffic crashes and reducing injuries when crashes occur. Funding for this report was provided by voluntary contributions from AAA/CAA and their affiliated motor clubs, individual members, AAA-affiliated insurance companies, and other organizations or sources.

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## Executive Summary

Driving automation technologies allow vehicles to perform some aspects of the dynamic driving task without direct driver input. The safe use of these systems depends on the driver having an accurate understanding of the capabilities and limitations of the system, including the appropriate driving contexts for the use of the system — often referred to as a mental model of the system. There is growing concern that marketing materials and other information provided by automobile manufacturers, the media, and other sources may influence the formation of inaccurate mental models.

The purpose of this study was to explore how different informational approaches affect drivers' expectations of, use of, and reactions to a Level 2 (L2) driving automation technology that allows the vehicle to control its speed and lane position without driver input, under certain conditions.

This study used a between-subjects design in which participants were randomly assigned to one of six training conditions. Each condition was a combination of a marketing/branding approach (to emphasize limitations or to emphasize capabilities) and a training mode (printed quick-start guide, training video, or in-person, on-road demonstration). Participants received training on how to use an L2 feature present as original equipment in a production vehicle. Participants then completed a post-training questionnaire assessing their mental model of system operation and capabilities. Participants then drove the vehicle on a freeway route using the L2 feature for approximately 35 minutes. Participants completed another questionnaire after completing the drive.

Nearly all participants in the study correctly understood that they must pay continuous attention to the driving task while using the L2 feature. Results show, however, that a branding approach that emphasizes feature capabilities and driver workload reduction – compared to a branding approach that emphasizes feature limitations and driver responsibility – tended to lead to greater confidence in the capabilities of the feature in ways that might lead drivers to over-rely on it or use it unsafely. This result is compounded by a greater likelihood to report willingness to engage in potentially distracting or risky behaviors while driving in the condition that emphasized capabilities. The differences observed in drivers' initial mental models often persisted after participants had the opportunity to use the L2 feature on the road. In some cases, participants' confidence that the L2 feature could handle safety-relevant scenarios increased after driving the vehicle, even for scenarios that are not within the L2's capabilities.

Results regarding training modes show that participants who received an in-person, on-road demonstration from a researcher on how to use the L2 feature found the training more useful than those who received a quick-start guide or video training. During the on-road drive, demo participants also showed the most confidence in the L2 feature, as measured by time with hands away from the steering wheel and feet away from the pedals. Demo participants were also least likely to respond promptly to an unexpected handoff of control.

Given that both branding conditions contained the same basic safety-relevant information (despite differences in how it was presented and what was emphasized), results suggest that a strong emphasis on the capabilities of an L2 feature can result in mental models that overestimate the capabilities of the feature. Importantly, these effects appear to extend beyond the scope of the information presented. For differences between training modes, there were fewer overt safety implications. However, results suggest that an in-person demonstration is most helpful for drivers to learn how to use a feature, and may make them more confident in their initial drive using the feature.

# Introduction

## Background

Driving automation technologies allow vehicles to perform some aspects of the driving task without direct driver input. These technologies encompass a broad range of capabilities.

The Society of Automotive Engineers (SAE) defines five levels of driving automation (SAE, 2018). Level 1 includes driver assistance technologies that allow the vehicle to automatically control speed (e.g., adaptive cruise control) or lane position under certain circumstances, but not both at the same time. Level 2 includes partial driving automation technologies, also referred to as active driving assistance (AAA et al., 2020), in which the vehicle can control both speed and lane position simultaneously. Levels 3 through 5 are considered automated driving systems (ADS), and range from conditional automation, where the vehicle can drive itself under limited conditions, up to fully self-driving vehicles.

The key distinction between Level 1 and 2 features and ADS is that Levels 1 and 2 always require the driver to be driving. This means the driver must remain attentive and ready to retake control at all times, even when using automation technologies that can control both speed and lane position without direct driver input. For ADS vehicles, the vehicle is considered to be self-driving while in an automated mode. While a driver may be present in an ADS vehicle, he or she is not required to continually attend to the driving task, though Level 3 ADS vehicles may request driver takeover if the vehicle exceeds its operational design domain (ODD) (i.e., the set of conditions within which it is designed or permitted to operate) for planned or unplanned reasons. Level 4 vehicles are capable of driving without any need for driver intervention within a limited ODD, while Level 5 vehicles are capable of driving without driver intervention under all conditions.

A national survey shows that Americans remain fearful of “self-driving” vehicles, with only 12% indicating that they would trust a vehicle to drive itself while they were in it (AAA, 2020). However, lower-level driver support technologies are becoming increasingly available on new vehicles, including Level 2 features that allow vehicles to control speed and lane position under certain conditions without any driver input.

Within any given level of automation, capabilities and operational aspects can vary widely. For instance, the current version of Tesla’s Autopilot feature can automatically make lane changes if the driver presses a button, whereas Cadillac’s Super Cruise requires drivers to change lanes manually. Autopilot requires a driver to provide steering input occasionally to indicate engagement in the driving task, whereas Super Cruise uses a camera to monitor the driver’s direction of gaze, based on the position and orientation of the driver’s head and eyes, to infer engagement. Both of these features are nominally Level 2, but there are numerous important differences between them.

The safe use of these systems depends on the driver having an adequate understanding of the capabilities and limitations of the systems, including the appropriate driving contexts for use of the system. This understanding is sometimes called a mental model. Carroll and Olson (1987) broadly describe a mental model as "any thought process in which there are defined inputs and outputs to a believable process which operates on the inputs to produce outputs." This general construct envisions a mental model as a collection of ideas about cause and effect relationships – if X happens, then Y will happen. Mental models include "the user's understanding of what the system contains, how it works, and why it works that way" (Carroll & Olsen, 1987). They can be used during learning, in problem solving, and when trying to understand previous system behaviors.

Previous research has explored how drivers' mental models of vehicle technology develop and how they affect driver behavior. Beggiato and Krems (2013) investigated how drivers' initial mental models of an adaptive cruise control (ACC) feature influenced their trust in and acceptance of the technology. Fifty-one participants received a description of the ACC feature that was either accurate, incomplete with omitted potential problems, or incorrect with non-existent problems added. Participants then completed three driving simulator trips using the ACC feature over a six-week period. While there were large differences between groups in perceived capabilities of the ACC feature after reading the divergent information sources, confidence ratings tended to converge toward the correct responses after experience using ACC in simulated driving. Participants who received correct or overstated information about the ability of ACC had higher initial trust in the feature than participants who received understated information. However, while correct and understated groups had generally increasing trust in the functionality after repeated drives, the group that received overstated information had decreasing trust scores after repeated drives, and had the lowest level of trust after the final drive. This suggests that overstating the capabilities of a technology can ultimately lead to less trust and acceptance than providing accurate, balanced information.

A subsequent on-road study by Beggiato, Pereira, Petzoldt, and Krems (2015) examined how mental models for ACC develop over time. In this study, 15 participants with no ACC experience were trained on how an ACC feature worked and then drove a vehicle with the feature ten times on the same on-road route over a two-month period. Results showed that participants' learning, trust, and acceptance developed most during the initial drives, then stabilized after the fifth drive, which equated to about 3.5 hours of driving. Results also indicated that system limitations noted in training tended to fall out of participants' mental models over time if they were not experienced in actual use.

Previous research has shown that drivers are often not aware of the capabilities and limitations of advanced in-vehicle technology (Jenness, Lerner, Mazor, Osberg, & Tefft, 2008; Braitman, McCartt, Zuby, & Singer, 2010; McDonald, Carney, & McGehee, 2018) and there is growing concern that marketing materials and other information provided by automobile manufacturers, the media, and other sources may influence formation of inaccurate mental models. In a series of blind interviews of automotive salespeople for six vehicle brands, researchers in the Boston, MA area found a wide disparity in the quality and accuracy of salespeople's descriptions of ADAS technologies, with many providing inadequate or inaccurate information about safety-critical systems to potential purchasers (Abraham, McAnulty, Mehler, & Reimer, 2017).

The names of vehicle features can also lead to driver confusion and inaccurate mental models. For any given ADAS function, there is little consistency in the terminology used to describe the feature across vehicle manufactures, regulators, and industry standards organizations. Adding to the potential for confusion, the names used to describe features often do not well represent the functions with which they are associated (AAA, 2019). Research shows that the name of driver assistance systems can influence drivers' expectations of responsibility between the driver and the system (Abraham, Seppelt, Reimer, & Mehler, 2017).

There has been particular concern about the use of the name Autopilot. Surveys have shown that consumers associate the name Autopilot with higher levels of automation than other brand names for available L2 systems (Nees, 2018), and that they are more likely to regard various non-driving tasks as safe to perform when using a system called Autopilot than when using other available L2 systems with other names (Teoh, 2020). The National Transportation Safety Board (NTSB) cited overreliance on the system as a factor in a fatal crash that it investigated (NTSB, 2017). In a supplemental comment, NTSB board member Christopher A. Hart expressed concern that drivers, "[M]ay conclude from the name 'autopilot' that they need not pay any attention to the driving task because the autopilot is doing everything" (NTSB, 2017, pg. 45).

While trust in automation is an important factor in the adoption of automated technologies (Ghazizadeh, Lee, & Boyle, 2012), appropriate levels of trust are important to ensure safe and appropriate use of systems (Lee & See, 2004). A driving simulator study conducted in Germany manipulated participants' trust level in a Level 3 ADS vehicle by providing them with trust-promoting or trust-lowering introductory materials (Körber, Baseler, & Bengler, 2018). Participants then drove a simulated route and experienced three potential handoff scenarios (i.e., instances of the driving automation technology ceasing support of vehicle control and handing full control to the driver). Participants in the trust-promoted group spent more time looking away from the road or instruments to a secondary task, were less likely to intervene in a situation where the automation's performance was of questionable safety, and were slower to respond to a safety-critical handoff event and were more likely to crash in this situation.

The nature of information and training on advanced vehicle features can also affect drivers' understanding of them. Abraham, Reimer, and Mehler (2017) provided research participants with ADAS-equipped vehicles to drive for four weeks. Training for all participants included a pre-drive and a during-drive explanation of features, a training video, and an on-road test drive where participants could try out ADAS features with a researcher present to assist. All but one of the 13 participants found the training they received helpful. Eight participants found the test drive to be the most useful part of the training, while five participants found the pre-drive and during-drive explanation to be most helpful. One participant cited the video as the most helpful.

Evidence from recent research shows that the names of ADAS features, how they are described, and the mode of training can influence expectations and opinions about the features. However, there remains limited evidence regarding how these variables influence actual on-road use of an ADAS feature, and how that on-road use in turn updates users' mental models of the feature. The present study expands upon previous research by manipulating the name and description of an actual Level 2 feature (Cadillac Super Cruise) to emphasize either its capabilities or its limitations, and providing training in one of three modes (text, video, or in-person demonstration). Participants completed questionnaires before and after driving a freeway route using the Level 2 feature.

**Objectives**

In this research, it is posited that the driver's mental model of driving automation technologies is formed initially by external information sources such as media coverage (including both positive and negative stories), marketing materials from the automobile manufacturer, online research, information from friends and family, and in-person visits to automobile dealers — and then is immediately and repeatedly confirmed or updated by driving experiences. It is important to consider how the influence of external sources of information persists and interacts with the driver's experience using the system. The mental model influences how the driver reacts to driving scenarios, but also influences which driving scenarios are encountered with the system active. The mental model supports expectations and predictions about what will happen in a given driving scenario. If the outcome is not expected, the mental model may be updated to accommodate that new experience.

In this report, the term "L2 feature" is used to refer to the specific active driving assistance system (an SAE Level 2 partial automation system) that was used in the study. All participants were exposed to the same vehicle system, but the name of the system and emphasis of training materials, as well as the delivery mode of training materials, differed between participants.

The specific objectives of this study were to:

1. Determine how differences in the marketing/branding approach, which emphasizes either the capabilities or limitations of the L2 feature, affect drivers' mental models of the L2 feature.
2. Determine how training mode (print quick-start guide, demonstration video, or in-person demonstration) affect drivers' mental models of the L2 feature.
3. Determine how branding and training mode affect drivers' use of the L2 feature in actual on-road driving.
4. Determine how actual experience using the L2 feature affects mental models and attitudes toward the feature.

The research hypotheses in this study were:

1. Participants who receive training that emphasizes the capabilities of the L2 feature will express more confidence in the L2 feature than participants who receive training that emphasizes the limitations of the L2 feature across all training modes. Specifically, participants who receive training that emphasizes the capabilities of the L2 feature will:
    a. Be more likely to expect the L2 feature to operate successfully and safely in a range of conditions and situations, including those it is not designed to handle
    b. Express higher levels of willingness to engage in secondary tasks while using the L2 feature
    c. Be more likely to expect the L2 feature to provide safety, comfort, and enjoyment
    d. Be more likely to engage in on-road behaviors indicative of confidence in the L2 feature (e.g., more hands-off-wheel time, higher travel speed, slower response to unexpected handoff).
2. After participants drive using the L2 feature, differences between the questionnaire responses of participants who received the contrasting marketing/branding approaches will be smaller than they were before the drive for hypotheses 1a through 1c above.

## Method

This study used a between-subjects design in which participants were randomly assigned to one of six training conditions. Each condition was a combination of a marketing/branding approach (emphasizing limitations or emphasizing capabilities) and a training mode (printed quick-start guide, training video, or in-person demonstration). Upon arrival, each participant completed an initial questionnaire about their demographics, personal characteristics, and driving habits. Next, participants received training on how to use the L2 feature according to their randomly assigned training condition. After training, participants completed a post-training questionnaire assessing their mental model and expectations for the L2 feature. Next, participants drove the L2 vehicle approximately 31 miles on a freeway route while using the L2 feature. After the drive, participants completed a final questionnaire that assessed their current post-drive mental model and reactions to using the L2 feature.

### Participants

Participants (N=90) were recruited from the Washington, DC metropolitan area using ads placed on the website Craigslist (Volunteers and Jobs sections) and Westat's intranet site. The intranet ad specified that Westat employees were not eligible, but their friends and family could participate. Ad text was carefully written to state the essential information about the vehicle participants would drive without introducing bias that might shape participants' initial mental model of the L2 feature. The ads stated, "If you participate, you will drive a vehicle on MD Route 200 (Intercounty Connector) while using a technology that allows the vehicle to accelerate, brake, and stay in its lane without the driver steering or using the pedals."

Participants were screened for eligibility over the phone. Participants were required to:

- Be a licensed driver for at least three years and drive at least three days per week,
- Be between the ages of 20 and 70,
- Report having never driven a vehicle with an L2 feature,
- Report having no medical conditions or medications that could impair their ability to drive safely,
- Be fluent reading and writing in English, and
- Pass a driver's license background check to ensure that they did not have any major moving violations (e.g., driving while intoxicated or reckless driving) within the past five years, or an accumulation of other moving violations (four or more current license point deductions).

A convenience sample was used, without quotas for age, gender, or other participant characteristics. Participants were assigned to experimental groups to ensure similar distributions of age and gender in each experimental condition. The mean age of participants was 47.3 years, with a standard deviation of 14.4. Table 1 shows mean participant age, standard distribution of age, and distribution of gender within each experiment condition.

## Study Materials

Participants were randomly assigned to receive training on the L2 feature in one of three modes: print quick-start guide, video, or in-person demonstration. Two versions of each training mode were developed: one in which the L2 feature was named *DriveAssist* and emphasized the feature's limitations and the driver's responsibility, and one in which the feature was named *AutonoDrive* and emphasized the feature's capabilities and driver workload reduction. Despite the differences in emphasis, neither version omitted any important safety information nor presented any false information.

### <u>Training Materials</u>

Training materials were developed based on real training and marketing materials associated with the L2 feature used in this study, which was Cadillac's Super Cruise. The primary information source was the 2018 CT6 Super Cruise Convenience & Personalization Guide (Cadillac, 2017). For this reason, the quick-start guides for this study were developed first, then were used as the basis to develop the video and in-person demo training materials.

#### *Quick-Start Guide*

The quick-start guides were produced as full-color, glossy booklets similar to the original Cadillac version (see Figure 1). The full quick-start guides are provided in Appendix A: DriveAssist Quick-Start Guide and Appendix B: AutonoDrive Quick-Start Guide. The research team maintained the style of the original guide, but the information was adapted to suit the needs of this study in the following ways:

- Cover text and image were replaced with those from a Super Cruise marketing brochure (brochure ID 18-CAD-CT6-SCR-25).
- Removed information intended for vehicle owners but not directly relevant to Super Cruise use (e.g., data downloads, map updates, OnStar operation, and system care).
- Removed a photo showing the dashboard with buttons and icons labeled.
- Rearranged sections of text to change flow and for formatting purposes.
- Replaced "Super Cruise" with "DriveAssist" or "AutonoDrive," depending on version.
- All Cadillac branding (names and logos) was removed.
- Revised the text to emphasize feature limitations and driver responsibility (DriveAssist version) or feature capabilities and workload reduction (AutonoDrive version).
- Added some marketing text from the brochure referenced above (brochure ID 18-CAD-CT6-SCR-25).
- Added a photo of a driver using L2 feature with hands on lap near wheel (DriveAssist version) or with hands behind head and smiling (AutonoDrive version).

*Video*

Two training videos were produced – one for DriveAssist and one for AutonoDrive. Videos were recorded with a resolution of 1080p. Each included video of a driver operating the vehicle, turning on the L2 feature, and using the L2 feature. Inset still images were used to show close-ups of important buttons and icons. Figure 2 shows an example video screenshot. The video included a running narration by a male speaker that paralleled the text of the equivalent quick-start guide. The phrasing of some text was changed to better suit the spoken narrative. The narrative style was also slightly different between video versions. The DriveAssist video narration featured a neutral tone of voice, and a vocal emphasis on feature limitations. The AutonoDrive video narration featured a more energetic tone through most of the video, but the sections addressing feature limitations were read quickly and in a flat tone. Like the quick-start guide, the video featured the driver either using the L2 feature with her hands on her lap near the wheel (DriveAssist) or with her hands behind her head and smiling (AutonoDrive). The video also included the driver changing the climate control setting on the center console with her right hand (DriveAssist) or picking up a water bottle, unscrewing the cap with two hands, and taking a drink (AutonoDrive). The DriveAssist version had a runtime of seven minutes and 36 seconds and the AutonoDrive version had a runtime of six minutes and 43 seconds.

*In-Person Demonstration*

In this training method, a member of the Westat project team trained the participant by directly explaining how to use the L2 feature, and demonstrating its use while driving on real roads. The same researcher conducted all in-person demonstrations to ensure consistency across participants. The entire demonstration was conducted in the study vehicle with the researcher in the driver's seat and the participant in the front passenger's seat. It began with the researcher giving a scripted overview of the feature, then explaining how to turn it on. Next, the researcher drove to a nearby limited-access freeway (I-270), and demonstrated how to use the L2 feature for three miles driving northbound, then turned around and demonstrated the feature again driving southbound. The demonstration drive included demonstrating lane changes and changing the L2 feature set speed using steering wheel buttons. The demonstration drive was conducted on a different freeway than the one on which participants would later drive. Upon returning to the parking lot, the researcher gave an additional scripted presentation to the participant, explaining system limitations and other safety-relevant information. The demonstrator researcher was not involved in any data collection procedures with participants. Those procedures were conducted by a second researcher.

As with the other training methods, the DriveAssist demonstration emphasized the limitations of the L2 feature and the driver's responsibility, while the AutonoDrive version emphasized its capabilities and driver workload reduction. In the DriveAssist demonstration, upon activating the L2 feature, the researcher cautiously placed his hands on his lap near the steering wheel and kept his foot near the pedals. In the AutonoDrive version, the researcher moved his foot away from the pedals and dramatically raised his hands away from the wheel to demonstrate "no hands," then rested his arms on the door and center console armrest, far from the steering wheel, in a relaxed posture. In the DriveAssist version, the researcher's demeanor was neutral, whereas in the AutonoDrive version, the researcher's demeanor was more exuberant when expressing the capabilities of the feature, and the researcher personally attested to its usefulness and reliability.

Branding and Emphasis Differences

The previous section described in general terms the types of differences between the DriveAssist and AutonoDrive versions of the training materials. This section provides specific examples of differences between the two versions.

DriveAssist materials emphasized the limitations of the L2 feature and the driver's responsibility to ensure safe operation of the vehicle, whereas AutonoDrive materials emphasized the capabilities of the L2 feature and driver workload reduction. The name DriveAssist was selected to suggest that the L2 feature is there to assist the driver, whereas the name AutonoDrive was selected to suggest autonomous driving. Examples of specific differences between DriveAssist and AutonoDrive training materials are presented in Table 2. The final example in the table shows the differences in driver hand position while using the L2 feature in the training video.

Questionnaires

In addition to an intake questionnaire that captured participant demographics and other personal characteristics, participants completed two pen-and-paper questionnaires:

- The *post-training questionnaire (PTQ),* completed immediately after participants were trained on how to use the L2 feature, captured whether or not participants expected the L2 feature to work in a variety of scenarios, comprehension of how to activate and use the feature, system trust, performance expectations, and other mental model aspects.
- The *final questionnaire (FQ)*, completed after participants actually drove using the L2 feature, included many of the same questions as the post-training questionnaire to assess changes in mental model, as well as questions about the perceived performance of the L2 feature and questions about the training materials themselves.

The questionnaires are presented in their entirety in Appendix C: Post-Training Questionnaire and Appendix D: Final Questionnaire.

Research Vehicle, Instrumentation

The research vehicle for this study was an instrumented 2018 Cadillac CT6, which is a midsize, four-door sedan. The vehicle was equipped with an L2 feature named Super Cruise. In addition to the stock equipment, the vehicle was outfitted with an Ergoneers

Vehicle Test Kit (VTK) as the foundation for the instrumentation package. The VTK includes four high-definition webcams that capture views of the road, driver's face, foot position, and an over-the-shoulder view of the driver's interaction with the cockpit controls (see Figure 3). The VTK includes GPS tracking, battery backup power, and removable data storage. Custom software captured Super Cruise status information continuously from the CAN bus and documented it for understanding the driver's behavior and use of the L2 feature. All data from the VTK and custom software application were synchronized through a local network connection between the researcher's laptop computer and the VTK system. Data from both systems were extracted and processed into a combined, synchronized dataset at the end of each session for further coding and analysis.

*L2 Feature*

The L2 feature used in this study was Cadillac's Super Cruise, which allows the vehicle to steer, accelerate, and brake without driver input, under certain conditions. The Super Cruise software used for this study was the 2018 software update version. Super Cruise can only be used on divided, limited-access highways that are within the system's predefined geographic database. Super Cruise can allow the vehicle to travel for an extended period of time in a single lane and can adjust its speed if slower traffic is detected ahead, but it is not a collision avoidance system, and it cannot change lanes, take evasive action, or respond appropriately to a variety of common hazards. Therefore, the driver is always expected to be paying attention and prepared to retake vehicle control without advance notice. If Super Cruise returns steering and speed control to the driver, it indicates the handoff by flashing the steering wheel light bar red (see illustrations in Appendix A: DriveAssist Quick-Start Guide and Appendix B: AutonoDrive Quick-Start Guide) and either vibrating the seat or beeping (alert mode can be selected by the user). There is no advance notice given before a handoff.

To engage Super Cruise, the driver must first turn on ACC by pressing the ACC button on the steering wheel. ACC status is remembered between trips, so once turned on, it will remain on for future trips unless the driver turns it off. When the vehicle is on a limited-access freeway within the Super Cruise geographic database, and all other conditions are met for Super Cruise use, the Super Cruise icon (a gray steering wheel) will appear in the instrument cluster. The driver can then press the Super Cruise button on the steering wheel to activate Super Cruise. The Super Cruise icon and a light bar at the top of the steering wheel both turn green to indicate that Super Cruise is active.

Super Cruise allows the driver to remove his or her hands from the steering wheel, but uses a camera to monitor the driver's face and eyes to determine whether the driver is looking forward. If the driver appears to be looking away from the forward roadway for several seconds, an escalating series of alerts will occur until the driver returns his or her attention to the forward roadway.

Super Cruise uses instrument cluster indicators, a light bar at the top of the steering wheel, and auditory or haptic signals to indicate system status and alerts. The status indications and alert progression for Super Cruise are described below.

- *Super Cruise inactive*: Steering wheel light bar is black (no light), instrument cluster icon is gray or not present
- *Super Cruise is controlling lane position and cruise speed is set:* Light bar is green, instrument cluster icon is green
- *Driver is manually overriding steering*: Light bar pulses blue, instrument cluster icon is blue.
- *Driver inattention alert (1st stage):* Light bar flashes green.
- *Driver inattention alert (2nd stage) or other handoff of control:* Light bar flashes red, beeping or haptic alert occurs, instrument cluster icon disappears. Super Cruise disengages and driver must retake control. Light bar continues flashing red until driver retakes control.
- *3rd (final) alert:* If the driver does not make a steering input within approximately 10 seconds of the 2nd stage alert initiation, the beeping or haptic alert reoccurs, and is immediately followed by a voice message that says "Please take control of the vehicle now." The light bar continues flashing until the driver retakes control. Super Cruise will be disabled for the remainder of this trip (i.e., until the engine is turned off and on again).
- *Vehicle intervention:* If the driver still has not made a steering input after the final alert, the vehicle will come to a controlled stop, activate the hazard lights, and contact emergency services.

In addition to Super Cruise, the vehicle has other safety alerts including forward collision warning and lane departure warning. All safety systems were active by default during this study, and the following distance for Super Cruise and ACC was set to the longest following distance. Participants were informed that the vehicle had forward collision and lane departure warning features during in-vehicle orientation, but were not given any additional information about those features, nor were these features described as part of the L2 system. Participants in this study were not permitted to adjust any safety system, vehicle display, or following distance settings.

It is important to note that this study was not an evaluation of Super Cruise itself. Rather, it was an evaluation of how different information types and training modes affect mental models and how drivers use the L2 feature. All Cadillac and GM logos on the inside and outside of the research vehicle were obscured, and no study materials made reference to the brand or model of the vehicle, or to the name Super Cruise.

Driving Route and Unexpected Handoff Event

The driving route used for the on-road portion of this study was MD Route 200, also known as the Intercounty Connector. The road was a divided, limited-access highway with a 60 mph speed limit and wide shoulders. The road generally has light traffic volumes and does not experience recurrent congestion. Participants drove nearly the full length of the road, from I-270 eastbound to Konterra Drive where they exited and re-entered the road to drive back westbound to I-270. The official eastbound study route began after participants exited the tunnel under Olde Mill Road and ended when participants crossed over Shady Grove Road traveling westbound, for a total study route mileage of approximately 31 miles. Figure 4 shows the study driving route.

Participants were instructed to drive in the right lane unless passing an emergency vehicle stopped in the shoulder. They were instructed to ask the researcher for permission if they wanted to pass a slower-moving vehicle. Participants were given no instruction on driving speed, though the researcher asked them to slow down if they exceeded 70 miles per hour. The researcher instructed the participant to use the L2 feature for as much of the study route as possible after passing through the tunnel under Olde Mill Road. During the drive, the researcher observed the driver and the roadway to ensure that there were no unsafe behaviors. The researcher also had a laptop with custom software that allowed him or her to record important events, notes, or interesting comments from the participant.

When approaching the Konterra Road exit (the end of the eastbound section of the route), the L2 feature handed control of the vehicle back to the driver without any advance warning. This location was near the end of MD Route 200 and the end of the area where Super Cruise is available for use. While the actual location at which the vehicle initiated the handoff of steering and speed control to the driver varied between participants by up to approximately 200 meters, the event had sufficient repeatability that it was used as a standard event that could be compared across participants. The researcher did not inform participants in advance that this handoff event would occur, or that they would be exiting at Konterra Drive, so it provided an opportunity to assess how participants reacted to the handoff notification (beeping sound and steering wheel light bar flashing red). The researcher carefully observed the participant's reaction. If the participant did not safely retake control, the researcher instructed the participant to retake the wheel at his or her own discretion, for safety reasons.

After the handoff event, the researcher instructed the participant to exit at Konterra Drive, get back on Route 200 traveling the opposite direction (westbound), and reengage the L2 feature. At the end of the main study route (Shady Grove Road overpass), the researcher explained that they had reached the end of the study route, and that the participant could either turn off the L2 feature or continue to use it until reaching the I-270 exit in approximately three miles.

### On-Road Dependent Variables

On-road data were collected using a combination of video, GPS, vehicle data, and researcher-entered data. The vehicle and GPS data were recorded continuously at a rate of 15 records per second. Video data were recorded continuously during the study route, but rather than analyze video data for the entire 30-minute study route, four two-minute segments of data were selected for reduction and analysis by video coding staff. The sampled segments were geographically-based, with two segments in the eastbound direction of travel and two in the westbound direction of travel. The same sections of road were used for the eastbound and westbound segments, so that the roadway geometry of the first and fourth segments would be similar, and the geometry of the second and third segments would be similar, but with the direction of curves reversed. Segments were selected to avoid major interchanges, lane drops, or other features that might affect driver attention or behavior.

The key dependent variables in these data are summarized below.

- L2 feature use, sampled from video within study route
  - Hand position (holding wheel, hovering near wheel, away from wheel)
  - Foot position (on gas, hovering over gas, on brake, hovering over brake, off pedals)
- Percentage of study route drive in which L2 feature was in use
- Mean speed while using L2 feature
- Time from unexpected handoff alert initiation to driver retaking control of wheel

**Procedure**

Study sessions were conducted from August through October in 2019. Upon arrival for their session, participants read and signed an informed consent form, then completed a questionnaire about their demographics and personal characteristics. A researcher verified the participant's driver's license, then participants were trained according to their randomly assigned condition. For the quick-start guide, participants were handed the guide and instructed to read it in its entirety. For the video condition, participants were seated at a computer monitor and the researcher played the video. Participants were not permitted to rewind the video or watch it more than once. For the in-person demonstration, a different researcher escorted the participant to the study vehicle and conducted the demonstration. After the demonstration was completed, the demonstrator escorted the participant back to the original researcher, and the participant completed the post-training questionnaire.

After completing the post-training questionnaire, the researcher escorted the participant to the research vehicle. The participant sat in the driver's seat and the researcher sat in the front passenger seat. The researcher was seated in the front seat rather than the back seat primarily for safety reasons, so he or she could more closely observe the participant's behavior and the roadway environment. The researcher allowed the participant to adjust the seat, steering wheel, and mirrors as needed, then the participant did a short introductory drive around the parking lot to get comfortable driving the vehicle. The researcher then instructed the participant to leave the parking lot and provided directions to the study route on MD Route 200.

When the participant reached the start of the study route, the researcher instructed him or her to turn on the L2 feature and use it for as much of the drive as they were comfortable. The participant then drove the eastbound length of Route 200 until reaching Konterra Drive, then exited and re-entered the road driving westbound. During the drive, the researcher encouraged the participant to narrate their thoughts and actions in a think-aloud process.

After completing the study route, the participant drove back to the parking lot. Next, participants completed the final questionnaire, were paid their $100 cash incentive and debriefed.

### Statistical Analysis

The criterion of $\alpha = .05$ was used as the threshold for reporting statistical significance. For most of the questionnaire-based data, responses were naturally ordered (e.g., strongly disagree to strongly agree). Thus Wilcoxon rank-sum tests were used. Wilcoxon rank-sum tests comparing branding were either one-tailed or two-tailed, depending on the question. For questions whose responses were not ordered, Pearson's chi square was used.

Before-after analyses comparing participants' responses in the PTQ versus the FQ use Wilcoxon signed-rank tests or McNemar's tests depending on the data structure. A Bonferroni correction was applied to control the family-wise error rate where there were multiple paired comparisons for a given question. When comparing the three training conditions, there were three paired comparisons; therefore, the adjusted $\alpha$ for these tests was .0167 (.05/3). When comparing the six different treatment groups, there were 15 paired comparisons to be performed for each question; therefore, the adjusted $\alpha$ for these tests was .0033 (.05/15). Given the large number of paired comparisons made in this study, interaction-level findings are only reported where statistically significant differences were identified. Additional details specific to certain statistical analyses are provided where relevant throughout the Results section.

## Results

This results section first presents findings from the post-training questionnaire and the final questionnaire. On-road driving behavior results are presented subsequently.

### Post-Training Questionnaire (PTQ)

Participants completed the PTQ immediately after receiving training on the L2 feature, so results of the questionnaire captured participants' mental models and expectations for use of the feature before they drove the vehicle themselves. Wilcoxon rank-sum and Pearson's chi-square tests were used to compare responses of participants in the DriveAssist and AutonoDrive conditions. Questions related to confidence and trust in the capabilities of the L2 feature and the potential benefits of the system hypothesized greater confidence and perceived benefits among AutonoDrive participants than DriveAssist participants. Thus, one-tailed tests were used for these comparisons. For training condition and branding/training interactions, two-tailed tests were performed.

#### Vehicle Control Scenarios

The first set of questions in the PTQ described 18 different driving situations. Each one asked participants to "indicate whether or not you expect DriveAssist/AutonoDrive to successfully control vehicle speed and keep the vehicle in its lane without the driver doing anything." Participants' response options were "definitely will," "probably will," "probably will not," "definitely will not," and "I have no idea." Participants were encouraged not to use the "I have no idea" option unless they felt that they had no basis whatsoever to make this assessment. Wilcoxon rank-sum tests were used to assess differences between branding and training conditions.

Table 3 shows that differences between DriveAssist and AutonoDrive groups reached statistical significance for seven of the 18 questions, and approached significance ($p \leq .10$) for two additional questions. In all of these situations, AutonoDrive participants indicated higher levels of confidence that the feature would successfully control the vehicle. This includes situations where the L2 feature would not successfully control the vehicle, such as reducing speed when the speed limit is reduced, and driving through a tollbooth with a 10 mph speed limit. Figure 5 shows response distributions for questions where AutonoDrive participants expressed significantly higher levels of confidence than DriveAssist participants.

When comparing training conditions, Wilcoxon rank-sum tests revealed a significant difference for only one of the 18 questions in this set (bringing the vehicle to a stop if the driver loses consciousness due to a medical emergency). For this scenario, quick-start participants expressed higher levels of confidence in the L2 feature than demo participants ($p = .006$). Figure 6 shows the response distributions for this question.

Collision Avoidance Scenarios

A related set of questions described eight potential collision scenarios and asked participants to "indicate whether or not you expect DriveAssist/AutonoDrive to take action and avoid a collision, without the driver doing anything." Table 4 shows significant differences in response distributions between DriveAssist and AutonoDrive participants for all eight questions, with AutonoDrive participants more likely to indicate higher confidence in the vehicle's collision avoidance capabilities in all cases. Figure 7 shows the distribution of responses by branding for six of the questions where responses were significantly different. Given the actual capabilities of the L2 feature, these results indicate overconfidence among AutonoDrive participants in the collision avoidance capabilities of the vehicle.

When comparing responses to these eight questions by training condition, there were no significant differences, but when comparing participants' responses in each pair of the six conditions, significant differences were observed for four of the eight scenarios in this set. For "Car in lane directly next to you starts changing into your lane," AutonoDrive video participants reported significantly higher levels of confidence in the L2 feature than both DriveAssist video ($p < .001$) and DriveAssist demo ($p < .001$) groups. For "Slower-moving vehicle in lane next to you changes lanes in front of you, leaving a very small gap," AutonoDrive video ($p < .001$) and AutonoDrive demo ($p = .003$) groups both reported significantly higher levels of confidence in the L2 feature than DriveAssist video participants. For "Approaching a slower moving motorcycle ahead in your lane," AutonoDrive quick start ($p < .001$) and AutonoDrive demo ($p < .001$) groups both reported significantly higher levels of confidence in the L2 feature than DriveAssist video participants. Finally, for the scenario "Approaching a deer that is on the roadside, but walking toward your lane," AutonoDrive demo participants reported significantly higher levels of confidence in the L2 feature than both DriveAssist video ($p = .003$) and DriveAssist demo ($p < .001$) groups.

Driver's Role while Using L2 Feature

Participants were asked which of these statements best reflects their understanding of the driver's role while using the L2 feature:

1. I have to keep my hands on the wheel and feet on the pedals to help guide DriveAssist/AutonoDrive.
2. I can take my hands off the wheel and feet off the pedals, but I need to pay attention to the road and be ready to steer or use the pedals at all times.
3. I can take my hands off the wheel and feet off the pedals, and I only need to occasionally glance at the road.
4. I can take my hands off the wheel and feet off the pedals, and I don't need to look at the road unless I get a notification from DriveAssist/AutonoDrive.

All but two of the 90 participants in the study correctly responded “2,” indicating an accurate understanding of the driver’s role.

Areas where L2 Feature Detects and Responds to Other Vehicles

Another set of questions asked, “In what areas around the vehicle does DriveAssist/AutonoDrive detect and respond to other vehicles?” Table 5 shows the results of chi square tests for this question. While all participants correctly understood that the vehicle detects and responds to vehicles in front, AutonoDrive participants were significantly more likely to believe incorrectly that the L2 feature can detect and respond to other vehicles behind the vehicle and to the sides (see Figure 8).

For training condition, results show a significant difference for “behind vehicle” ($\chi^2 = 6.94$, $p = .034$) (see Table 6). Figure 9 shows that 90 percent of video participants, 83 percent of demo participants, and 63 percent of quick-start guide participants correctly respond that the vehicle does not detect and respond to other vehicles behind it. All participants correctly understood that the vehicle detects and responds to vehicles in front, and there was no significant difference between training conditions in the proportion of participants who believed incorrectly that the vehicle would respond to vehicles to the sides.

Chi square tests comparing all six conditions for this set of questions showed significant differences between groups for the questions about detecting and responding to vehicles behind and to the sides of the vehicle. Table 7 shows the percentage of participants in each condition who correctly responded that the L2 feature does not detect and respond to vehicles in these areas. The table shows that DriveAssist conditions ranged from 80 to 100 percent correct, whereas the AutonoDrive conditions ranged from 27 to 80 percent correct.

Comprehension of L2 Feature Activation, Use, and Displays

The next set of questions assessed participants’ comprehension of requirements to be able to activate the L2 feature, how the feature notifies the driver when it is activated, how it notifies the driver when it gives control back to the driver, and what happens when the driver presses the brake pedal or accelerator, changes lanes, or leaves the feature’s mapped area. All questions were phrased as yes/no or multiple choice. Across 17 questions in this set, chi square tests show that only one question had significantly different responses between DriveAssist and AutonoDrive participants. When asked whether or not lane lines must be visible on the road, 96 percent of DriveAssist participants correctly answered yes, while only 76 percent of AutonoDrive participants answered correctly ($\chi^2 = 7.28$, $p = .011$). Table 8 shows chi square test results for all of the questions in this set.

Only one question had significantly different responses between participants in different training conditions. For the question, “What must happen before DriveAssist/AutonoDrive will begin steering?” 97 percent of quick start and video participants correctly understood that the vehicle must be on a limited-access highway, while only 70 percent of demo participants responded correctly ($\chi^2 = 13.26$, $p = .004$).

Willingness to Drive while Using L2 Feature in Various Situations

A set of questions asked participants how willing they would be to drive in various situations using the L2 feature, relative to driving without it. Wilcoxon rank-sum tests show that there were significant differences between DriveAssist and AutonoDrive participants for four of the 11 questions. When using the L2 feature, AutonoDrive participants expressed higher levels of willingness than DriveAssist participants to drive while having a handheld cellphone conversation, having a hands-free cellphone conversation, eating, and driving faster than they normally do. AutonoDrive participants were also marginally more likely than DriveAssist participants to express willingness to drive using the L2 feature with back or shoulder pain. Table 9 shows Wilcoxon rank-sum test results for all questions in this set, and Figure 10 shows the distributions of responses for each of these four situations in which there were significant differences between branding conditions.

Only one question in this set had significantly different responses between participants in different training conditions. Demo participants reported significantly higher levels of willingness to drive with back or shoulder pain when using the L2 feature, compared to video participants ($p = .002$). There was also one significant interaction for this group of questions. AutonoDrive demo participants were significantly more likely than DriveAssist video participants to express a willingness to drive using the L2 feature with back or shoulder pain ($p < .001$).

Expectations for Upcoming Drive

The final set of questions in the PTQ asked participants how well they expect the L2 feature to work on their upcoming drive, and their expectations with regard to safety, stress reduction, physical comfort, and emotional reactions. Table 10 shows results of Wilcoxon rank-sum tests for these questions. AutonoDrive participants expressed significantly higher levels of trust in the L2 feature to avoid conflicts with other vehicles, and were marginally more comfortable about using the L2 feature on their upcoming drive. There were no significant differences between DriveAssist and AutonoDrive participants with regard to these questions. There were no significant differences between training conditions for the questions in this set.

## Final Questionnaire (FQ)

Participants completed the FQ immediately after completing their drive using the L2 feature, so the results of the questionnaire captured participants' mental models and reactions to use of the feature after firsthand experience using it. In addition to statistical tests analogous to those presented in the previous section, tests were also conducted to compare participants' responses to comparable questions from the PTQ (administered before driving) to the FQ (administered after driving) where possible. Wilcoxon signed-rank tests (two-tailed) were used for the majority of comparisons. McNemar's test was used where response options were binary (e.g., yes or no).

Vehicle Control Scenarios

The first set of questions in the FQ was the same 18 driving situations presented in the PTQ. Each one asked participants to "indicate whether or not you expect DriveAssist/AutonoDrive to successfully control vehicle speed and keep the vehicle in its lane without the driver doing anything." Table 11 shows that there were significant differences for five of the scenarios (driving at night without street lights, driving into direct glare at sunset, driving where lane lines are badly faded, driving down a steep hill, and driving through a one-mile-long tunnel). An additional three scenarios had marginally significant differences between conditions (exiting onto a freeway from one ramp to another, driving in stop-and-go traffic due to a traffic jam, and reduce speed on a tight curve where the current set speed is set too fast). In all of these scenarios, AutonoDrive participants were more likely to believe that the L2 feature could successfully control the vehicle. Figure 11 shows the distribution of responses by branding for each of the five scenarios with significant differences.

For this set of questions, there were no significant differences between training conditions, but there was one significant interaction. AutonoDrive demo participants expressed significantly higher levels of confidence that the L2 feature would successfully control the vehicle in a one-mile long tunnel than DriveAssist demo participants did ($p = .003$).

Because the set of 18 scenarios discussed above was also asked in the PTQ, it is possible to assess whether participants' responses changed significantly after actually using the L2 feature. Table 12 shows the results of Wilcoxon signed-rank tests on repeated measures for branding. DriveAssist participants' responses changed significantly for five of the 18 scenarios and AutonoDrive participants' responses changed significantly for six scenarios. In all of the scenarios where significant changes were observed, participants expressed higher levels of confidence in the L2 feature after actually using it. Some of the scenarios where confidence increased were actually beyond the technology's ODD. For example, after driving the vehicle, both DriveAssist and AutonoDrive participants expressed higher levels of confidence in the L2 feature's ability to successfully control the vehicle while driving in a work zone where lanes shifted from their usual location, to reduce speed on a tight curve where the current set speed is too fast, and while driving down a steep hill. After driving the vehicle, AutonoDrive participants also expressed higher levels of confidence that the L2 feature could successfully control the vehicle in heavy rain and heavy snow, and driving at night without streetlights. DriveAssist participants reported higher levels of confidence in L2 feature's ability to keep a safe distance from a truck with a pole extending 15 feet out from the back of the truck and operate while driving through a one-mile tunnel after driving the vehicle than they did in the PTQ.

Figure 12 shows the response distributions for six of the scenarios where there were significant changes within a branding condition from the PTQ to the FQ. The percentage of DriveAssist participants who incorrectly reported that the L2 feature definitely or probably would reduce speed on a tight curve when the current speed is set too fast increased from 27 percent to 62 percent, which could have potential safety consequences. Among

AutonoDrive participants, the scenarios about driving through a work zone with a lane shift, and the L2 feature reducing speed on a tight curve when the current speed is set too fast, showed shifts toward higher levels of confidence in the L2 feature that indicate a potential safety concern related to inaccurate beliefs in the vehicle's capabilities.

When examining changes from PTQ to FQ by training condition for the 18 scenarios discussed above, significant changes exist within all three conditions. As with branding condition, all significant changes were in the direction of higher levels of confidence after using the L2 feature on the road than before using the L2 feature. Table 13 shows the questions and training modes where significant changes occurred. Among the 18 scenarios, quick start participants expressed significantly higher levels of confidence in four, video participants expressed higher levels of confidence in five, and demo participants expressed higher levels of confidence in two.

<u>Collision Avoidance Scenarios</u>

A related set of questions described eight potential collision scenarios. Each one asked participants to "indicate whether or not you expect DriveAssist/AutonoDrive to take action and avoid a collision, without the driver doing anything." Whereas the PTQ revealed significant differences between DriveAssist and AutonoDrive participants for all eight questions, there were only significant differences between conditions for three of the eight questions in the FQ (see Table 14), suggesting that differences in mental models between the two conditions were reduced after experience using the L2 feature. Figure 13 shows the response distributions for these three questions.

There were also two significant interactions for the scenario "Car in lane directly next to you starts changing into your lane." AutonoDrive video participants reported significantly higher levels of confidence that the L2 feature would take action and avoid a collision than both DriveAssist quick start ($p = .002$) and DriveAssist demo ($p < .002$) groups.

Wilcoxon signed-rank tests were conducted to determine whether participants' confidence in the L2 feature to take action and avoid a collision changed from the PTQ to the FQ. Results are shown in Table 15. DriveAssist participants expressed significantly higher levels of confidence in the L2 feature to take action and avoid a collision after driving than they did in the PTQ for five of the eight scenarios. There were no significant changes in AutonoDrive participants' responses. Figure 14 shows response distributions for DriveAssist participants for the five questions where they shifted significantly toward positive responses.

For the eight collision avoidance scenarios, there was only one significant difference between training groups. A Wilcoxon rank-sum test showed that demo participants were significantly less likely than video participants to believe that the L2 feature would take action and avoid a collision with an adjacent vehicle that starts moving into their lane ($p = .003$). Figure 15 shows response distributions for the three training conditions.

An analysis of responses in the PTQ versus the FQ, revealed some significant changes in responses (see Table 16). Wilcoxon signed-rank tests show that quick start participants' expectations of the L2 feature changed significantly for one of the eight scenarios, video participants' expectations changed for six scenarios, and demo participants' expectations did not change significantly for any of the scenarios. In all cases, participants' confidence in the L2 feature to take action and avoid a collision increased.

Areas where L2 Feature Detects and Responds to Other Vehicles

For the set of questions about which areas around the vehicle the L2 feature can detect and respond to other vehicles, significant differences persisted between DriveAssist and AutonoDrive in the FQ. Table 17 shows that AutonoDrive participants were significantly more likely than DriveAssist participants to believe incorrectly that the vehicle could detect and respond to vehicles to its sides and behind it, even after experience driving the vehicle. Figure 17 shows that 89 percent of DriveAssist participants correctly responded that the L2 feature cannot detect and respond to other vehicles behind it, compared to only 69 percent of AutonoDrive participants. Also, while 84 percent of DriveAssist participants correctly responded that the L2 feature cannot detect and respond to vehicles to its left and right, only 44 percent of AutonoDrive participants responded correctly. These differences show that even after experiencing the L2 feature, AutonoDrive participants were significantly more likely to hold incorrect beliefs about the L2 feature's capabilities that could result in inappropriate driver behaviors. McNemar's tests show that neither DriveAssist nor AutonoDrive participants significantly changed their responses to these questions between the PTQ and FQ.

For the set of questions about which areas around the vehicle the L2 feature can detect and respond to other vehicles, there was a significant difference between training conditions regarding whether or not the vehicle could detect and respond to vehicles behind it ($\chi^2$ = 9.74, p = .01). Figure 18 shows that while 90 percent of video participants and 87 percent of demo participants correctly responded that the vehicle does not detect and respond to vehicles behind it, only 60 percent of quick start participants answered correctly, even after experience driving the vehicle. When comparing changes among participants' responses from PTQ to FQ by training condition, data show no change in the number of participants who answered correctly for any of the three questions.

There was also a significant interaction between branding and training conditions for the questions about whether the L2 feature will detect and respond to vehicles behind ($\chi^2$ = 5.4, p = .04) and to the sides of the vehicle ($\chi^2$ = 26.23, p < .001). Table 18 shows that the percentage of participants who responded correctly varied from 73 to 100 percent among DriveAssist groups, and 33 to 87 percent for AutonoDrive groups.

Willingness to Drive while Using L2 Feature in Various Situations

A set of 11 questions asked participants how willing they would be to drive in various situations using the L2 feature, relative to driving without it. There were significant differences between DriveAssist and AutonoDrive participants for four of the eight questions (see Table 19). Figure 19 shows that AutonoDrive participants expressed higher levels of willingness to drive using the L2 feature when experiencing back or shoulder pain, having a hands-free cell phone conversation, having a handheld cell phone conversation, and eating. There was also a marginally significant finding of AutonoDrive participants being more willing than DriveAssist participants to drive faster than usual with the L2 feature ($p = .052$). When comparing participants' responses to this set of questions in the PTQ versus the FQ, Wilcoxon signed-rank tests show that there were three scenarios where DriveAssist participants' ratings changed significantly and one scenario where AutonoDrive participants' ratings changed significantly (see Table 20). In all cases, participants shifted toward higher levels of willingness to drive in the stated situation. Response distributions for situations with significant differences are shown in Figure 20. There were no significant differences between training conditions for this set of questions, nor were there any significant differences when comparing all six groups.

### Feedback from Use of L2 Feature

The next set of questions asked participants how well the L2 feature worked on their drive, with regard to safety, stress-reduction, physical comfort, and emotional reactions (i.e., scary or fun to use). As with the parallel questions asked in the PTQ to assess participants' expectations prior to their drive, there were no significant differences between DriveAssist and AutonoDrive participants with regard to these questions. There were, however, some significant changes from the PTQ to the FQ (see Table 21). Figure 21 shows that DriveAssist participants were significantly more likely to report after driving that the L2 feature improved their physical comfort and was fun to use, relative to their expectations before the drive. Both DriveAssist and AutonoDrive participants were less likely to report after driving that the L2 feature was scary to use, relative to their initial expectations.

There were no significant differences between training conditions with regard to these questions. There were, however, some significant changes from the PTQ to the FQ (see Table 22). Participants in all three training conditions reported significantly lower levels of agreement that the L2 feature was scary to use after using the feature, relative to their expectations before the drive. Demo participants also reported higher levels of agreement that the L2 feature was fun to use after the on-road drive compared to before the drive. Figure 22) shows the changes in response distributions where significant changes were observed.

### Performance of L2 Feature

The next two questions in the FQ asked about the performance of the L2 feature (excellent, very good, fair, or poor) and its performance compared to participants' expectations (much better, somewhat better, met expectations, somewhat worse, much worse). There were no significant differences between DriveAssist and AutonoDrive participants, or participants in the three training conditions, for these questions.

Feedback about L2 Feature Training

The next set of five questions asked about the training participants received before driving the vehicle, and the name of the L2 feature. Wilcoxon rank-sum tests show that there were no significant differences between DriveAssist and AutonoDrive participants regarding their ratings of how useful the training was in understanding how to activate the L2 feature, accuracy in describing the capabilities and limitations of the L2 feature, or how well the training reflected the actual capabilities of the L2 feature. AutonoDrive participants, however, were significantly more likely than DriveAssist participants to believe that the name of the feature makes the technology sound more capable than it actually is ($p = .002$). Figure 23 shows that 42 percent of AutonoDrive participants felt that the name AutonoDrive makes the feature sound more capable than it is, whereas only 11 percent of DriveAssist participants felt that the name DriveAssist makes the feature sound more capable than it is.

For these same five questions, there was one significant difference between training conditions (see Table 23). A Wilcoxon rank-sum test revealed that demo participants rated the training as more useful in understanding how to activate the L2 feature than video participants. Figure 24 shows the response distribution for this question. When comparing each of the six conditions against one another, AutonoDrive video participants were significantly less like to agree that the training was useful in understanding how to activate the L2 feature than both AutonoDrive demo ($p < .001$) and DriveAssist quick start groups ($p < .001$).

**Driving Behaviors**

There were five key dependent variables in the on-road portion of this study: hands-away-from-wheel time, foot-off-pedals time, percentage of time using the L2 feature, mean speed while using the L2 feature, and response time to an unexpected handoff of control from the L2 feature to the driver. The driver hand position and foot position were analyzed over the course of four 2-minute segments during the drive. For analyses of both hand and foot position, data were first transformed using ordered quantile normalization. Quantile normalization was determined to be the best transformation method for these data according to the Pearson P statistic divided by its degrees of freedom, which is a measure of the departure from normality. Transformed data were then analyzed using ANOVA, and follow-up pairwise comparisons were conducted using Tukey Honestly Significant Difference (HSD) tests. The results for each of these variables are described below.

Hand Position

Driver hand position was analyzed to determine the percentage of time the participant had both hands away from the steering wheel. Participants were considered to have their hands away from the wheel only if both hands were neither touching the wheel nor poised close to the wheel in preparation to grab it (i.e., hand within approximately three inches of the wheel with palm facing wheel). Hands away from the wheel was considered an indicator of confidence in the L2 feature to control the vehicle's lane position.

The first of the four analyzed segments began within approximately one mile of participants activating the L2 feature for the first time. Therefore, it is of interest to analyze this segment individually to determine how willing participants were to remove their hands from the wheel shortly after first engaging the L2 feature. Results show a significant difference in segment 1 hands-away-from-wheel time between DriveAssist and AutonoDrive participants ($F = 4.99$, $p = .028$). Figure 25 shows that, in segment 1, DriveAssist participants had their hands away from the wheel for 61 percent of the time, whereas AutonoDrive participants had their hands away from the wheel 81 percent of the time. Follow-up pairwise comparisons show that AutonoDrive demo participants had their hands off the wheel for significantly more of the first segment than participants in all three DriveAssist training conditions, and AutonoDrive video participants.

Differences between training conditions approached, but did not reach, statistical significance ($F = 2.83$, $p = .065$). Demo participants had their hands away from the wheel 82 percent of the time, followed by quick start participants at 67 percent, and video participants at 65 percent (see Figure 26).

When comparing hands-away-from-wheel time across all four segments combined, results show that throughout the drive, AutonoDrive participants had their hands away from the wheel more than DriveAssist participants ($F = 6.33$, $p = .014$). AutonoDrive participants had their hands off the wheel 88 percent of the time, whereas DriveAssist participants had their hands off the wheel for 77 percent of the time (see Figure 27). Pairwise comparisons using Tukey HSD show no significant differences between individual conditions, though AutonoDrive demo participants had marginally significantly more hands-off-wheel time than both DriveAssist quick start ($p = .053$) and DriveAssist video ($p = .089$) participants.

Across all four segments, differences between training conditions were not statistically significant ($F = 2.09$, $p = .13$).

Foot Position

Foot-away-from-pedals is a behavior that might indicate confidence in the L2 feature to control vehicle speed without driver inputs. The participant was considered to have their foot away from the pedals if neither foot was on or hovering over the gas or brake pedal. In segment 1, foot-away-from-pedals time difference between DriveAssist and AutonoDrive participants did not reach statistical significance ($F = 2.27$, $p = .136$). There was, however, a significant foot-away-from-pedals time difference between training conditions ($F = 3.69$, $p = .029$). Pairwise comparisons of the three training conditions show that there was a significant difference between demo participants and video participants ($p = .027$), with demo participants and video participants having foot-away-from-pedal time proportions of 68 percent and 33 percent, respectively (see Figure 28). When comparing all six experiment conditions, there were no significant differences, but AutonoDrive demo participants had their feet away from the pedals for marginally significantly more time than DriveAssist video participants (p = .065).

For all four segments combined, AutonoDrive participants had significantly more foot-away-from-pedal time than DriveAssist participants ($F = 6.44$, $p = .013$), with time proportions of 70 percent and 54 percent, respectively (see Figure 29). There was also a significant difference between training conditions ($F = 6.90$, $p = .002$). Pairwise comparisons of training conditions show that demo participants had significantly more foot-away-from-pedal time than both quick start participants ($F = -0.56$, $p = .04$) and video participants ($F = -0.82$, $p = .001$). Foot-away-from-pedal time proportions for demo, quick start, and video participants were 79 percent, 58 percent, and 49 percent, respectively (see Figure 30). When comparing all six experiment conditions, results show that AutonoDrive demo participants had significantly more foot-away-from-pedal time than both DriveAssist quick start ($p = .01$) and video ($p = .002$) participants, as well as marginally significantly more foot-away-from-pedal time than AutonoDrive video participants ($p = .083$).

Time using L2 Feature and Travel Speed

The percentage of time using the L2 feature was also calculated for participants across the entire study route, minus the unexpected handoff and turnaround location. There were no significant differences between branding or training conditions, with participants in all six conditions using the L2 feature for 92-93 percent of the study drive, indicating a high willingness to use the feature across all conditions.

Mean speed was calculated for each participant while using the L2 feature. ANOVA results show no significant differences in mean speed between branding conditions, but training condition differences were marginally significant ($p = .079$). There was also a significant difference between all six conditions ($p = .039$). However, the magnitude of differences was small. Mean speeds across the six conditions ranged from 58.1 mph (AutonoDrive quick start) to 60.4 mph (DriveAssist demo), close to the 60-mph speed limit on the study route.

Unexpected Handoff

Participants experienced an unexpected handoff of control from the L2 feature to the driver shortly before reaching the eastbound turnaround point of the route. Each participant's response time was calculated as the time from alert initiation (the moment the auditory alert and steering wheel flashing began to indicate an immediate handoff of control) to the participant retaking control of the steering wheel. Retaking control was defined as the moment the participant grasped the wheel with at least one hand. Participants whose hands were on the wheel at the time of the alert, or those who were not using the L2 feature at the time were excluded from analysis. In total, 76 participants were included in response time analysis. Response times were somewhat constrained because the researcher instructed participants to retake control if they did not do so themselves promptly. This and other potential limitations of the handoff event are described in the Limitations section of this report.

Mean response time across all participants was 2.72 s, with a standard deviation of 2.98 s, and a range of 0.25 s to 12 s. Given the nature of handoff events and the number of long response time outliers observed in this study, however, measures of central tendency alone do not provide a full representation of the data. An alternative approach is to compare takeover response times of a generally safe duration against takeovers of a generally unsafe duration. The difference between safe and unsafe takeover response times depends on the specific takeover scenario. Takeover requests in response to imminent safety hazards typically require a rapid response, while advance notice of an impending handoff might allow for a longer takeover time. The takeover event in this study occurred on a relatively straight section of road and was caused by reaching the end of the L2 feature's ODD, rather than by any imminent safety concern. Therefore, participants did not need to respond as quickly as they might if there was an imminent safety concern. Given the nature of the handoff in this study, the research team selected 4 s as the cutoff time between appropriate and inappropriate takeovers. For analysis purposes, data were treated as binary rather than continuous because, as noted above and in the Limitations section of this report, the absolute values of longer takeover times were often constrained by the experimenter instructing the participant to retake control. The 4-s cutoff was selected *a priori* based on a review of handoff events to determine what response times could generally be deemed appropriate versus inappropriate from a safety perspective, and the distribution of response times (i.e., to ensure a sufficient number of cases in each category for analysis). Fifty-eight participants had takeover times less than 4 s, and 15 participants had takeover times greater than 4 s. Figure 31 and Figure 32 show the number of participants who responded within each 1-s interval by branding and by training condition, respectively. Logistic regression was used to model the probability of participants having takeover times less than or greater than 4 s by branding and training conditions. Results show that branding did not have a significant effect ($p = .22$), though data show that 23 percent of AutonoDrive participants had response times greater than 5 s, versus only 6 percent of DriveAssist participants. There was a significant effect of training ($p = .043$), with demo participants being least likely to respond within 4 s to the unexpected handoff. Figure 33 shows the percentage of participants in each of the six individual conditions whose handoff response times were 4 s or less.

## Discussion

In this study, participants were randomly assigned to one of two branding conditions (DriveAssist emphasized system limitations, AutonoDrive emphasized system capabilities), and one of three training modes (text quick-start guide, video, or in-person demonstration). Based on their assigned conditions, participants were given information about an L2 feature and trained on how to use it. They completed a questionnaire after training, then drove the vehicle on a freeway route using the L2 feature, then completed another questionnaire after the drive.

The primary research hypothesis was that AutonoDrive participants would demonstrate higher levels of confidence in the L2 feature after training and during the on-road drive. Results of this study provide insights on how branding approach and training mode can may influence drivers' mental models and their behavior when using the L2 feature. In the discussion that follows, the effects of the branding approach are discussed first, followed by the effects of training mode, study limitations, and overall conclusions.

### Branding findings

All but two of the 90 participants in this study correctly understood after training that the driver of the vehicle must remain alert and prepared to retake control of steering and speed control at all times, indicating an almost universal understanding of the driver's proper role while using the L2 feature. Despite this finding, there were substantial differences between participants with regard to perceptions of the L2 feature's capabilities.

Participants' responses to a questionnaire administered after training — but before driving the vehicle — show that branding had significant and potentially important effects on participants' expectations of the L2 feature's capabilities. For seven of 18 scenarios, AutonoDrive participants were significantly more confident than DriveAssist participants that the L2 feature could successfully control the vehicle without driver input. This included situations outside of the L2 feature's ODD, such as reducing speed when the speed limit decreases or when approaching a toll booth, as well as situations where L2 feature performance is uncertain (e.g., driving where lane lines are badly faded). For all of the other 11 scenarios where differences were not statistically significant, the trend consistently pointed in the direction of higher confidence among AutonoDrive participants, suggesting that the training emphasis on L2 feature capabilities rather than limitations had a broad impact on drivers' expectations of the L2 feature across a range of scenarios.

Subsequently in the questionnaire, participants were presented with several scenarios in which there was potential for a collision to occur, and for each one, they were asked to report whether they believed the L2 feature would not take action to avoid a collision without the driver doing anything. For all eight scenarios, AutonoDrive participants expressed significantly higher levels of confidence that the L2 feature would take action and avoid a collision. In the majority of these scenarios, it is unlikely that the L2 feature would actually take sufficient action to avoid a collision without driver input, so the higher confidence levels expressed by AutonoDrive participants could potentially increase their risk for adverse safety outcomes. It is also important to reiterate that participants in both branding conditions received the same information about the collision avoidance capabilities of the L2 feature, so the differences observed between DriveAssist and AutonoDrive participants is not attributable to overt misinformation in training materials.

Similarly, AutonoDrive participants were significantly more likely than DriveAssist participants to believe incorrectly that the L2 feature can detect and respond to other vehicles to the sides and rear of the vehicle. Participants in both conditions were correctly instructed that the vehicle only detected and responded to vehicles in front of the vehicle, but this information was given extra emphasis for DriveAssist participants.

In addition to overconfidence in the L2 feature's capabilities, AutonoDrive participants also expressed higher levels of willingness to engage in potentially distracting or risky behaviors while using the L2 feature. These behaviors included having hands-free or handheld phone conversations, eating while driving, and driving faster than usual.

Taken together, the above findings suggest that AutonoDrive participants, who received training that emphasized the capabilities of the L2 feature—though still factually accurate about capabilities and limitations—had higher confidence in the feature's capabilities than DriveAssist participants, who received training that emphasized the feature's limitations and the driver's responsibility. Confidence in the capabilities of an L2 feature can be appropriate when that confidence is commensurate with the actual abilities of the feature. This study shows, however, that the differences in language used in AutonoDrive training materials led to higher expectations for the feature's capabilities, particularly with regard to conflict and collision avoidance, and in many cases, AutonoDrive participants expressed confidence that the L2 feature could take action and avoid a collision in situations that are explicitly outside the feature's ODD.

The differences in mental models observed in the questionnaire administered immediately after the training were reflected in some of participants' actual behaviors when they subsequently drove the vehicle using the L2 feature on a freeway. AutonoDrive participants were more likely to keep their hands away from the steering wheel and their feet away from the pedals while using the L2 feature, indicating higher levels of confidence in the feature's ability to control vehicle lane position, speed, and headway. While 20 percent of all participants took longer than four seconds to retake control after the unexpected handoff, there was not a statistically significant difference between branding conditions in time to retake control. There were limitations to the unexpected handoff event that are detailed in the Limitations section below.

After finishing the on-road drive, participants completed a final questionnaire. Responses to this questionnaire indicated that many of the differences observed between DriveAssist and AutonoDrive participants in the post-training (pre-drive) questionnaire persisted even after participants had firsthand experience using the L2 feature. For example, AutonoDrive participants remained more likely than DriveAssist participants to incorrectly believe that the L2 feature could take action and avoid a crash in situations such a car in an adjacent lane immediately beside the subject vehicle changing lanes toward the car, or a deer walking toward the road and threatening to enter into its path. Moreover, after driving the vehicle and using the L2 feature, participants in both branding conditions became even more likely to overestimate some of its capabilities in ways that could potentially have negative safety consequences. As one example, after driving the vehicle, more participants in both conditions expressed higher levels of confidence that the L2 feature vehicle would reduce its speed if approaching a curve too fast. This and other similar results suggest that a brief experience using the L2 feature does not necessarily lead to a more accurate impression of its capabilities, especially if the capabilities in question were never put to the test on the road. Although it is unclear why participants held these incorrect assumptions, and why they were more likely to report such incorrect assumptions after driving the vehicle compared with immediately after training but before driving, it is possible that participants' post-drive responses were influenced in part by an overall good impression of the performance of the L2 feature during the drive. Participants generally rated the L2 feature as more fun to use and less scary to use after the drive than they expected it would be before the drive.

After driving the vehicle, AutonoDrive participants also continued to express higher levels of willingness to engage in some potentially distracting or risky behaviors while driving, likely indicating higher levels of confidence in the L2 feature. This elevated willingness to engage in risky behaviors combined with overconfidence in feature capabilities indicates potential risks of training and other materials that emphasize L2 feature capabilities and workload reduction rather than feature limitations and driver responsibility.

**Training findings**

The effect of training mode was the other main effect of interest in this study. In the questionnaire completed after training but before driving the vehicle, there were few differences between conditions with regard to mental models of system capabilities, and where differences exist, there was no clear trend indicating consistent differences between training modes.

During the on-road portion of the study, differences between training conditions became more apparent in driving behaviors. Demo participants had spent more time with their foot away from the pedals both during the first segment and throughout the drive. Demo participants also were less likely than participants in the other conditions to respond to the unexpected handoff within 4 seconds. Among demo participants, the AutonoDrive demo group was especially likely to have more time with their hands and feet away from vehicle controls. These findings suggest that demo participants were more confident in the L2 feature's capabilities, perhaps because they had already seen it demonstrated in person and had spent a greater amount of time observing the system operating.

Neither the post-training questionnaire nor the final questionnaire revealed many clear differences in mental models between training conditions. However, there were some significant shifts in mental models observed after participants drove the vehicle compared with the post-training questionnaire. After driving, quick start and video participants expressed generally greater levels of confidence in the L2 feature's ability to control the vehicle and avoid collisions in some circumstances. Some drivers also expressed more positive emotional reactions toward the L2 feature. Demo participants' mental models and attitudes were less likely to change after the on-road drive, perhaps because they had already seen the L2 feature in action before completing the post-training (pre-drive) questionnaire. There were no significant differences between groups in terms of perceived performance of the L2 feature, but demo participants were significantly more likely to report that the training was useful in learning how to activate the L2 feature.

**Context and Implications**

The findings of this study add to the growing body of literature showing that the information provided to drivers about a driver assistance feature, and how the information is provided, can influence mental models in ways that could have negative safety implications.

While some past research has manipulated the accuracy of information provided to participants (e.g., Beggiato & Krems, 2013), adding inaccurate information or excluding relevant information, all participants in the present study were fully informed about the safety-relevant capabilities of the L2 feature. The differences between conditions were related to the name given for the feature, what information was emphasized, the language used to present the information, and the behavior of the feature demonstrator (in quick-start guide photo, training video, or in-person demonstration).

A surprising result of this study was that after experience actually using the L2 feature, participants in both DriveAssist and AutonoDrive conditions tended to increase their confidence in the L2 feature's ability to maintain control of the vehicle and avoid collisions, even in situations outside of the feature's ODD. By contrast, Beggiato & Krems (2013) found that participants whose initial mental models of an ACC feature were manipulated toward overestimating capabilities or understating capabilities tended to converge toward an accurate mental model after each of three subsequent simulated drives. A key difference in the present study is that participants rarely experienced events that allowed them to confirm or reject their assumptions about the L2 feature's capabilities. In the absence of evidence, it is possible that participants increased their expectations of the L2 feature due to an overall positive experience during the drive. A subsequent study by Beggiato & Krems (2015) in which participants drove an on-road route ten times using an ACC feature found that system limitations noted in training tended to fall out of participants' mental models of the system over time if they were not experienced in actual use, which could help to explain the findings of the present study.

Past research shows that the name given to a driving automation technology can influence drivers' expectations of its capabilities (AAA, 2019; Abraham, Seppelt et al., 2017; Nees, 2018; Teoh, 2020). The present study manipulated the L2 feature's name in addition to numerous other aspects of training, so it is not possible to determine the extent to which the feature name influenced participants. In the final questionnaire, however, 42 percent of AutonoDrive participants reported that the name AutonoDrive made the feature sound more capable than it actually is. Only 11 percent of DriveAssist participants reported that the name DriveAssist made the feature sound more capable than it actually is. It is notable that despite the substantial number of AutonoDrive participants who felt that the name AutonoDrive overstated the capabilities of the feature, AutonoDrive participants still were more likely to overestimate the capabilities of the feature across a range of scenarios than DriveAssist participants were. This may indicate that branding can still influence drivers' perceptions of system capabilities even when they recognize that the branding is misleading.

With regard to on-road behaviors, simulator-based research suggests that drivers who receive trust-promoting introductory materials are more likely to engage in potentially distracting tasks while driving and take longer to retake control after an unexpected handoff of control, compared to drivers who receive trust-lowering introductory materials (Körber et al., 2018). The present study found in questionnaire data higher levels of willingness to engage in some potentially distracting tasks among AutonoDrive participants, as well as some indication that AutonoDrive participants were confident in the L2 feature's abilities while actually driving. While reaction times to an unexpected handoff of control were not significantly different between DriveAssist and AutonoDrive participants, there was an indication of a trend toward longer takeover times among AutonoDrive participants, and particularly among AutonoDrive participants who received in-person demonstration training. Limitations of the on-road unexpected handoff method (discussed in the subsequent subsection) might have contributed to a lack of significant differences in takeover times.

## Limitations

The design of this study allowed for the exploration of the effects of different informational types and modes on drivers' attitudes toward, and use of, an L2 feature. There were, however, some limitations to this design.

Participants in this study had not previously driven a vehicle with an L2 system, and their learning about the system and use of the system occurred under contrived rather than natural circumstances. Outside of this study, drivers' reasons for using and learning about the L2 feature would vary, as would the ways that they learn about the technology. Real-world learning before using the feature could vary dramatically, and unlike the present study, could lack important information or include misinformation. Some drivers might learn little or nothing about the technology before attempting to use it on the road. Under real-world circumstances, drivers' mental models for an L2 feature might vary widely and reflect ways of thinking not observed in study participants, given their highly controlled learning and use context.

It is also possible that the initial study advertisements could have instilled some bias in participants. The wording in the advertisement was intended to state the basic capabilities of the study vehicle succinctly and with as little bias as possible toward emphasizing capabilities or limitations. The ad described the study task as follows: "If you participate, you will drive a vehicle on MD Route 200 (Intercounty Connector) while using a technology that allows the vehicle to accelerate, brake, and stay in its lane without the driver steering or using the pedals." This explanation was reiterated and expanded upon during the screening phone call, but without changing the basic description of the technology. Anecdotal evidence from experimenters suggests that many participants upon arrival indicated that they expected the vehicle to have greater self-driving capabilities than it actually did, equivalent to Level 3+ automation. While responses to the post-training questionnaire suggest that these elevated expectations were corrected by training, they could possibly have affected who volunteered for the study and/or their impressions of the L2 feature.

While not necessarily a limitation of the study, it is important to note that the questions used in the questionnaires were designed specifically to address the research questions of interest in this study, and were not validated as measures of mental models, though they did undergo pilot testing and revision. Therefore, the reliability and validity of the measures were not demonstrated in advance of this research.

While the questionnaires specifically directed participants to think about the L2 feature when answering questions, the study vehicle did have additional safety features, including forward collision alert and lane departure warning. No safety features other than the L2 feature itself were mentioned to participants until they were ready to begin the on-road drive, at which point the experimenter said the following: "Also, please note that this car has lane departure warning and forward distance alert features, so you may hear alerts from those features as you drive." Anecdotal evidence from experimenters suggests that participants' responses to questionnaires were focused on the L2 feature, as intended.

In this study, participants' experience using the L2 feature was limited to one limited-access highway with relatively low workload demand, unchallenging roadway infrastructure, and few opportunities for conflicts with other vehicles. Sessions were only conducted in dry, daylight conditions, with a researcher present in the front seat. Participants had a total of approximately 30 minutes to use the L2 feature. Given these conditions, participants had only a limited opportunity to experience the feature and how it works under varied circumstances. The limited opportunity to use the feature allowed this study to explore how an initial driving experience affects mental models, but it did not investigate how mental models are further refined through additional, more naturalistic experiences, including encountering situations that might confirm or contradict participants' expectations.

One objective of the driving portion of the study was to explore the occurrence of unsafe uses of the L2 feature, especially as they relate to how drivers were trained and their mental models of the feature. While this study did observe unsafe behaviors (e.g., participants failing to recognize that the L2 feature had ceded control to them), the researcher always intervened before an improper behavior could compromise safety, so it is unclear how quickly drivers would recognize and correct errors if they were not in the presence of a trained observer.

This study observed substantial differences between participants in the DriveAssist and AutonoDrive conditions. However, information within these conditions varied on several dimensions, so it is not possible to determine the degree to which specific differences affected outcomes overall, or outcomes for specific questionnaire responses and driving behaviors. Similarly, while the training modes (quick-start guide, video, and in-person demo) largely contained identical or equivalent information, there is limited opportunity to determine what specific differences between these modes affected study outcomes.

Finally, the unexpected handoff event when approaching the Konterra Drive exit at the eastbound end of the route occurred for all participants, allowing researchers to investigate participants' reactions to unexpected handoffs under comparable conditions. However, some participants experienced unexpected handoffs at other locations as well. Unlike the Konterra handoff, these other handoffs were largely unpredictable and varied in number, location, and cause between participants. Some occurred before the Konterra handoff, meaning that the Konterra handoff was not the first handoff experienced by some participants. These additional handoff events were very rare during pilot testing and early in the study, but increased in frequency later in the study, possibly due to increased sun glare as the sun rose lower in the sky over the duration of the field period (August through October).

In addition to the unpredictability of handoff event occurrence, researchers often verbally intervened after the handoff to instruct the participant to retake control of steering. For safety reasons, researchers were given total discretion to verbally intervene if the participant did not quickly retake control of steering. As a result, reaction times were often constrained by researcher intervention. This was an important aspect of the study design to ensure safety on the road, but meant that researcher intervention could occur at different times, or not at all, for each subject. It is possible that such interventions may have had an influence on participants' responses to the questionnaire administered after the drive or on their driving behavior following the intervention. Furthermore, it is possible that the mere presence of the researcher in the vehicle affected participants' reactions to the handoff. Specifically, some participants might have been less likely to react promptly to the handoff alert because they expected the researcher – as the leader of the session and an expert on the L2 feature – to say something in this situation. Participants might have interpreted the researcher's lack of reaction to the alert to mean that there was no need to take action. For these reasons, handoff response times may not reflect naturalistic behaviors.

## Conclusions

In this study, participants were randomly assigned to learn about the L2 feature of a vehicle under one of two branding conditions (DriveAssist, which emphasized system limitations or AutonoDrive, which emphasized system capabilities), and one of three training modes (text quick-start guide, video, or in-person demonstration). Results provided evidence that information emphasizing the capabilities of an L2 feature can result in substantially different expectations of system capabilities than emphasizing the limitations of the feature, that these differences in expectations can influence behaviors in an initial use of the feature, and that these differences persist after brief initial use. In fact, the relatively high, and in some cases excessive, expectations of AutonoDrive participants for L2 feature capabilities actually increased somewhat after using the feature. These differences were observed despite the fact that all participants received accurate and complete information about the L2 feature's capabilities and limitations.

Training mode had relatively little impact on safety-relevant expectations of L2 feature capabilities, but participants who experienced an on-road demonstration were significantly more likely to exhibit on-road behaviors indicative of higher levels of confidence, including keeping their hands and feet away from vehicle controls while using the feature. Demonstration participants, and particularly those in the AutonoDrive group, were less likely to react quickly to an unexpected handoff of control from the L2 feature.

While this study explored participants' confidence that the L2 feature would or would not work in a variety of situations, ultimately, what is important is whether confidence is justified. The generally higher confidence of AutonoDrive participants relative to DriveAssist participants included situations where confidence was justified, and where it was not. Ideally, potential users of a driving automation technology would have an accurate understanding of the situations it can and cannot handle, but the branding condition manipulations used in this study show that differences between DriveAssist and AutonoDrive participants were largely broad-based, and crossed a wide range of scenarios, especially those related to collision avoidance.

In summary, this study finds that consumer-oriented information emphasizing a partially automated driving system's capabilities, without commensurate emphasis given to the system's limitations, can produce inflated expectations regarding what the system can do and the situations that it can handle, with possible implications for safety. Results underscore the importance of providing consumer-oriented information that is not only technically accurate but also balanced, with appropriate emphasis given to the limitations of technology and the importance of driver engagement. These results add to the growing body of literature that suggests that the information drivers receive about driving automation technologies, including the name of the feature, can influence their expectations, and their actual use of the feature, in ways that have the potential to affect safety.

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## Figures

DRIVEASSIST OVERVIEW

DriveAssist is a driver assistance technology for use on limited-access freeways. The system helps you drive by automatically steering the vehicle to maintain lane position while also monitoring your attention to the road. It reduces the need for you to frequently steer, brake or accelerate under available operating conditions.

To maintain automatic control of vehicle steering during freeway driving, DriveAssist uses:

- Global Positioning System (GPS) sensing,
- GPS-enhanced data,
- maps, and
- cameras.

Using these technologies, DriveAssist is able to maintain speed and lane position under most limited-access highway driving conditions.

**HOW DRIVEASSIST WORKS**

For safety reasons, DriveAssist is available only on limited access freeways that are separated from opposing traffic. The GPS determines the vehicle's location while the Lane Sensing Camera detects the marked lanes on the freeway to help the vehicle automatically steer and maintain lane position. As the driver, you are responsible for monitoring the system and all aspects of the vehicle's operation. On some occasions, such as when the lane lines are too faint, you will need to take back control from the system and steer manually. Simply grasp the steering wheel and begin steering when necessary.

DriveAssist works with Adaptive Cruise Control, which detects vehicles in your path and accelerates or brakes your vehicle based on surrounding traffic conditions, to maintain a driver-selected following time from a vehicle ahead, even in stop-and-go traffic conditions.

The steering wheel light bar intuitively provides a status of system operation, including when the system is assisting with steering and when you need to manually steer the vehicle yourself. You can override DriveAssist at any time by steering, braking or accelerating.

If you do not respond to system prompts to manually steer the vehicle, DriveAssist will be disabled and a support technician will be contacted to provide support.

ENGAGING DRIVEASSIST

To use DriveAssist, Adaptive Cruise Control must be on. Adaptive Cruise Control maintains a speed you set like regular cruise control, but it can automatically adjust your vehicle's speed if there is a slower vehicle in front of you.

1. Press the **Adaptive Cruise Control** button (A) on the steering wheel to turn on Adaptive Cruise Control. The symbol (C) will illuminate in white on the instrument cluster. If the Adaptive Cruise Control is already set, the symbol will be green with a speed shown.
2. When DriveAssist detects you are on a limited-access freeway, paying sufficient attention, and all other driving conditions are met (lane markings visible, GPS available, no system faults, etc.), the **DriveAssist** symbol (D) will illuminate in white on the instrument cluster.
3. When it is safe to do so, press the **DriveAssist** button (B) on the steering wheel to engage DriveAssist. If an Adaptive Cruise Control speed was not previously set, DriveAssist will be set to your current speed. When the symbol and steering wheel light bar illuminate in green, you may remove your hands from the steering wheel. Now DriveAssist is helping you to steer and maintain speed. You must continue to monitor the system and the road ahead. Do not engage in distracting tasks such as reading or using your mobile device.

You can increase your set speed by pressing the RES+ button or decrease your set speed by pressing the SET- button on the steering wheel. A light press on the button will change your set speed by one mile per hour. A hard press will change your set speed by five miles per hour.

► To disengage DriveAssist, press the **DriveAssist** again or press the brake pedal.

*Figure 1.* Photo of quick-start DriveAssist booklet.

*Figure 2.* Screenshot from training video.

*Figure 3.* Views captured by the four in-vehicle cameras.

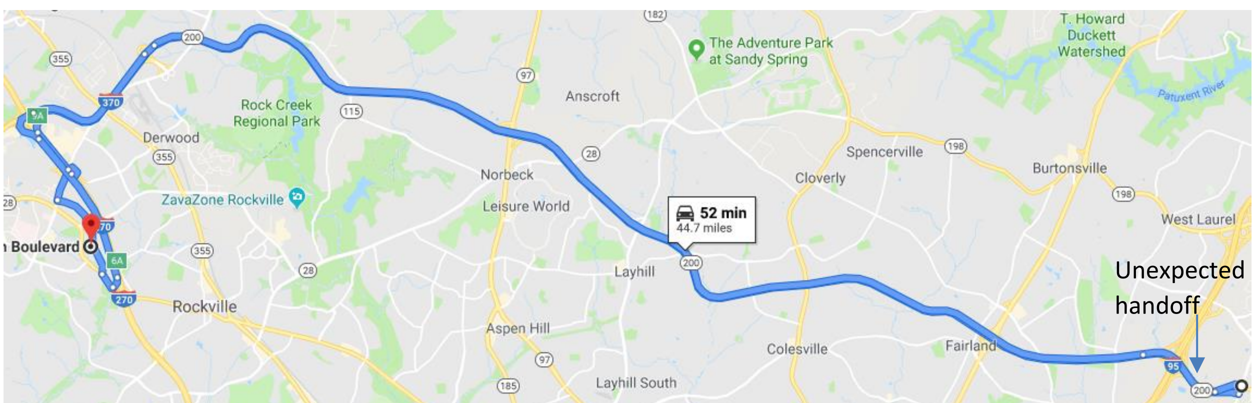


*Figure 4.* Complete driving route from parking lot to turnaround and back.
(Map data © 2019 Google)

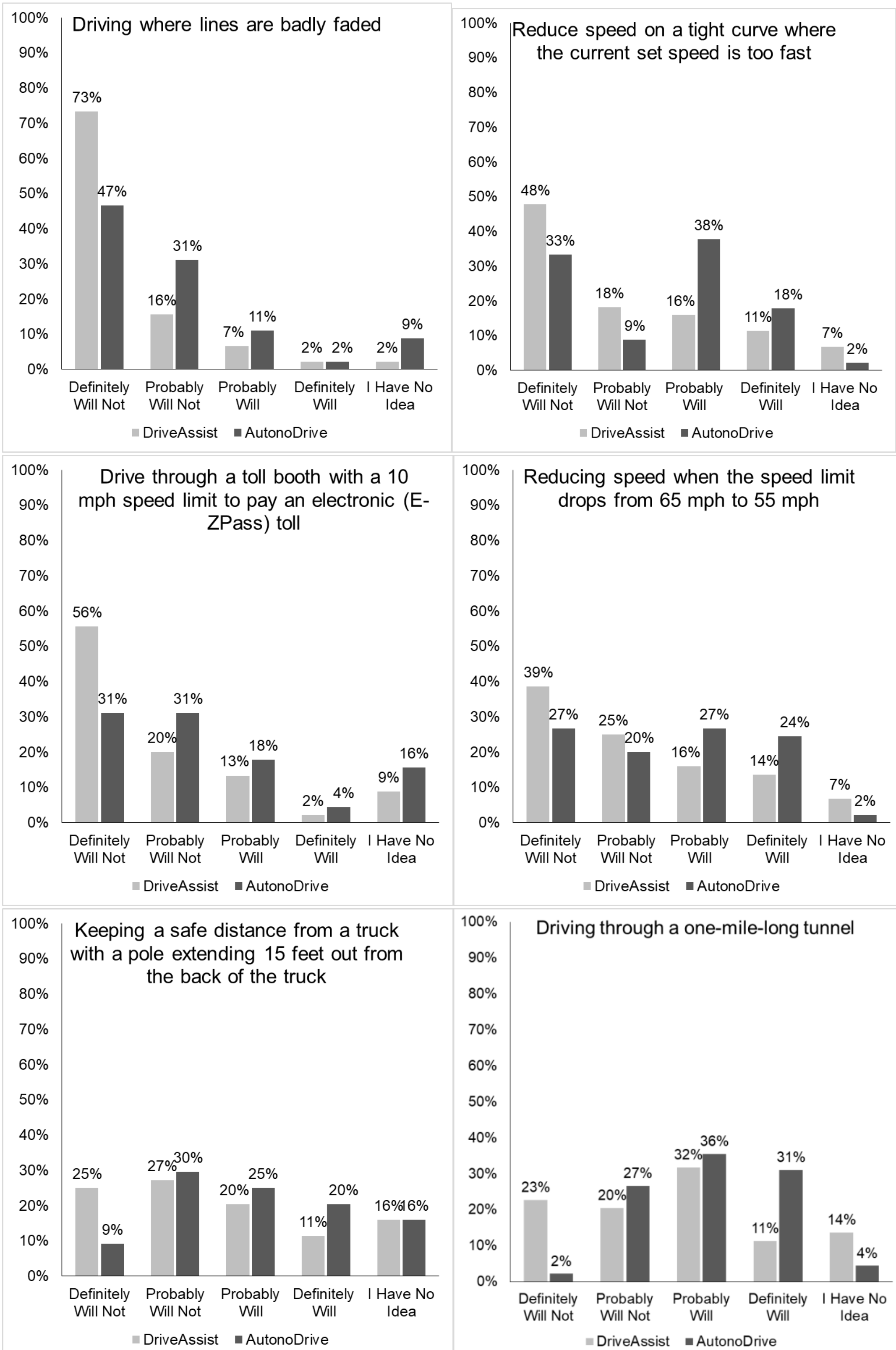


*Figure 5.* Responses to question regarding whether L2 feature would "successfully control vehicle speed and keep the vehicle in its lane without the driver doing anything" in specific scenarios (Post-Training Questionnaire).

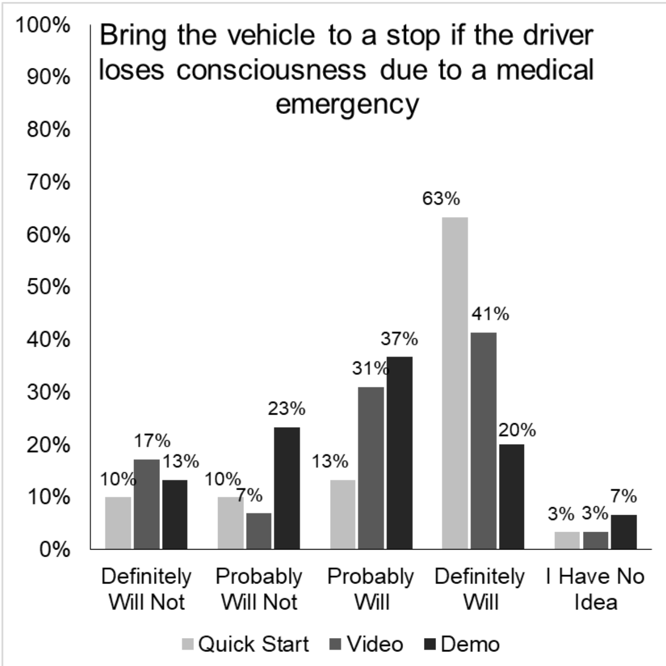


*Figure 6*. Responses to question regarding whether L2 feature would "successfully control vehicle speed and keep the vehicle in its lane without the driver doing anything" in specific scenarios (Post-Training Questionnaire).

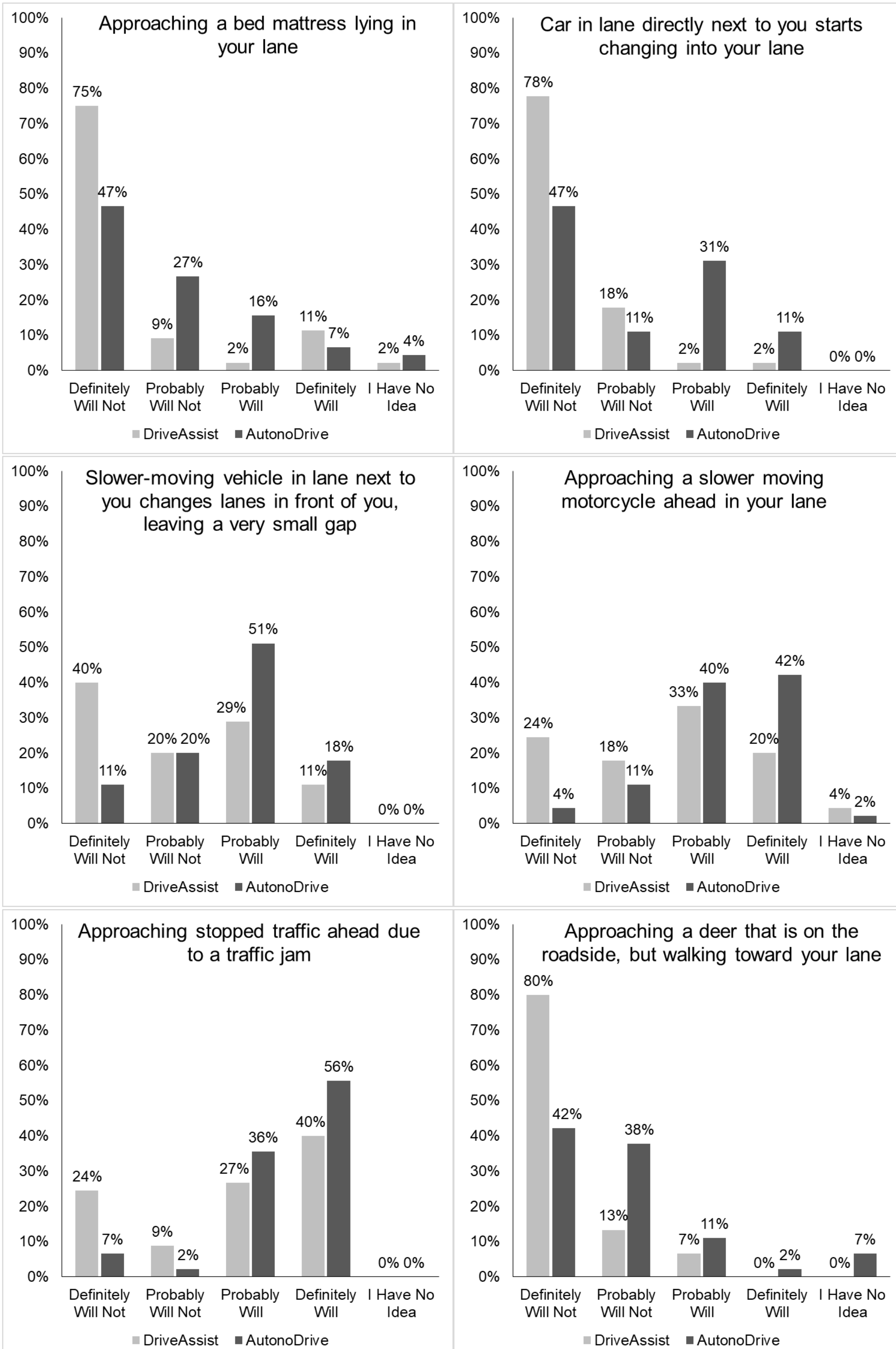


*Figure 7.* Responses to question regarding whether DriveAssist/AutonoDrive would "take action and avoid a collision without the driver doing anything" in specific scenarios (Post-Training Questionnaire).

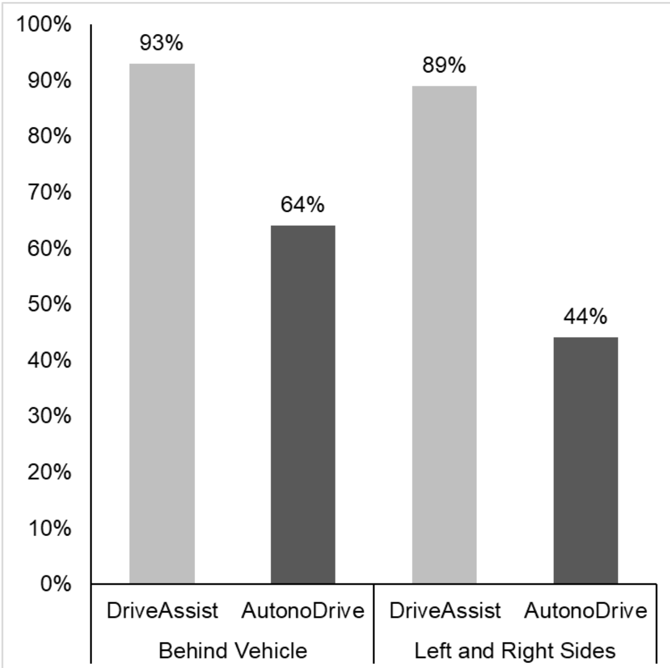


*Figure 8.* Percentage of participants who correctly answered that the L2 feature cannot detect and respond to other vehicles behind and to the left and right sides of the vehicle (Post-Training Questionnaire).

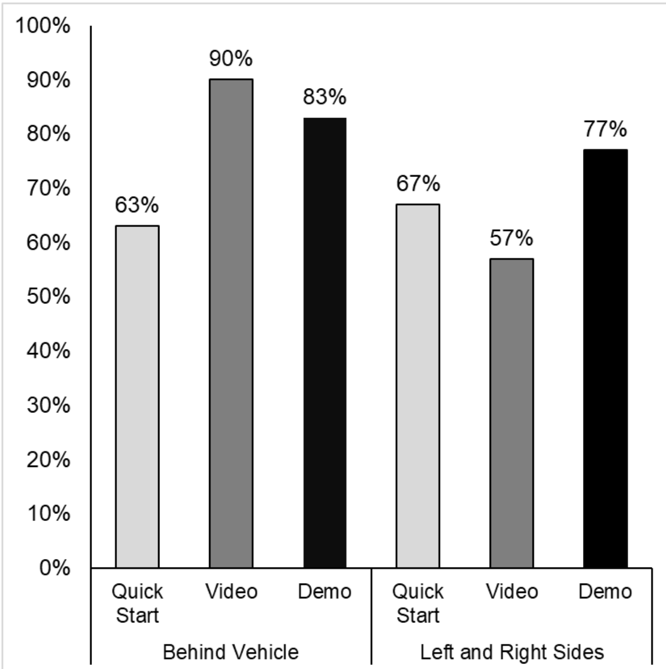

*Figure 9.* Percentage of participants who correctly answered that the L2 feature cannot detect and respond to other vehicles behind and to the left and right sides of the vehicle (Post-Training Questionnaire).

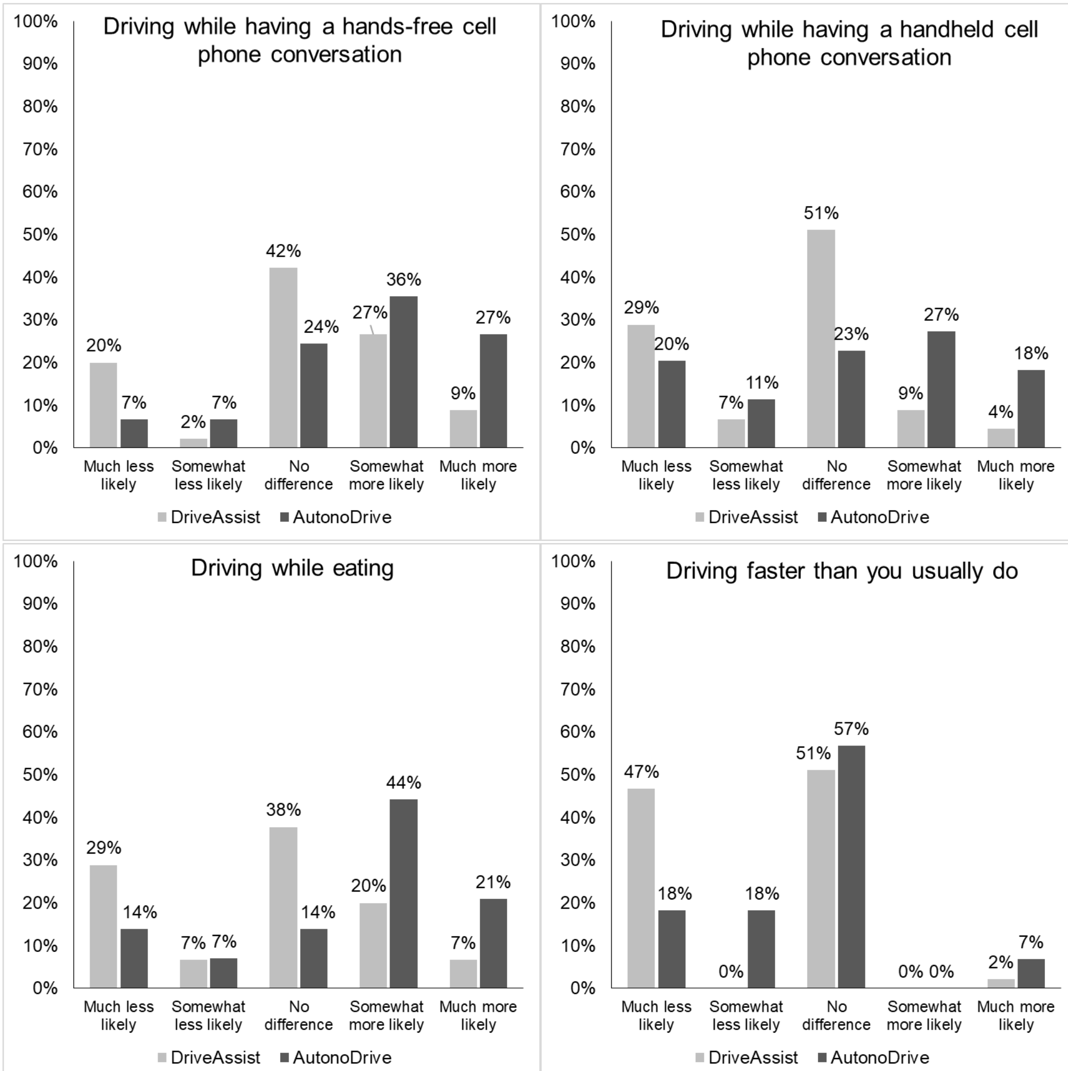


*Figure 10*. Willingness to drive in various situations while using DriveAssist/AutonoDrive, compared to driving a vehicle without DriveAssist/AutonoDrive (Post-Training Questionnaire).

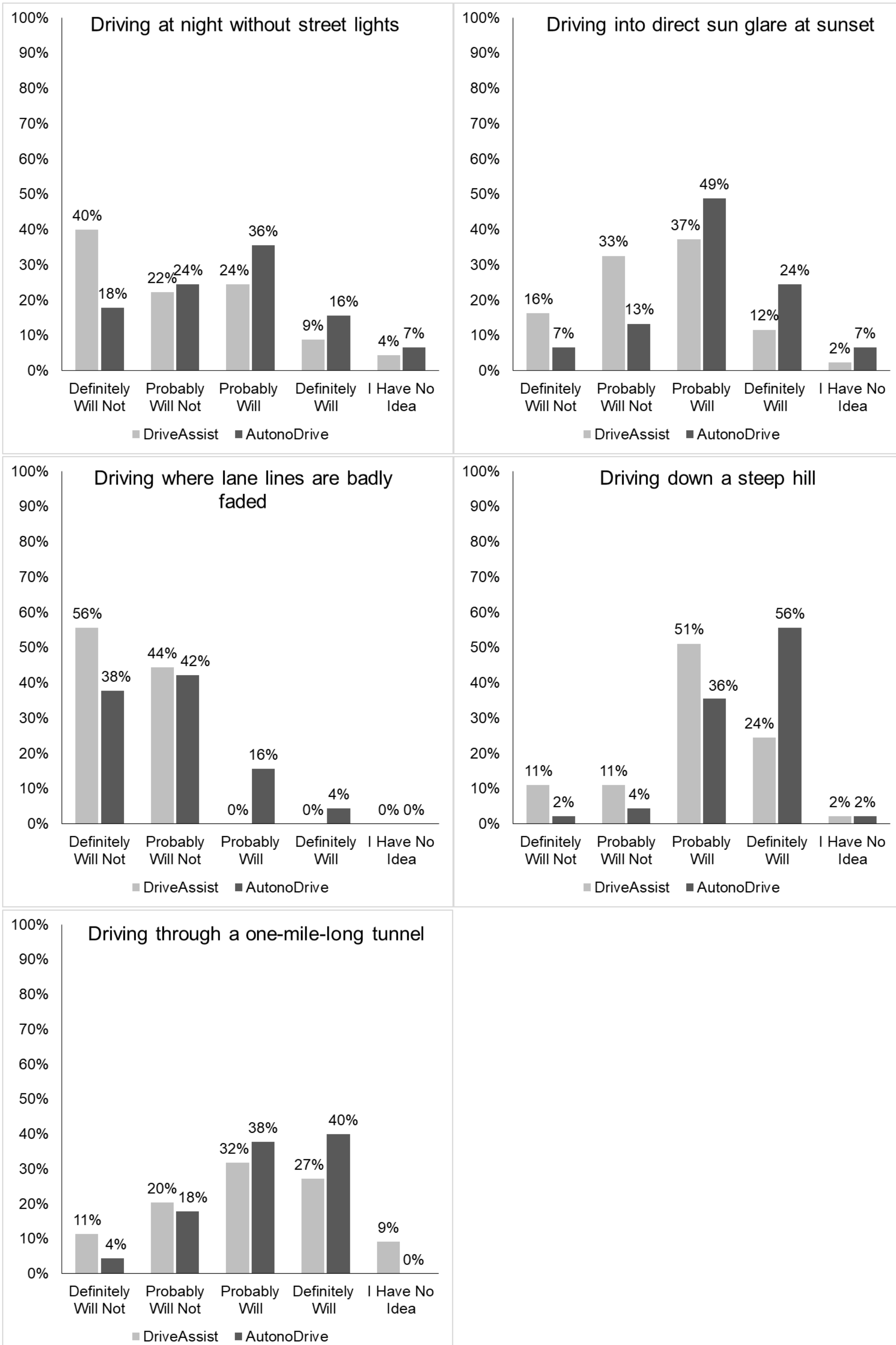


*Figure 11*. Responses to question regarding whether L2 feature would "successfully control vehicle speed and keep the vehicle in its lane without the driver doing anything" in specific scenarios (Post-Training Questionnaire).

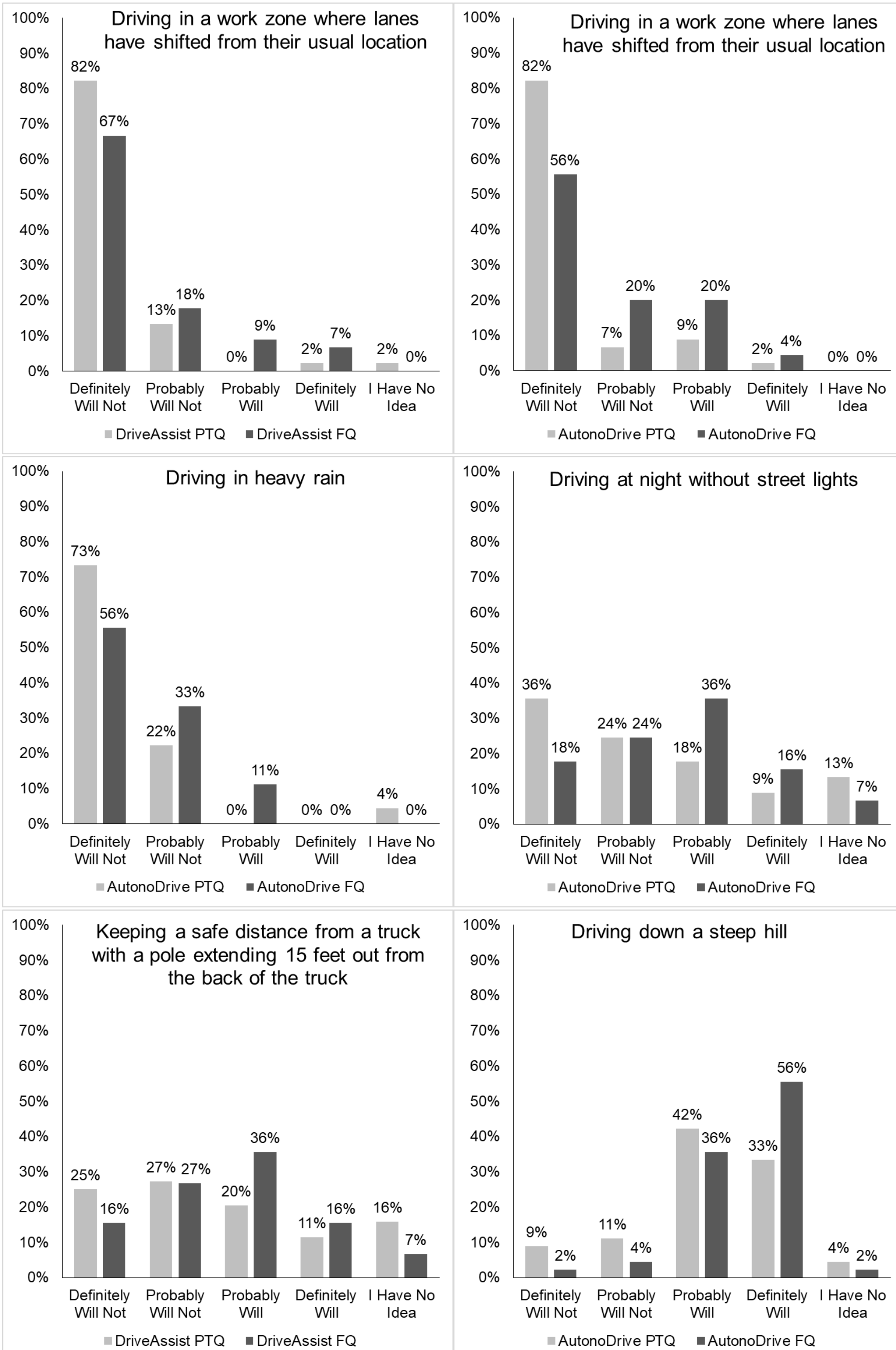


*Figure 12.* Responses to question regarding whether L2 feature would “successfully control vehicle speed and keep the vehicle in its lane without the driver doing anything” in specific scenarios (Post-Training Questionnaire [PTQ] and Final Questionnaire [FQ]).

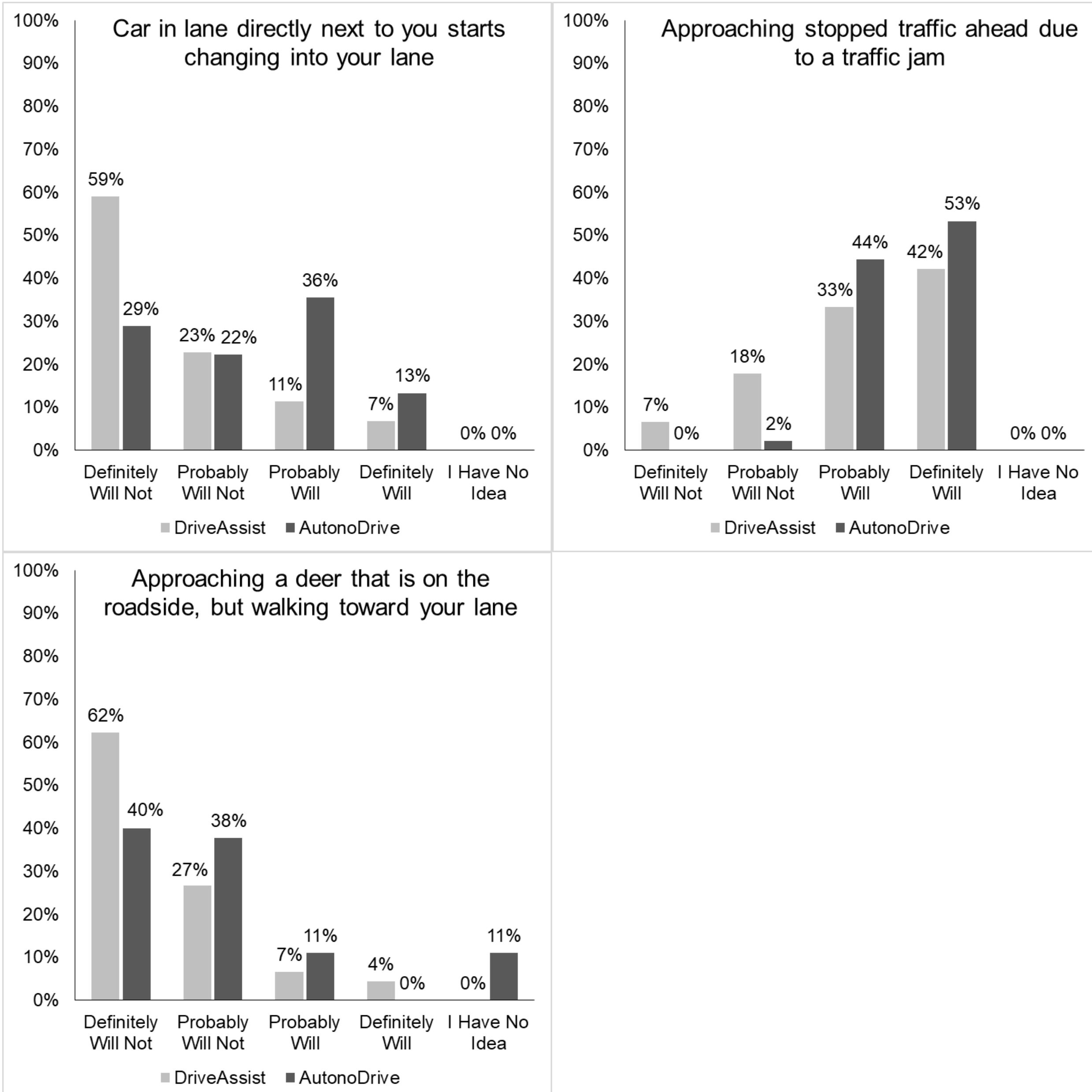


*Figure 13.* Responses to question regarding whether DriveAssist/AutonoDrive would “take action and avoid a collision, without the driver doing anything” in specific scenarios (Final Questionnaire).

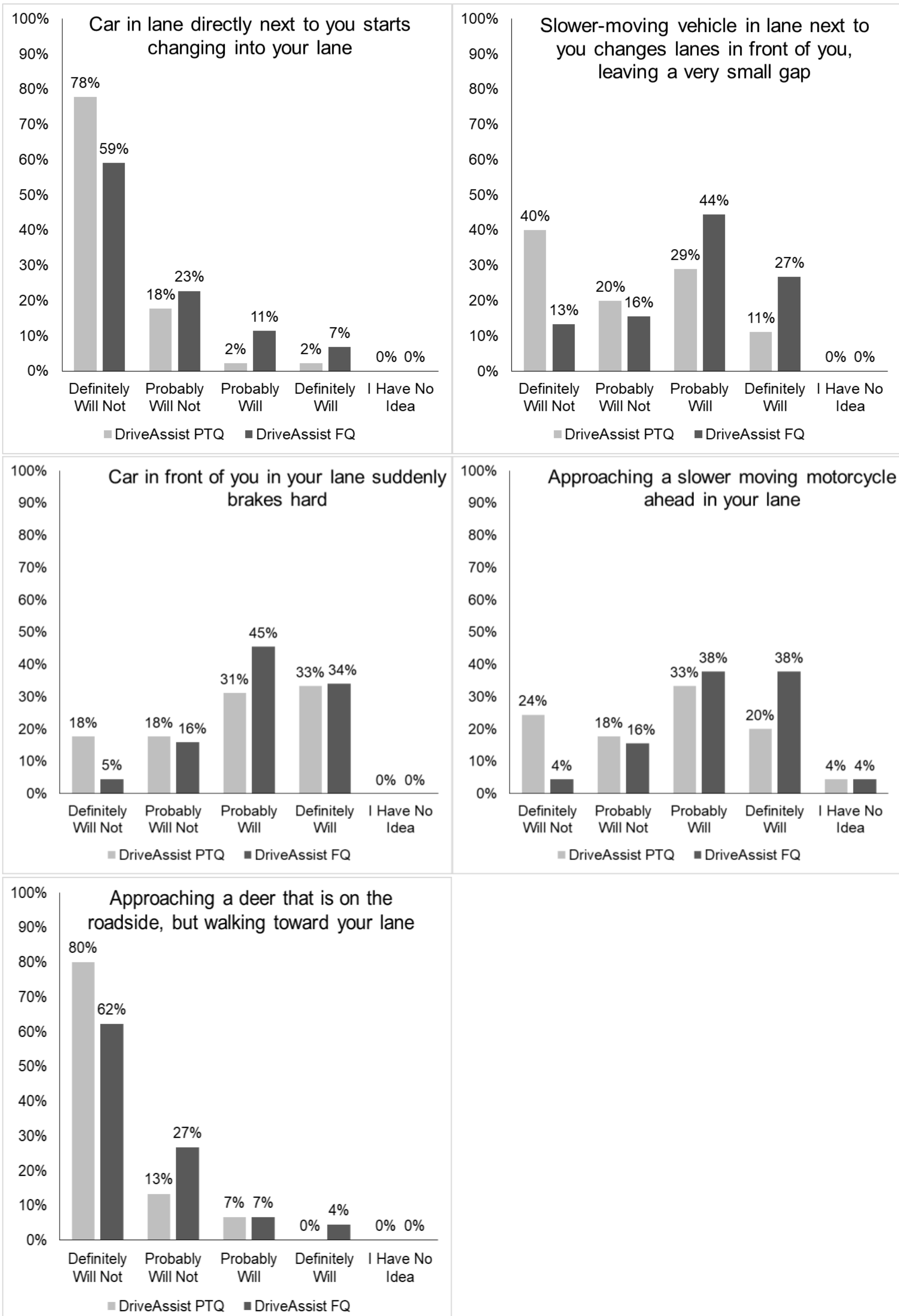


*Figure 14.* Responses to question regarding whether DriveAssist/AutonoDrive would "take action and avoid a collision, without the driver doing anything" after training (PTQ) and after driving the vehicle (FQ), statistically significant changes within branding conditions.

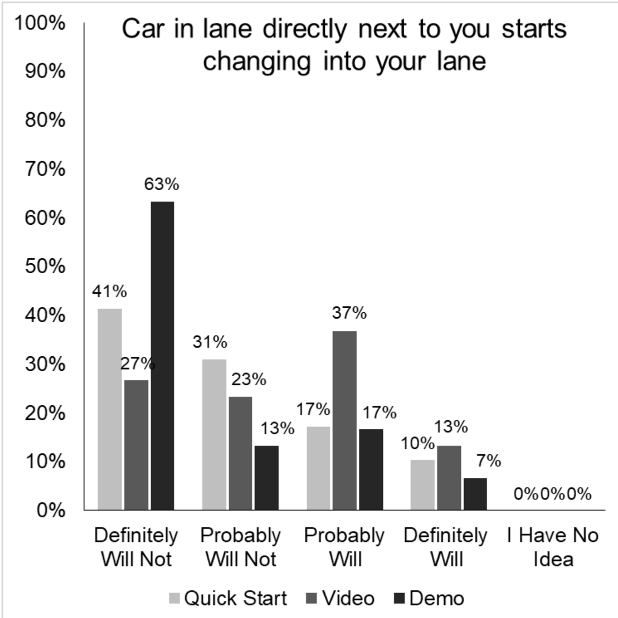


*Figure 15*. Responses to question regarding whether DriveAssist/AutonoDrive would "take action and avoid a collision, without the driver doing anything" in relation to type of training (Final Questionnaire).

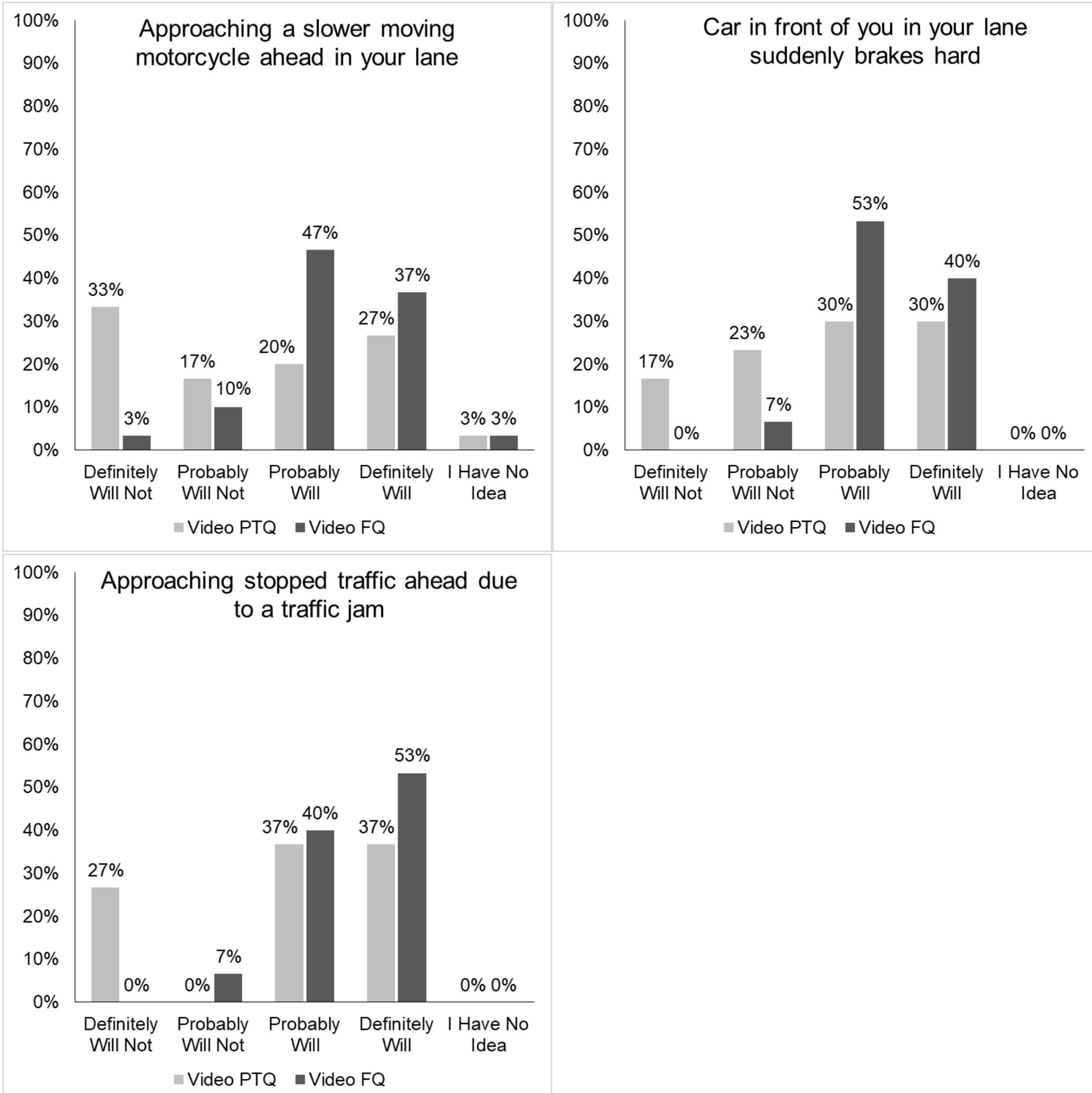


*Figure 16.* Responses to question regarding whether DriveAssist/AutonoDrive would "take action and avoid a collision, without the driver doing anything" in specific scenarios among participants in video training condition (Post-Training Questionnaire [PTQ] and Final Questionnaire [FQ]).

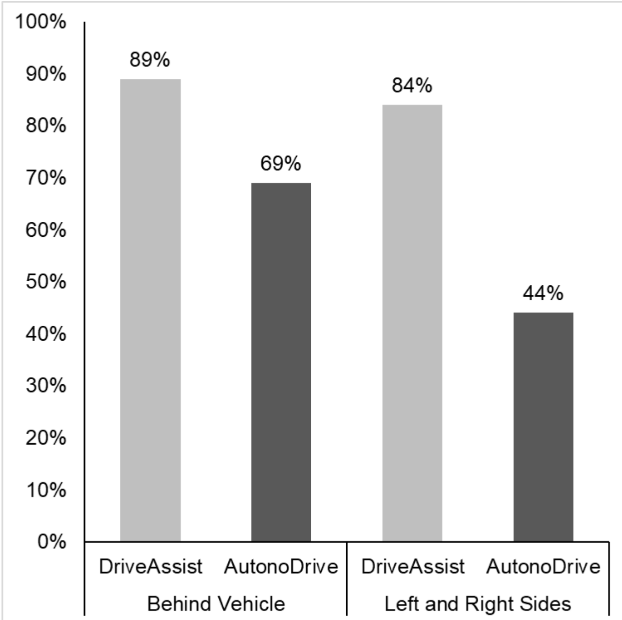


*Figure 17*. Percentage of participants who correctly answered that the L2 feature cannot detect and respond to other vehicles behind and to the left and right sides of the vehicle – branding group data (Final Questionnaire).

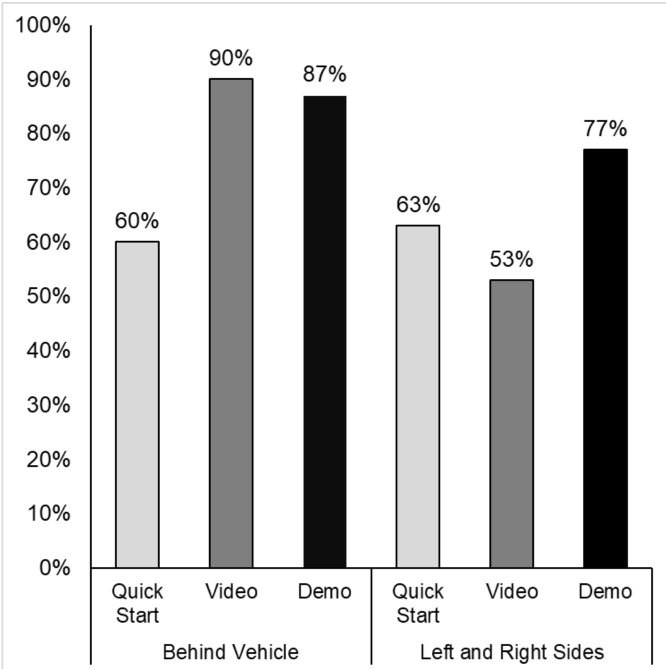


*Figure 18.* Percentage of participants who correctly answered that the L2 feature cannot detect and respond to other vehicles behind and to the left and right sides of the vehicle – training group data (Final Questionnaire).

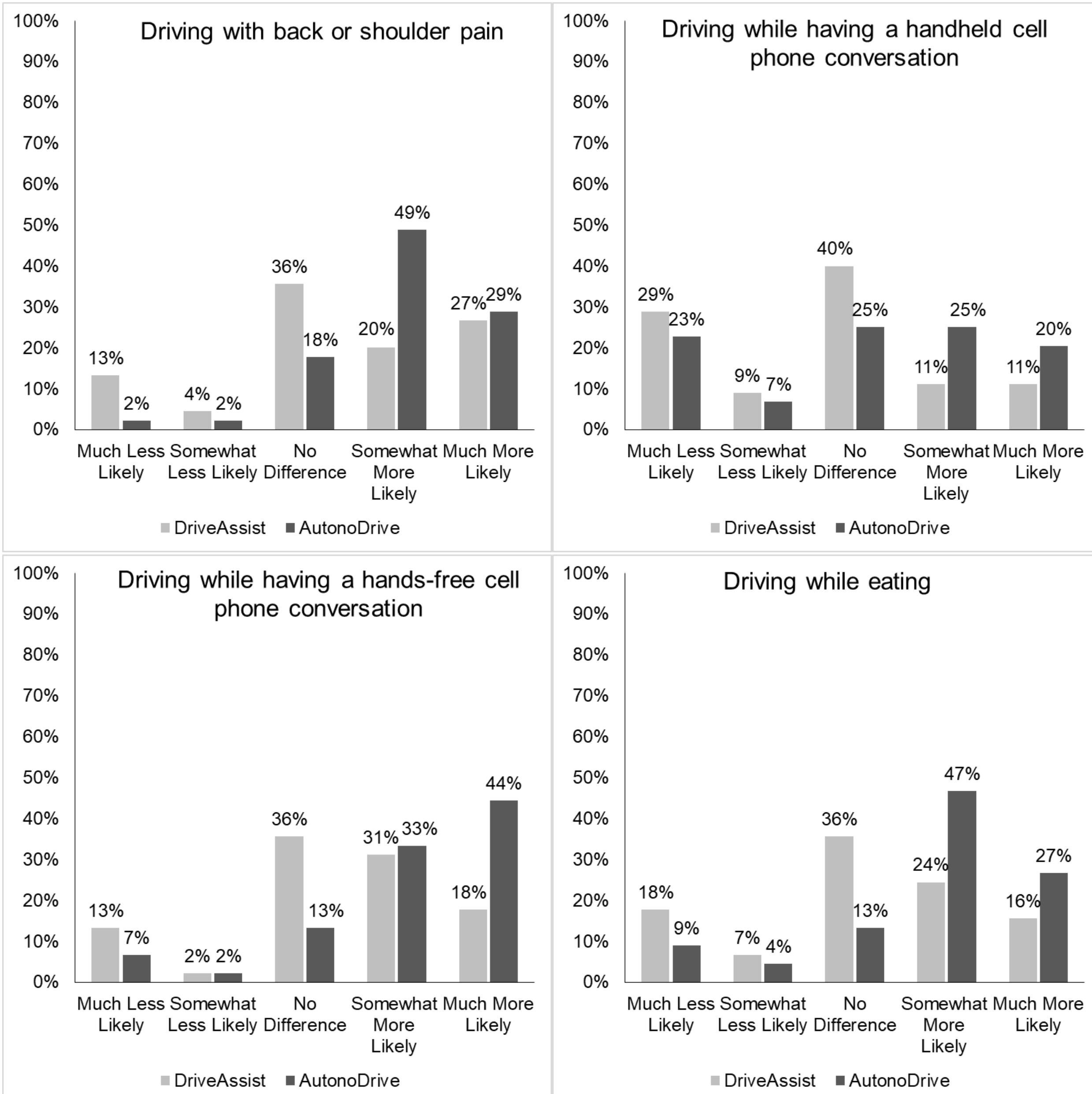


*Figure 19.* Willingness to drive in specific situations while using DriveAssist/AutonoDrive, compared to driving a vehicle without DriveAssist/AutonoDrive (Final Questionnaire).

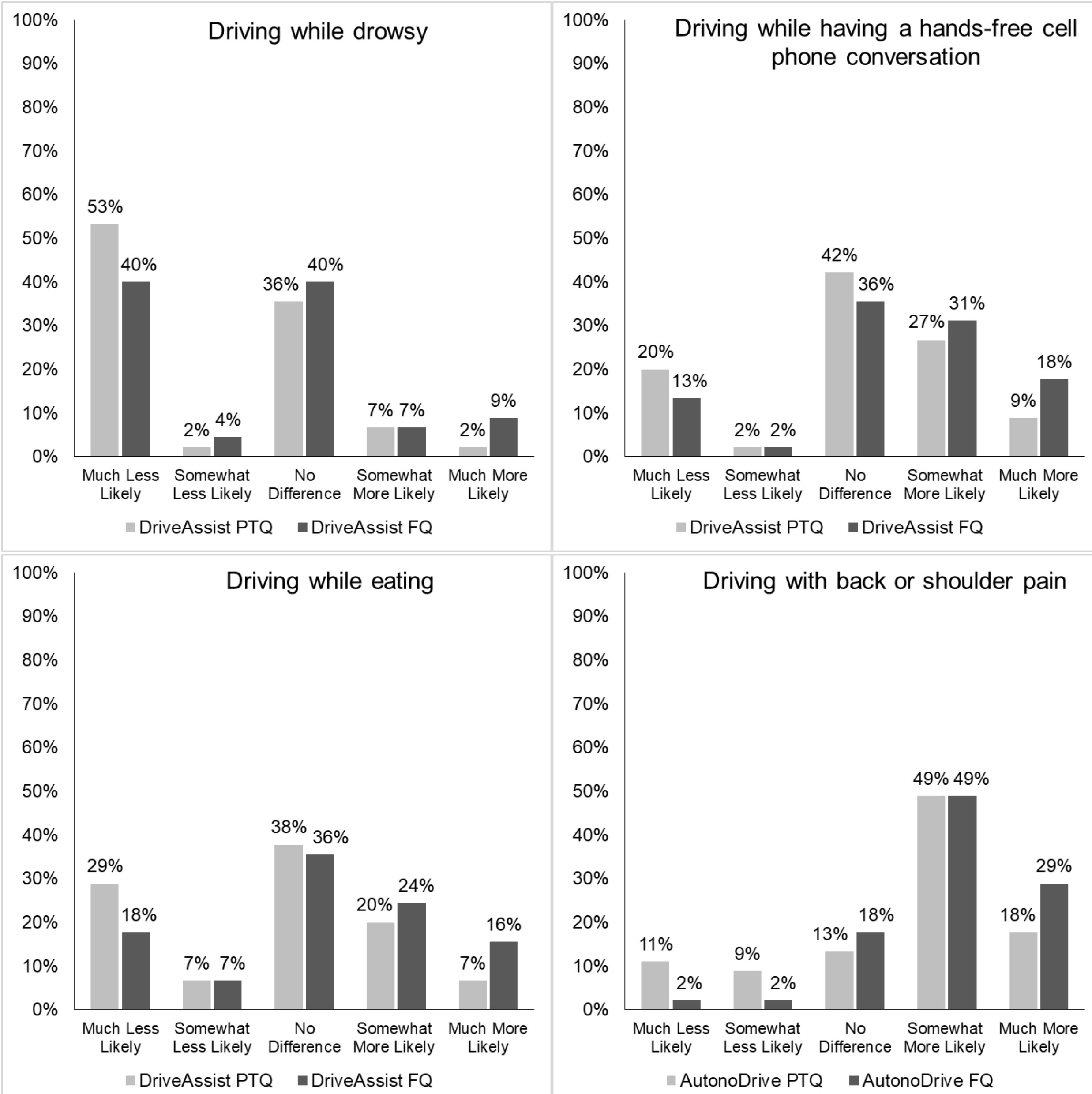


*Figure 20.* Willingness to drive in specific situations while using DriveAssist/AutonoDrive, compared to driving a vehicle without DriveAssist/AutonoDrive after training (PTQ) and after driving the vehicle (FQ), statistically significant changes within branding conditions.

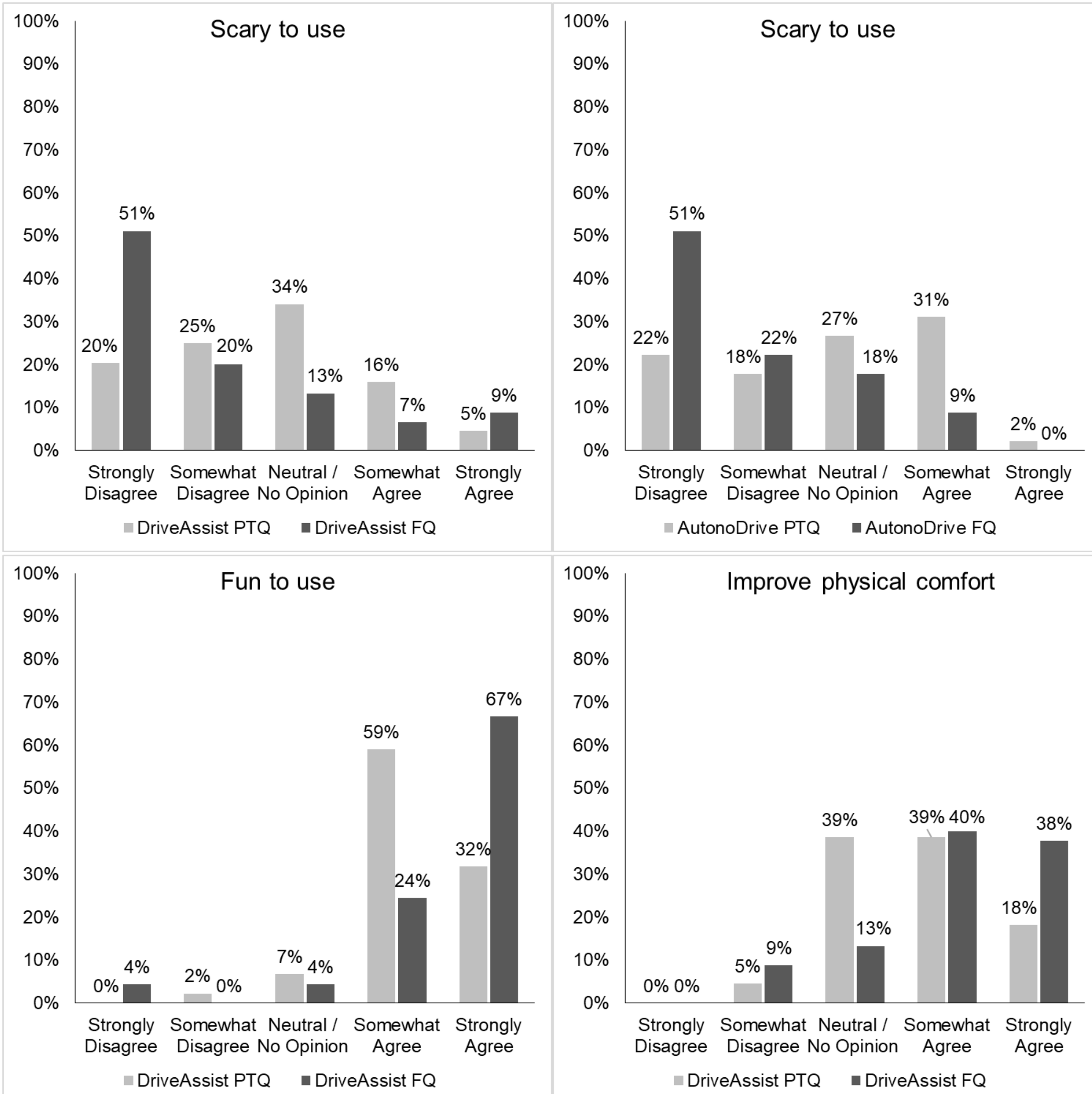


*Figure 21*. Agreement with statements regarding expectations of DriveAssist/AutonoDrive after training [PTQ] and experiences with DriveAssist/AutonoDrive after driving the vehicle [FQ], statistically significant changes within branding conditions.

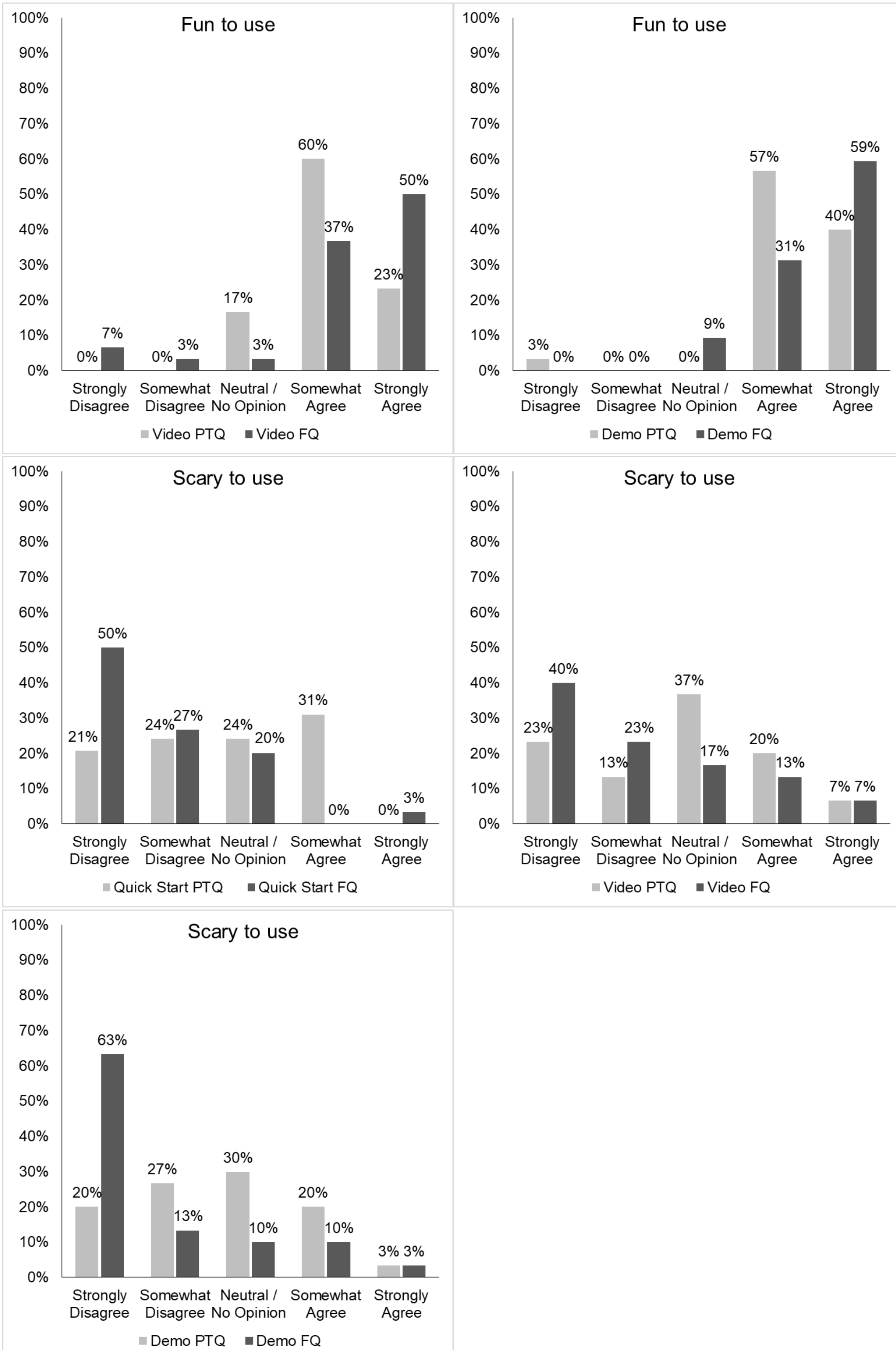


*Figure* 22. Agreement with statements regarding expectations of DriveAssist/AutonoDrive after training [PTQ] and experiences with DriveAssist/AutonoDrive after driving the vehicle [FQ], statistically significant changes within training groups.

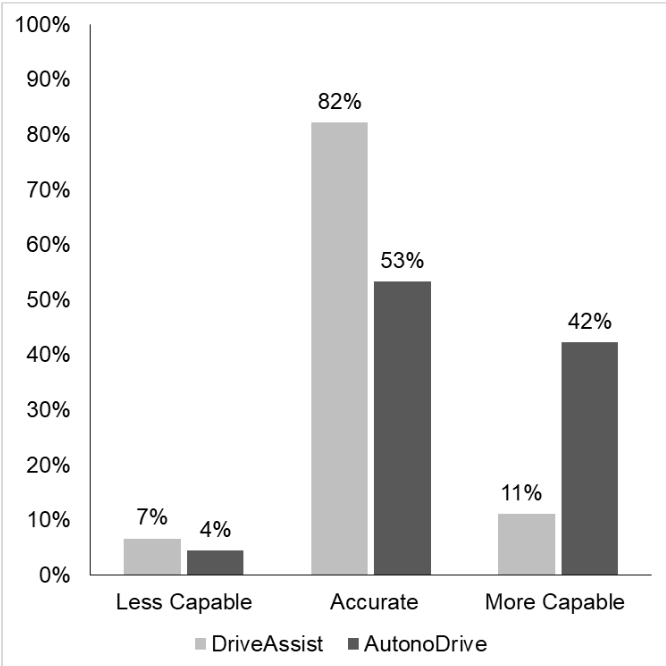

*Figure 23.* Opinions regarding whether name DriveAssist/AutonoDrive accurately reflects the capabilities of the technology, or whether the name makes it seem more or less capable than it actually is, after driving the vehicle (Final Questionnaire).

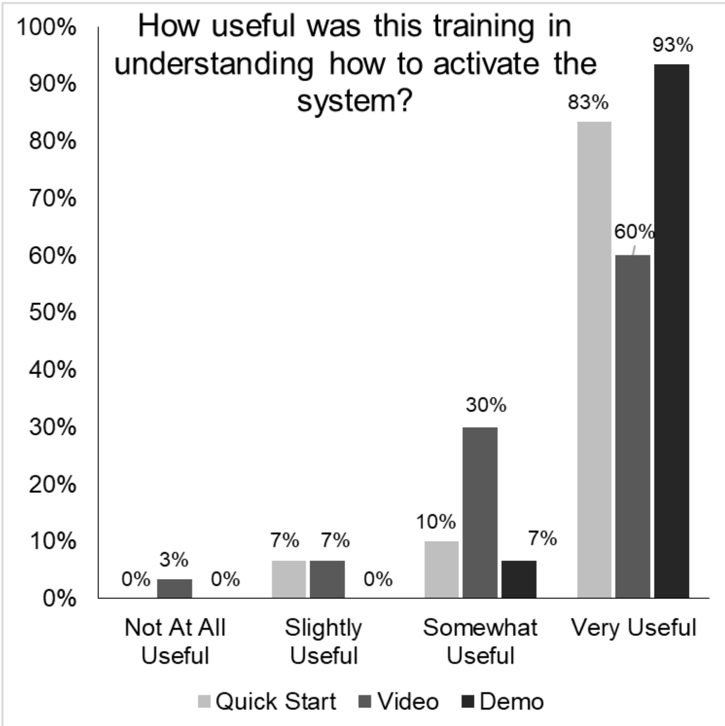

*Figure 24.* Perceived usefulness of training in understanding how to activate the L2 feature, by training group (Final Questionnaire).

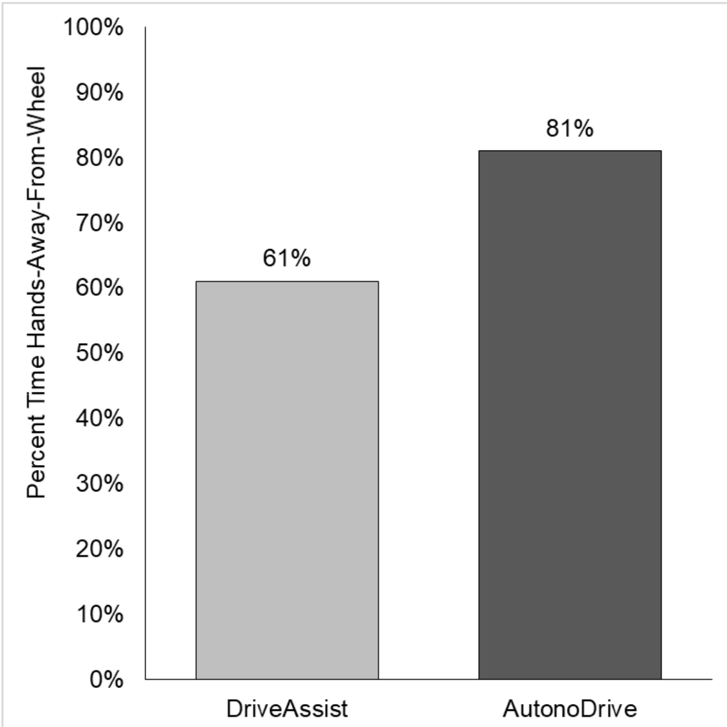


*Figure 25.* Percentage of total time in which participants' hands were away from steering wheel while driving in Segment 1, by branding condition.

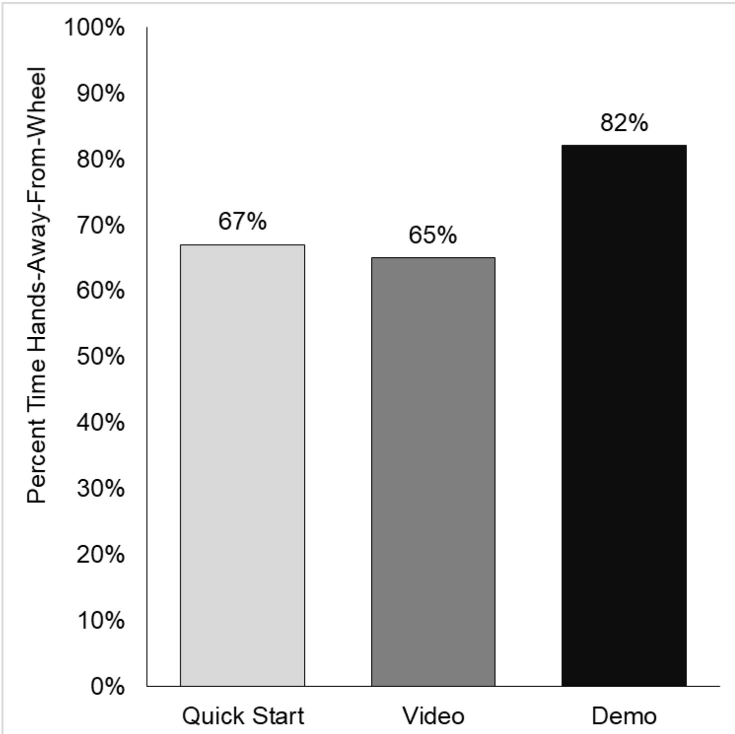

*Figure 26.* Percentage of total time in which participants' hands were away from steering wheel while driving in Segment 1, by training condition.

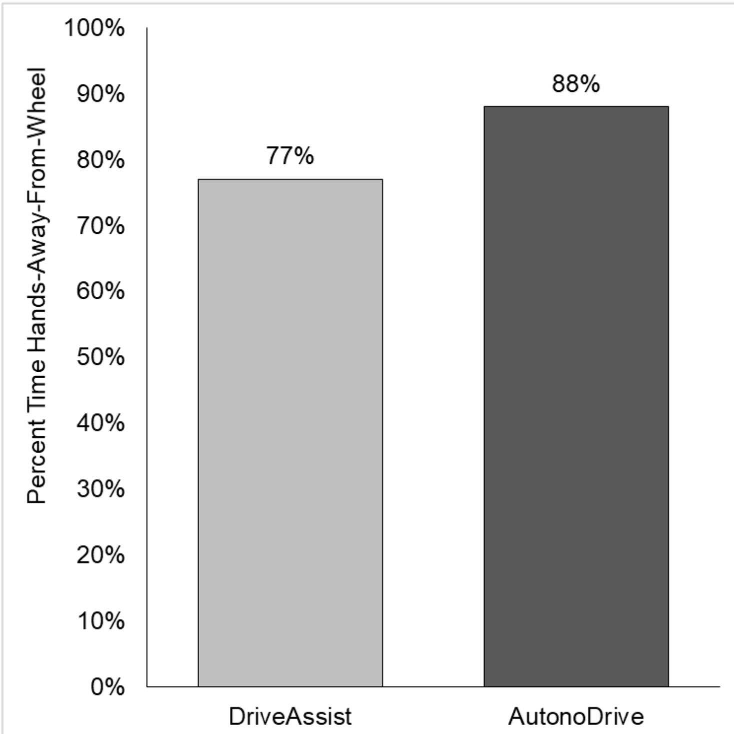

*Figure 27*. Percentage of total time in which participants' hands were away from steering wheel while driving in all recorded segments, by branding condition.

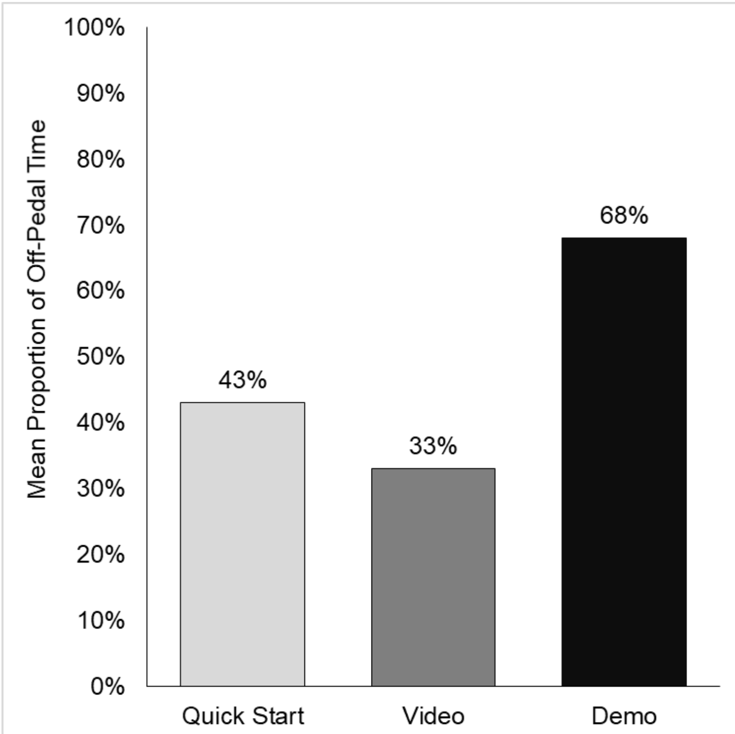

*Figure 28.* Percentage of total time in which participants' foot was away from pedals while driving in Segment 1, by training condition.

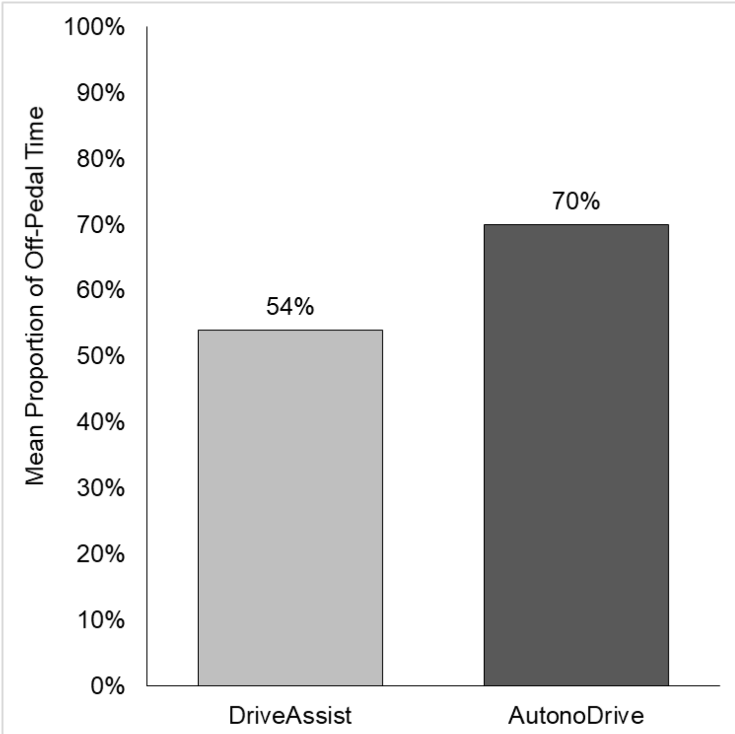


*Figure 29.* Percentage of total time in which participants' foot was away from pedals while driving in all recorded segments, by branding condition.

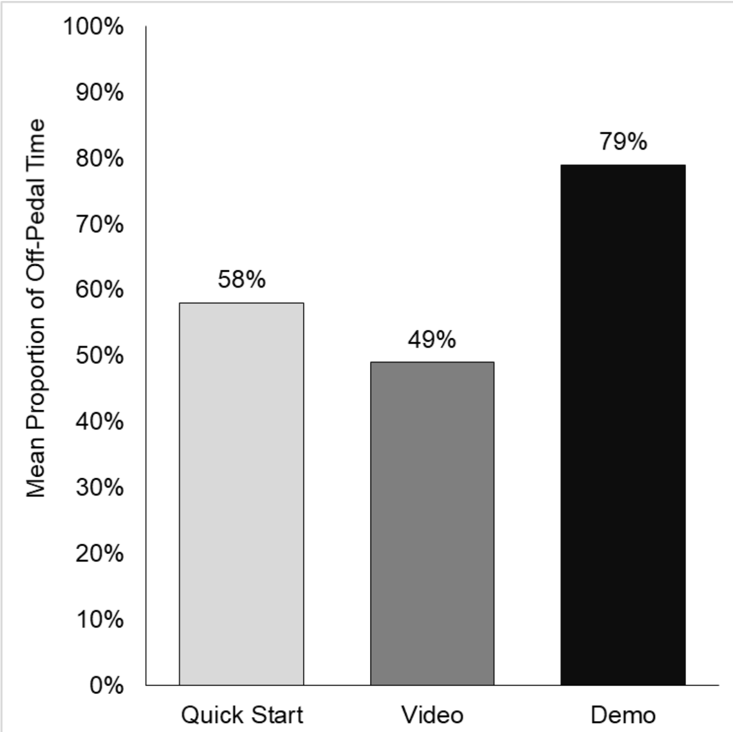


*Figure 30.* Percentage of total time in which participants' foot was away from pedals while driving in all recorded segments, by training condition.

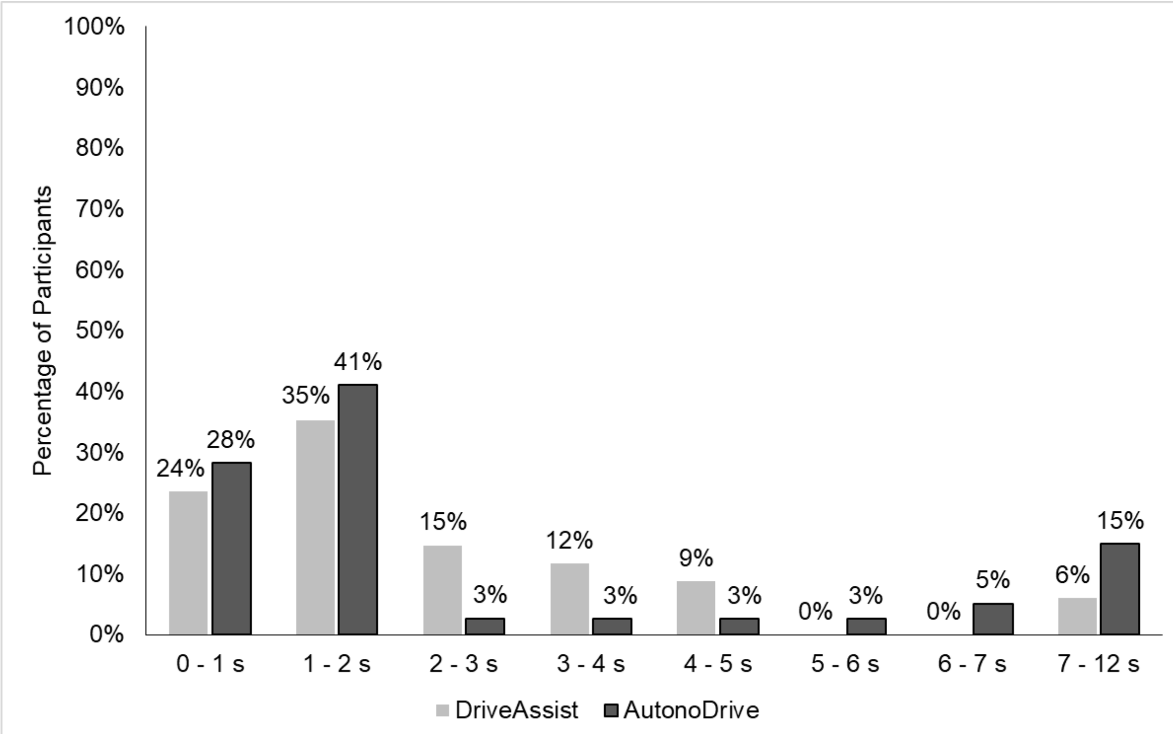


*Figure 31*. Response times to unexpected handoff event, by branding condition.

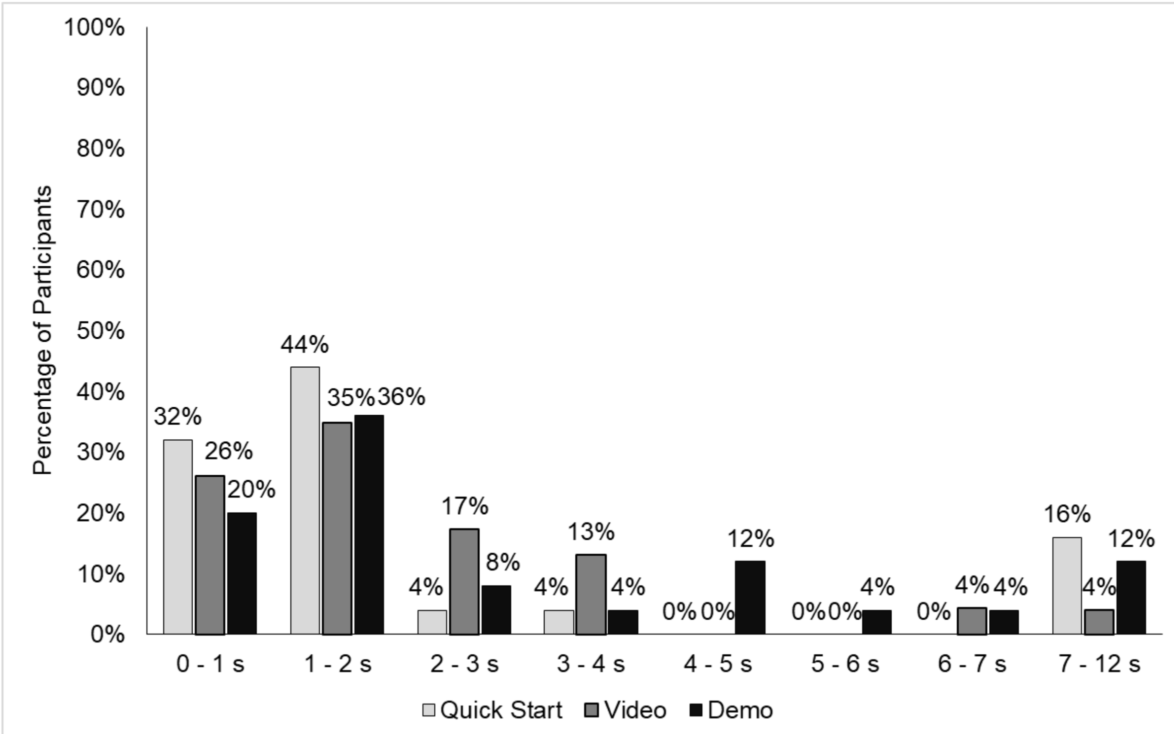

*Figure 32.* Response times to unexpected handoff event, by training condition.

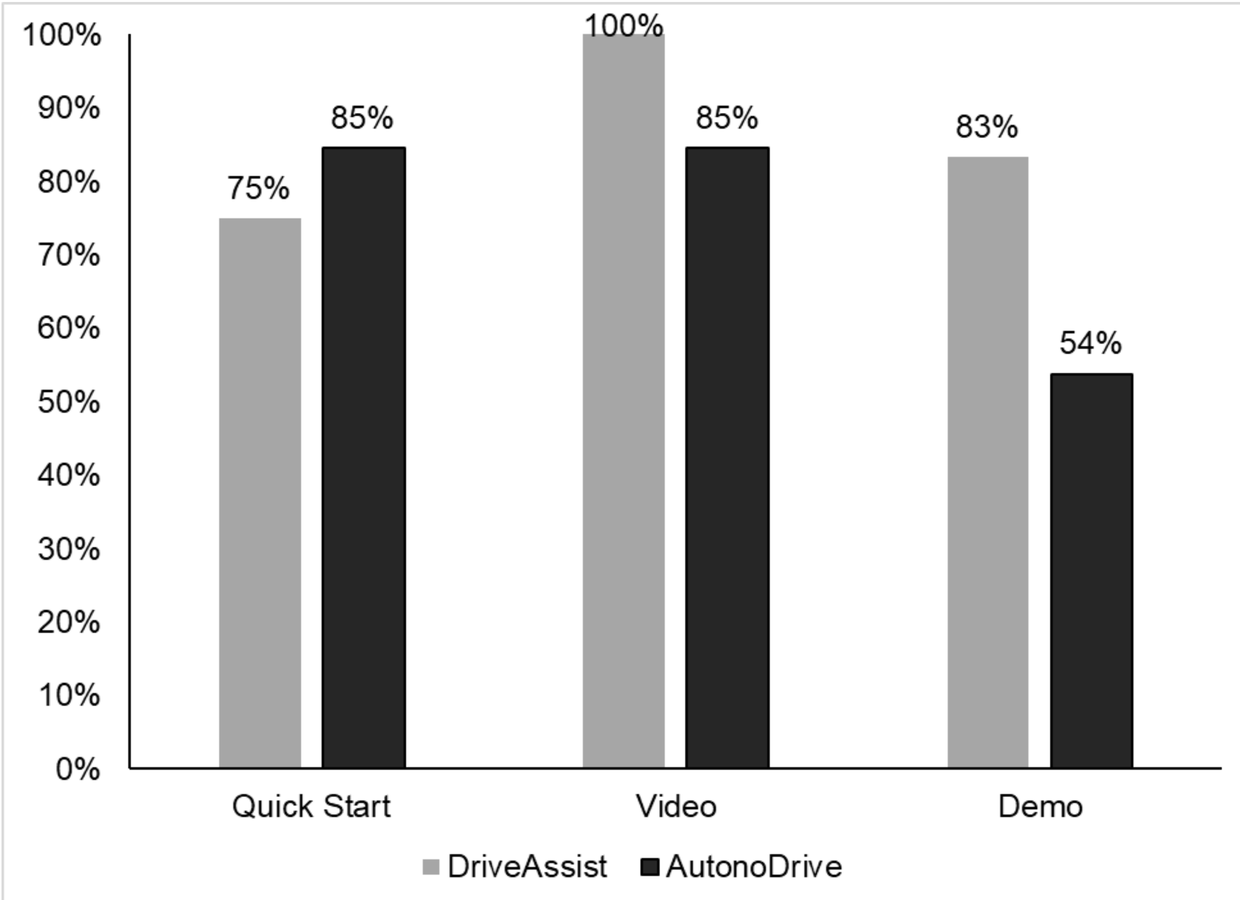

*Figure 33.* Percentage of participants who responded to the unexpected handoff within 4 seconds.

## Tables

*Table 1.* Participant age and gender by branding and training condition.

| Condition | Mean age (SD) | Males | Females |
|---|---|---|---|
| 1. DriveAssist Quick Start | 48.1 (14.6) | 8 | 7 |
| 2. DriveAssist Video | 49.1 (12.6) | 7 | 8 |
| 3. DriveAssist Demo | 43.6 (13.9) | 7 | 8 |
| 4. AutonoDrive Quick Start | 49.1 (14.5) | 7 | 8 |
| 5. AutonoDrive Video | 47.4 (14.4) | 6 | 9 |
| 6. AutonoDrive Demo | 45.9 (13.6) | 6 | 9 |

*Table 2.* Examples of differences between DriveAssist and AutonoDrive training materials.

| **DriveAssist** | **AutonoDrive** |
|---|---|
| The future of driving is here. And it's hands-free. | The future of driving is here. And it's self-driving. |
| DriveAssist is a driver assistance technology… | AutonoDrive is a hands-free and feet-free autonomous driving technology… |
| It reduces the need for you to frequently steer, brake or accelerate under available operating conditions. | It reduces the need for you to steer, brake or accelerate, and takes the stress out of driving. |
| Using these technologies, DriveAssist is able to maintain speed and lane position under most limited-access highway driving conditions. | Using these cutting edge technologies, AutonoDrive knows the position of your car up to 1.5 miles ahead and makes you feel like you're riding on rails. |
| It's extremely important that you pay attention to the operation of the vehicle, even while using DriveAssist. Do not use a hand-held device while driving, even with DriveAssist engaged. You must always be prepared to take over operation of the vehicle at all times. | It's important that you pay attention to the operation of the vehicle, even while using AutonoDrive. Always be prepared to take over operation of the vehicle. |
| Remember that DriveAssist does not work reliably in all conditions. You must be prepared to take over steering and speed control at all times. | AutonoDrive is a powerful self-driving feature that works reliably under most limited-access highway conditions. |
|  |  |

*Table 3.* Percentage of participants who reported that L2 feature probably or definitely would “successfully control vehicle speed and keep the vehicle in its lane without the driver doing anything” in specific scenarios, by branding condition (Post-Training Questionnaire).

| **Scenario** | **Drive Assist** | **Autono Drive** | **P value** |
|---|---|---|---|
| Driving in a work zone where lanes have shifted from their usual location | 2% | 11% | 0.442 |
| Driving in heavy rain | 7% | 0% | 0.475 |
| Driving in heavy snow | 4% | 0% | 0.245 |
| Driving at night without street lights | 30% | 27% | 0.422 |
| Driving into direct sun glare at sunset | 45% | 50% | 0.076 |
| Driving where lane lines are badly faded | 9% | 13% | 0.008 |
| Changing lanes to pass a slower vehicle in your lane | 7% | 9% | 0.173 |
| Exiting onto a ramp from one freeway to another freeway | 7% | 13% | 0.356 |
| Driving in stop-and-go traffic due to a traffic jam | 57% | 68% | 0.067 |
| Reduce speed on a tight curve where the current set speed is too fast | 27% | 56% | 0.022 |
| Bring the vehicle to a stop if the driver loses consciousness due to a medical emergency | 71% | 67% | 0.808 |
| Driving on an undivided highway with no median or barrier separating traffic traveling in the opposite direction | 13% | 7% | 0.219 |
| Drive through a toll booth with a 10 mph speed limit to pay an electronic (E-ZPass) toll | 16% | 22% | 0.019 |
| Merging one lane to the left when the right lane ends | 16% | 27% | 0.097 |
| Reducing speed when the speed limit drops from 65 mph to 55 mph | 30% | 51% | 0.039 |
| Keeping a safe distance from a truck with a pole extending 15 feet out from the back of the truck | 32% | 45% | 0.034 |
| Driving down a steep hill | 48% | 76% | 0.004 |
| Driving through a one-mile-long tunnel | 43% | 67% | 0.003 |

*Table 4.* Percentage of participants who reported that L2 feature probably or definitely would "take action and avoid a collision, without the driver doing anything" in specific scenarios, by branding condition (Post-Training Questionnaire).

| **Scenario** | **Drive Assist** | **Autono Drive** | **P value** |
|---|---|---|---|
| Approaching a bed mattress lying in your lane | 14% | 22% | 0.011 |
| Car in lane directly next to you starts changing into your lane | 4% | 42% | < 0.001 |
| Slower-moving vehicle in lane next to you changes lanes in front of you, leaving a very small gap | 40% | 67% | 0.002 |
| Car in front of you in your lane suddenly brakes hard | 64% | 84% | 0.021 |
| Approaching a highway construction worker standing in your lane | 16% | 27% | 0.024 |
| Approaching a slower moving motorcycle ahead in your lane | 53% | 82% | 0.001 |
| Approaching stopped traffic ahead due to a traffic jam | 67% | 91% | 0.014 |
| Approaching a deer that is on the roadside, but walking toward your lane | 7% | 13% | < 0.001 |

*Table 5.* Differences in percentages of participants who reported that DriveAssist / AutonoDrive detects and respond to other vehicles in each of three areas, by branding condition (Post-Training Questionnaire).

| Area | $\chi^2$ | P value |
|---|---|---|
| In front of vehicle | 0 | 1 |
| Behind vehicle | 11.28 | .002 |
| Left and right sides of vehicle | 20 | < .001 |

*Table 6.* Differences in percentages of participants who reported that DriveAssist / AutonoDrive detects and respond to other vehicles in each of three areas, by training condition (Post-Training Questionnaire).

| Area | $\chi^2$ | P value |
|---|---|---|
| In front of vehicle | 0.52 | 1 |
| Behind vehicle | 6.94 | 0.033 |
| Left and right sides of vehicle | 2.7 | 0.286 |

*Table 7.* Percentage of participants who correctly reported that the L2 feature does not detect and respond to other vehicles to the sides of, and behind, the subject vehicle, by branding and training condition (Post-Training Questionnaire).

| | **Correctly reported L2 feature <u>does not</u> detect and respond to other vehicles to the sides of the vehicle** | | **Correctly reported L2 feature <u>does not</u> detect and respond to other vehicles behind vehicle** | |
|---|---|---|---|---|
| | **DriveAssist** | **AutonoDrive** | **DriveAssist** | **AutonoDrive** |
| **Quick start** | 80% | 47% | 80% | 53% |
| **Video** | 100% | 80% | 87% | 27% |
| **Demo** | 100% | 67% | 100% | 53% |

*Table 8.* Percentage of respondents who provided correct answers to questions regarding specific aspects of L2 feature operations after training (Post-Training Questionnaire).

| | **% correct** | | | |
|---|---|---|---|---|
| **Scenario** | **Drive Assist** | **Autono Drive** | $\chi^2$ | **P value** |
| What must happen before the L2 feature will begin steering? | | | | |
| Vehicle must be on a limited access highway | 84% | 91% | 0.932 | 0.531 |
| Vehicle's speed must be over 40mph | 76% | 89% | 2.737 | 0.173 |
| Vehicle must be centered in the lane | 87% | 71% | 3.269 | 0.120 |
| Another vehicle must be present in the same lane ahead | 100% | 100% | NA | 1 |
| Lane lines must be visible on the roadway | 96% | 76% | 7.283 | 0.013 |
| How does DriveAssist notify the driver when the L2 feature is activate? | | | | |
| Icon on instrument cluster/dashboard | 87% | 93% | 1.111 | 0.499 |
| Light on top of steering wheel | 98% | 96% | 0.345 | 1 |
| Beeping sound | 98% | 91% | 1.906 | 0.374 |
| "DriveAssist/AutonoDrive on" voice message | 100% | 96% | 2.046 | 0.503 |
| How does the L2 feature notify the driver when it gives steering control back to the driver? | | | | |
| Icon on instrument cluster/dashboard | 71% | 69% | 0.053 | 1 |
| Light on top of steering wheel | 91% | 93% | 0.155 | 1 |
| Beeping sound | 67% | 67% | 0 | 1 |
| "DriveAssist/AutonoDrive off" voice message | 91% | 84% | 0.932 | 0.514 |
| If a driver is using the L2 feature, what happens after… | | | | |
| the driver presses the brake pedal? | 86% | 89% | 0.213 | 1 |
| ...the driver presses the accelerator pedal? | 20% | 18% | 0.209 | 1 |
| ...the driver uses a turn signal and changes lanes? | 66% | 52% | 2.192 | 0.339 |
| ...the vehicle leaves the area mapped in the DriveAssist/AutonoDrive database? | 20% | 9% | 3.594 | 0.218 |

*Table 9.* Percentage of participants who reported that they would be somewhat or much more willing to drive in various situations with the L2 feature compared with driving a vehicle without it, by branding condition (Post-Training Questionnaire).

| **Driving situation** | **Drive Assist** | **Autono Drive** | **P value** |
|---|---|---|---|
| Driving while drowsy | 9% | 20% | 0.142 |
| Driving with back or shoulder pain | 44% | 67% | 0.059 |
| Taking a six-hour drive to another state | 78% | 84% | 0.239 |
| Driving after having three alcoholic drinks | 9% | 18% | 0.388 |
| Driving after taking a medication that warns you not to drive | 9% | 12% | 0.613 |
| Driving while having a hands-free cell phone conversation | 36% | 62% | 0.004 |
| Driving while having a handheld cell phone conversation | 13% | 45% | 0.014 |
| Driving while having a text message conversation | 13% | 29% | 0.230 |
| Driving while eating | 27% | 65% | 0.001 |
| Driving faster than you usually do | 2% | 7% | 0.029 |
| Driving with a severe headache | 22% | 32% | 0.254 |

*Table 10.* Participants' confidence in, and expectations of, L2 feature: differences between branding conditions (Post-Training Questionnaire).

| | **P value** |
|---|---|
| How confident are you that DriveAssist/AutonoDrive will work as it was described to you today? | 0.591 |
| Overall, how much do you trust DriveAssist/AutonoDrive to maintain your lane position and speed? | 0.634 |
| Overall, how much do you trust DriveAssist/AutonoDrive to avoid conflicts with other vehicles? | 0.035 |
| Please indicate whether you agree or disagree with each of the following statements about your expectations for your upcoming trip using DriveAssist/AutonoDrive. | |
| I expect that DriveAssist/AutonoDrive will increase my safety | 0.417 |
| I expect that DriveAssist/AutonoDrive will reduce my stress | 0.129 |
| I expect that DriveAssist/AutonoDrive will improve my physical comfort | 0.102 |
| I expect that DriveAssist/AutonoDrive will be scary to use | 0.243 |
| I expect that DriveAssist/AutonoDrive will be fun to use | 0.482 |
| How comfortable are you about using DriveAssist/AutonoDrive on the road today? | 0.084 |

*Table 11.* Percentage of participants who reported that L2 feature probably or definitely would "successfully control vehicle speed and keep the vehicle in its lane without the driver doing anything" in specific scenarios, after driving the vehicle (Final Questionnaire).

| **Scenario** | **Drive Assist** | **Autono Drive** | **P value** |
|---|---|---|---|
| Driving in a work zone where lanes have shifted from their usual location | 16% | 24% | 0.144 |
| Driving in heavy rain | 13% | 11% | 0.493 |
| Driving in heavy snow | 5% | 11% | 0.163 |
| Driving at night without street lights | 33% | 51% | 0.013 |
| Driving into direct sun glare at sunset | 48% | 73% | 0.005 |
| Driving where lane lines are badly faded | 0% | 20% | 0.008 |
| Changing lanes to pass a slower vehicle in your lane | 7% | 18% | 0.724 |
| Exiting onto a ramp from one freeway to another freeway | 9% | 16% | 0.078 |
| Driving in stop-and-go traffic due to a traffic jam | 55% | 67% | 0.07 |
| Reduce speed on a tight curve where the current set speed is too fast | 62% | 67% | 0.067 |
| Bring the vehicle to a stop if the driver loses consciousness due to a medical emergency | 78% | 68% | 0.636 |
| Driving on an undivided highway with no median or barrier separating traffic traveling in the opposite direction | 16% | 11% | 0.191 |
| Drive through a toll booth with a 10 mph speed limit to pay an electronic (E-ZPass) toll | 20% | 24% | 0.253 |
| Merging one lane to the left when the right lane ends | 32% | 24% | 0.814 |
| Reducing speed when the speed limit drops from 65 mph to 55 mph | 48% | 45% | 0.415 |
| Keeping a safe distance from a truck with a pole extending 15 feet out from the back of the truck | 51% | 56% | 0.153 |
| Driving down a steep hill | 76% | 91% | 0.001 |
| Driving through a one-mile-long tunnel | 59% | 78% | 0.043 |

*Table 12.* Post-drive (Final Questionnaire) vs. pre-drive (Post-Training Questionnaire) changes in percentage of participants who reported that L2 feature probably or definitely would "successfully control vehicle speed and keep the vehicle in its lane without the driver doing anything" in specific scenarios, by branding condition.

| **Scenario** | **Drive Assist P value** | **Autono Drive P value** |
|---|---|---|
| Driving in a work zone where lanes have shifted from their usual location | 0.039 | 0.028 |
| Driving in heavy rain | 0.081 | 0.047 |
| Driving in heavy snow | 0.124 | 0.024 |
| Driving at night without street lights | 1 | 0.025 |
| Driving into direct sun glare at sunset | 0.772 | 0.058 |
| Driving where lane lines are badly faded | 0.892 | 0.6 |
| Changing lanes to pass a slower vehicle in your lane | 0.146 | 0.251 |
| Exiting onto a ramp from one freeway to another freeway | 0.816 | 0.558 |
| Driving in stop-and-go traffic due to a traffic jam | 0.965 | 0.807 |
| Reduce speed on a tight curve where the current set speed is too fast | 0.001 | 0.04 |
| Bring the vehicle to a stop if the driver loses consciousness due to a medical emergency | 0.564 | 0.654 |
| Driving on an undivided highway with no median or barrier separating traffic traveling in the opposite direction | 0.469 | 0.267 |
| Drive through a toll booth with a 10 mph speed limit to pay an electronic (E-ZPass) toll | 0.186 | 0.972 |
| Merging one lane to the left when the right lane ends | 0.061 | 0.669 |
| Reducing speed when the speed limit drops from 65 mph to 55 mph | 0.079 | 0.644 |
| Keeping a safe distance from a truck with a pole extending 15 feet out from the back of the truck | 0.037 | 0.118 |
| Driving down a steep hill | 0.022 | 0.021 |
| Driving through a one-mile-long tunnel | 0.008 | 0.422 |

*Table 13.* Post-drive (Final Questionnaire) vs. pre-drive (Post-Training Questionnaire) changes in percentage of participants who reported that L2 feature probably or definitely would “successfully control vehicle speed and keep the vehicle in its lane without the driver doing anything” in specific scenarios, by training condition.

| **Scenario** | **Quick Start P value** | **Video P value** | **Demo P value** |
|---|---|---|---|
| Driving in a work zone where lanes have shifted from their usual location | 0.056 | 0.13 | 0.075 |
| Driving in heavy rain | 0.005 | 0.044 | 0.665 |
| Driving in heavy snow | 0.066 | 0.12 | 0.098 |
| Driving at night without street lights | 0.046 | 0.887 | 0.634 |
| Driving into direct sun glare at sunset | 0.666 | 0.03 | 0.443 |
| Driving where lane lines are badly faded | 0.554 | 0.336 | 0.295 |
| Changing lanes to pass a slower vehicle in your lane | 0.491 | 0.103 | 0.59 |
| Exiting onto a ramp from one freeway to another freeway | 1 | 0.619 | 0.796 |
| Driving in stop-and-go traffic due to a traffic jam | 0.419 | 0.591 | 0.331 |
| Reduce speed on a tight curve where the current set speed is too fast | 0.004 | 0.137 | 0.023 |
| Bring the vehicle to a stop if the driver loses consciousness due to a medical emergency | 0.691 | 1 | 0.065 |
| Driving on an undivided highway with no median or barrier separating traffic traveling in the opposite direction | 0.773 | 0.371 | 0.222 |
| Drive through a toll booth with a 10 mph speed limit to pay an electronic (E-ZPass) toll | 0.781 | 0.376 | 0.413 |
| Merging one lane to the left when the right lane ends | 0.835 | 0.111 | 1 |
| Reducing speed when the speed limit drops from 65 mph to 55 mph | 0.604 | 0.135 | 0.698 |
| Keeping a safe distance from a truck with a pole extending 15 feet out from the back of the truck | 0.044 | 0.025 | 1 |
| Driving down a steep hill | 0.084 | 0.025 | 0.061 |
| Driving through a one-mile-long tunnel | 0.817 | 0.036 | 0.008 |

*Table 14.* Percentage of participants who reported that L2 feature probably or definitely would "take action and avoid a collision, without the driver doing anything" in specific scenarios, after driving the vehicle (Final Questionnaire).

| **Scenario** | **Drive Assist** | **Autono Drive** | **P value** |
|---|---|---|---|
| Approaching a bed mattress lying in your lane | 23% | 36% | 0.11 |
| Car in lane directly next to you starts changing into your lane | 18% | 49% | 0.001 |
| Slower-moving vehicle in lane next to you changes lanes in front of you, leaving a very small gap | 71% | 82% | 0.202 |
| Car in front of you in your lane suddenly brakes hard | 80% | 96% | 0.062 |
| Approaching a highway construction worker standing in your lane | 20% | 29% | 0.185 |
| Approaching a slower moving motorcycle ahead in your lane | 76% | 80% | 0.479 |
| Approaching stopped traffic ahead due to a traffic jam | 76% | 98% | 0.028 |
| Approaching a deer that is on the roadside, but walking toward your lane | 11% | 11% | 0.024 |

*Table 15.* Post-drive (Final Questionnaire) vs. pre-drive (Post-Training Questionnaire) changes in percentage of participants who reported that L2 feature probably or definitely would "take action and avoid a collision, without the driver doing anything" in specific scenarios, by branding condition.

| Scenario | Drive Assist P value | Autono Drive P value |
|---|---|---|
| Approaching a bed mattress lying in your lane | 0.064 | 0.289 |
| Car in lane directly next to you starts changing into your lane | 0.009 | 0.249 |
| Slower-moving vehicle in lane next to you changes lanes in front of you, leaving a very small gap | < 0.001 | 0.119 |
| Car in front of you in your lane suddenly brakes hard | 0.037 | 0.351 |
| Approaching a highway construction worker standing in your lane | 0.217 | 0.766 |
| Approaching a slower moving motorcycle ahead in your lane | 0.007 | 0.711 |
| Approaching stopped traffic ahead due to a traffic jam | 0.189 | 0.704 |
| Approaching a deer that is on the roadside, but walking toward your lane | 0.006 | 0.963 |

*Table 16.* Post-drive (Final Questionnaire) vs. pre-drive (Post-Training Questionnaire) changes in percentage of participants who reported that L2 feature probably or definitely would "take action and avoid a collision, without the driver doing anything" in specific scenarios, by training condition.

| Scenario | Quick Start P value | Video P value | Demo P value |
|---|---|---|---|
| Approaching a bed mattress lying in your lane | 0.718 | 0.002 | 0.944 |
| Car in lane directly next to you starts changing into your lane | 0.305 | 0.01 | 0.232 |
| Slower-moving vehicle in lane next to you changes lanes in front of you, leaving a very small gap | 0.042 | 0.002 | 0.390 |
| Car in front of you in your lane suddenly brakes hard | 0.924 | 0.002 | 0.942 |
| Approaching a highway construction worker standing in your lane | 0.24 | 0.464 | 0.836 |
| Approaching a slower moving motorcycle ahead in your lane | 0.715 | 0.003 | 0.394 |
| Approaching stopped traffic ahead due to a traffic jam | 0.677 | 0.012 | 0.772 |
| Approaching a deer that is on the roadside, but walking toward your lane | 0.359 | 0.289 | 0.706 |

*Table 17.* Differences in percentages of participants who reported that DriveAssist / AutonoDrive detects and respond to other vehicles in each of three areas, by branding condition, after driving the vehicle (Final Questionnaire).

| **Area** | $\chi^2$ | **P value** |
|---|---|---|
| In front of vehicle | 0.345 | 1 |
| Behind vehicle | 5.404 | 0.041 |
| Left and right sides of vehicle | 15.711 | 0.001 |

*Table 18.* Percentage of participants who correctly reported that the L2 feature does not detect and respond to other vehicles to the sides of, and behind, the subject vehicle, by branding and training condition, after driving the vehicle (Final Questionnaire).

| | **L2 feature does not detect and respond to other vehicles to the sides of the vehicle** | | **L2 feature does not detect and respond to other vehicles behind vehicle** | |
|---|---|---|---|---|
| | **DriveAssist** | **AutonoDrive** | **DriveAssist** | **AutonoDrive** |
| **Quick start** | 73% | 47% | 80% | 47% |
| **Video** | 93% | 87% | 73% | 33% |
| **Demo** | 100% | 73% | 100% | 53% |

*Table 19.* Percentage of participants who reported that they would be somewhat or much more willing to drive in various situations with the L2 feature compared with driving a vehicle without it, by branding condition, after driving the vehicle (Final Questionnaire).

| Driving situation | Drive Assist | Autono Drive | P value |
|---|---|---|---|
| Driving while drowsy | 16% | 22% | 0.343 |
| Driving with back or shoulder pain | 47% | 78% | 0.015 |
| Taking a six-hour drive to another state | 78% | 93% | 0.125 |
| Driving after having three alcoholic drinks | 13% | 16% | 0.566 |
| Driving after taking a medication that warns you not to drive | 16% | 14% | 0.591 |
| Driving while having a hands-free cell phone conversation | 49% | 78% | 0.001 |
| Driving while having a handheld cell phone conversation | 22% | 45% | 0.045 |
| Driving while having a text message conversation | 18% | 32% | 0.145 |
| Driving while eating | 40% | 73% | 0.004 |
| Driving faster than you usually do | 11% | 20% | 0.052 |
| Driving with a severe headache | 27% | 40% | 0.149 |

*Table 20.* Post-drive (Final Questionnaire) vs. pre-drive (Post-Training Questionnaire) changes in percentage of participants who reported that reported that they would be somewhat or much more willing to drive in various situations with the L2 feature compared with driving a vehicle without it.

| Driving situation | Drive Assist P value | Autono Drive P value |
|---|---|---|
| Driving while drowsy | 0.023 | 0.415 |
| Driving with back or shoulder pain | 0.232 | 0.018 |
| Taking a six-hour drive to another state | 0.882 | 0.195 |
| Driving after having three alcoholic drinks | 0.525 | 0.784 |
| Driving after taking a medication that warns you not to drive | 0.259 | 0.354 |
| Driving while having a hands-free cell phone conversation | 0.036 | 0.082 |
| Driving while having a handheld cell phone conversation | 0.177 | 0.735 |
| Driving while having a text message conversation | 0.345 | 0.488 |
| Driving while eating | 0.006 | 0.306 |
| Driving faster than you usually do | 0.051 | 0.481 |
| Driving with a severe headache | 0.621 | 0.73 |

*Table 21*. Post-drive (Final Questionnaire) vs. Pre-drive (Post-Training Questionnaire) changes in perceptions of L2 feature, by branding condition.

| **Dimension** | **DriveAssist P value** | **AutonoDrive P value** |
|---|---|---|
| Increase safety | 0.383 | 0.262 |
| Reduce stress | 0.297 | 0.048 |
| Improve physical comfort | 0.055 | 0.254 |
| Scary to use | 0.008 | 0.001 |
| Fun to use | 0.018 | 0.237 |

*Table 22*. Post-drive (Final Questionnaire) vs. Pre-drive (Post-Training Questionnaire) changes in perceptions of L2 feature, by training condition.

| **Dimension** | **Quick Start P value** | **Video P value** | **Demo P value** |
|---|---|---|---|
| Increase safety | 0.776 | 0.482 | 0.053 |
| Reduce stress | 0.289 | 0.167 | 0.079 |
| Improve physical comfort | 0.182 | 0.174 | 0.379 |
| Scary to use | 0.004 | 0.006 | 0.005 |
| Fun to use | 0.143 | 0.338 | 0.042 |

*Table 23.* Perceptions of training and L2 feature name: differences between training conditions (Final Questionnaire).

| **Question** | **Quick start vs. Video P value** | **Quick start vs. Demo P value** | **Video vs. Demo P value** |
|---|---|---|---|
| How useful was this training in understanding how to activate DriveAssist/AutonoDrive? | 0.059 | 0.217 | 0.002 |
| How accurate was this training in describing the capabilities of DriveAssist/AutonoDrive, or what it can do? | 0.063 | 0.891 | 0.055 |
| How accurate was this training in describing the limitations of DriveAssist/AutonoDrive, or what it cannot do? | 0.118 | 0.551 | 0.043 |
| Overall, how well did the training you received before using DriveAssist/AutonoDrive reflect the actual capabilities of DriveAssist/AutonoDrive? | 0.195 | 0.662 | 0.082 |
| How accurately does the name DriveAssist/AutonoDrive reflect the capabilities of the technology you experienced on the road today? | 0.023 | 0.323 | 0.209 |

## Appendix A: DriveAssist Quick-Start Guide


### DRIVEASSIST OPERATION

DriveAssist is a driver assistance technology for use on limited-access freeways. The system helps you drive by automatically steering the vehicle to maintain lane position while also monitoring your attention to the road. Working with the Adaptive Cruise Control system, it reduces the need for you to frequently steer, brake or accelerate under available operating conditions.

To maintain automatic control of vehicle steering during freeway driving, DriveAssist uses:

- Global Positioning System (GPS) sensing,
- GPS-enhanced data,
- maps, and
- cameras.

Using these technologies, DriveAssist is able to maintain speed and lane position under most limited-access highway driving conditions.

**HOW DRIVEASSIST WORKS**

For safety reasons, DriveAssist is available only on limited access freeways that are separated from opposing traffic. The GPS determines the vehicle's location while the Lane Sensing Camera detects the marked lanes on the freeway to help the vehicle automatically steer and maintain lane position. As the driver, you are responsible for monitoring the system and all aspects of the vehicle's operation. On some occasions, such as when the lane lines are too faint, you will need to take back control from the system and steer manually. Simply grasp the steering wheel and begin steering when necessary.

DriveAssist works with Adaptive Cruise Control, which detects vehicles in your path and accelerates or brakes your vehicle based on surrounding traffic conditions, to maintain a driver-selected following time from a vehicle ahead, even in stop-and-go traffic conditions.

## ENGAGING DRIVEASSIST

The steering wheel light bar intuitively provides a status of system operation, including when the system is assisting with steering and when you need to manually steer the vehicle yourself. You can override DriveAssist at any time by steering, braking or accelerating.

If you do not respond to system prompts to manually steer the vehicle, DriveAssist will be disabled and a support technician will be contacted to provide support.

It is important to keep in mind that DriveAssist does not:

- Detect or steer through construction zones.
- Perform all aspects of driving, nor do everything a driver can do.
- Detect whether you are drowsy or focused on safe driving.
- Steer to avoid any objects, including vehicles, animals, pedestrians, bicyclists, potholes, debris, construction barriers, and cones.
- Steer the vehicle in reaction to vehicles or objects next to your vehicle, including other vehicles that attempt to enter your lane.
- Steer to merge the vehicle into the appropriate lane of traffic or to exit the freeway.
- Make lane changes.

It's extremely important that you pay attention to the operation of the vehicle, even while using DriveAssist. Do not use a hand-held device while driving, even with DriveAssist engaged. You must always be prepared to take over operation of the vehicle at all times.

To use DriveAssist, Adaptive Cruise Control must be on. Adaptive Cruise Control is like regular cruise control, but it can automatically adjust your vehicle's speed if there is a slower vehicle in front of you.


1. Press the **Adaptive Cruise Control** button (A) on the steering wheel to turn on Adaptive Cruise Control. The symbol (C) will illuminate in white on the instrument cluster. If Adaptive Cruise Control is already set, the symbol will be green with a speed shown.


2. When DriveAssist detects you are on a limited-access freeway, paying sufficient attention, and all other driving conditions are met (lane markings visible, GPS available, no system faults, etc.), the DriveAssist symbol (D) will illuminate in white on the instrument cluster.

3. When it is safe to do so, press the **DriveAssist** button (B) on the steering wheel to engage DriveAssist. If an Adaptive Cruise Control speed was not previously set, DriveAssist will be set to your current speed. When the symbol and steering wheel light bar illuminate in green, you may remove your hands from the steering wheel. Now DriveAssist is helping you to steer and maintain speed. You must continue to monitor the system and the road ahead. Do not engage in distracting tasks such as reading or using your mobile device.

You can increase your set speed by pressing the RES+ button or decrease your set speed by pressing the SET- button on the steering wheel. A light press on the button will change your set speed by one mile per hour. A hard press will change your set speed by five miles per hour.

► To disengage DriveAssist, press the **DriveAssist** button again or press the brake pedal.

## STEERING WHEEL LIGHT BAR INDICATORS

### CHANGING LANES

**The vehicle can be steered manually at any time.**

1. Move the steering wheel manually. The steering wheel light bar pulses blue.
2. Steer the vehicle into the desired lane.
3. To allow DriveAssist to resume steering, center the vehicle in the lane until the light bar turns green.

### DRIVEASSIST AVAILABILITY

**DriveAssist only can be engaged when:**

- Adaptive Cruise Control is on.
- Forward Automatic Braking is on. Go to Settings > Vehicle > Collision/Detection Systems > Forward Collision System.
- The vehicle is on a limited-access freeway, which generally only allows high-speed traffic; is separated from opposing traffic; and is only accessible by ramps.
- Camera or radar sensors are not obstructed or damaged.
- Lane markings are clearly visible. Do not use DriveAssist in poor weather conditions or when visibility is limited.
- Driver attention is detected.

When DriveAssist is not engaged, the light bar is not visible on the steering wheel and the DriveAssist symbol on the instrument cluster is not illuminated. You must steer the vehicle.

When DriveAssist is engaged, the steering wheel light bar and DriveAssist symbol indicate system status. While using DriveAssist, you are still the driver, and you are responsible for paying attention to the road ahead at all times. An escalating series of prompts lets you know if the system senses that you need to pay more attention to the road ahead.

### 1ST ALERT

When engaged, DriveAssist provides feedback on system status while tracking driver head position and to determine where you are looking. If the system detects that you may not be paying attention sufficiently to the road ahead, the steering wheel light bar flashes green to prompt you to return your attention to the road.

The light bar will stop flashing when the system detects your attention to the road has resumed.

### 2ND ALERT

If the steering wheel light bar flashes green for too long and the system determines continued lack of attention to the road ahead, the steering wheel light bar flashes red to notify you that this is not safe! At this point, you must look at the road and take over by steering manually.

The driver's seat also pulses or beeps sound.

The vehicle will not accelerate while the light bar is flashing red.

The steering wheel light bar will also warn you to take over by flashing red when:

- Adaptive Cruise Control is canceled.
- The vehicle is on a tight curve or speed is too fast.
- Lane markings are poor or visibility is limited.
- The lane or freeway ends.
- The vehicle is exiting the freeway.
- There is a system fault.

### 3RD ALERT

If the steering wheel light bar flashes red for too long, a voice prompt will be heard. You need to take over steering immediately; otherwise, the vehicle will slow in your lane of travel and eventually brake to a stop. DriveAssist and Adaptive Cruise Control will disengage.

In the event of an unresponsive driver, the vehicle will come to a controlled stop, activate the hazard lights, and contact Emergency Services. Remember that DriveAssist does not work reliably in all conditions. You must be prepared to take over steering and speed control at all times.

DriveAssist is not a collision avoidance system. It will not steer to avoid objects within your lane or engage emergency braking. DriveAssist only monitors lane lanes and vehicles in front of the car. It does not monitor traffic to your sides or behind you.

DriveAssist is a powerful self-driving feature that works reliably under most limited-access highway conditions. DriveAssist reduces your workload and frees your hands to do other things. With safety and innovation at its core, DriveAssist offers the greatest luxuries of all – trust, confidence, and peace of mind.

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## Appendix B: AutonoDrive Quick-Start Guide


### AUTONODRIVE OPERATION

AutonoDrive is a hands-free and feet-free autonomous driving technology for use on limited-access freeways. The highly capable system reduces your workload and enhances your comfort by automatically steering the vehicle to maintain lane position. It reduces the need for you to steer, brake or accelerate, and takes the stress out of driving.

To maintain automatic control of vehicle steering during freeway driving, AutonoDrive uses:

- state-of-the-art Global Positioning System (GPS) sensing,
- GPS-enhanced data,
- a high precision map accurate to within two inches, and
- a network of advanced cameras.

Using these cutting edge technologies, AutonoDrive knows the position of your car up to 1.5 miles ahead and makes you feel like you're riding on rails.

**HOW AUTONODRIVE WORKS**

AutonoDrive is available on limited access freeways that are separated from opposing traffic. The GPS uses real-time corrections and map data to determine the vehicle's location while the Lane Sensing Camera detects the marked lanes on the freeway to help the vehicle automatically steer and maintain lane position.

AutonoDrive works with Adaptive Cruise Control, which detects vehicles in your path and accelerates or brakes your vehicle based on surrounding traffic conditions, to maintain a driver-selected following time from a vehicle ahead, even in stop-and-go traffic conditions.

The steering wheel light bar intuitively provides a status of system operation, including when the system is steering and when you need to manually steer the vehicle. When the light bar is green, AutonoDrive is in control. You can override AutonoDrive at any time by steering, braking or accelerating.

If you do not respond to system prompts to manually steer the vehicle, AutonoDrive will be temporarily disabled.

## ENGAGING AUTONODRIVE

To use AutonoDrive, Adaptive Cruise Control must be on. Adaptive Cruise Control is like regular cruise control, but it can automatically adjust your vehicle's speed if there is a slower vehicle in front of you.


1. Press the **Adaptive Cruise Control** button (A) on the steering wheel to turn on Adaptive Cruise Control. The symbol (C) will illuminate in white on the instrument cluster. If Adaptive Cruise Control is already set, the symbol will be green with a speed shown.
2. When AutonoDrive detects you are on a limited-access freeway and all other driving conditions are met, the AutonoDrive symbol (D) will illuminate in white on the instrument cluster.
3. When it is safe to do so, press the **AutonoDrive** button (B) on the steering wheel to engage AutonoDrive. If an Adaptive Cruise Control speed was not previously set, AutonoDrive will be set to your current speed. When the symbol and steering wheel light bar illuminate in green, you may remove your hands from the steering wheel. Now AutonoDrive is in control and you can relax.


You can increase your set speed by pressing the RES+ button or decrease your set speed by pressing the SET- button on the steering wheel. A light press on the button will change your set speed by one mile per hour. A hard press will change your set speed by five miles per hour.

▶ To disengage AutonoDrive, press the **AutonoDrive** button again or press the brake pedal.

### CHANGING LANES

**The vehicle can be steered manually at any time.**

1. Move the steering wheel manually. The steering wheel light bar pulses blue.
2. Steer the vehicle into the desired lane.
3. To allow AutonoDrive to resume steering, center the vehicle in the lane until the light bar turns green.

### AUTONODRIVE AVAILABILITY

**AutonoDrive only can be engaged when:**

- Adaptive Cruise Control is on.
- Forward Automatic Braking is on. Go to Settings > Vehicle > Collision/Detection Systems > Forward Collision System.
- The vehicle is on a limited-access freeway, which generally only allows high-speed traffic; is separated from opposing traffic; and is only accessible by ramps.
- Camera or radar sensors are not obstructed or damaged.
- Lane markings are clearly visible. Do not use AutonoDrive in poor weather conditions or when visibility is limited.
- Driver is facing forward.

**AutonoDrive does not:**

- Detect or steer through construction zones.
- Perform all aspects of driving, nor do everything a driver can do.
- Detect whether you are drowsy or focused on safe driving.
- Steer to avoid any objects, including vehicles, animals, pedestrians, bicyclists, potholes, debris, construction barriers, and cones.
- Steer the vehicle in reaction to vehicles or objects next to your vehicle, including other vehicles that attempt to enter your lane.
- Steer to merge the vehicle into the appropriate lane of traffic or to exit the freeway.
- Make lane changes.

**It's important that you pay attention to the operation of the vehicle, even while using AutonoDrive. Always be prepared to take over operation of the vehicle.**

## STEERING WHEEL LIGHT BAR INDICATORS

**When AutonoDrive is not engaged, the light bar is not visible on the steering wheel and the AutonoDrive symbol on the instrument cluster is not illuminated. You must steer the vehicle.**

**When AutonoDrive is engaged, the steering wheel light bar and AutonoDrive symbol indicate system status.**

### 1ST ALERT

When engaged, AutonoDrive provides feedback on system status while tracking driver head position to determine where you are looking. If the system detects that you may not be looking forward, the steering wheel light bar flashes green to prompt you to return your attention to the road.

The light bar will stop flashing when the system detects your attention to the road has resumed.

### 2ND ALERT

If the steering wheel light bar flashes green for too long and the system determines continued lack of attention to the road ahead, the steering wheel light bar flashes red to notify you to look at the road and steer the vehicle manually.

The driver's seat also pulses or beeps sound

The vehicle will not accelerate while the light bar is flashing red.

The steering wheel light bar may also flash red when:
- Adaptive Cruise Control is canceled.
- The vehicle is on a tight curve or speed is too fast.
- Lane markings are poor or visibility is limited.
- The lane or freeway ends.
- The vehicle is exiting the freeway.
- There is a system fault.

### 3RD ALERT

If the steering wheel light bar flashes red for too long, a voice prompt will be heard. You should take over steering immediately; otherwise, the vehicle will slow in your lane of travel and eventually brake to a stop. AutonoDrive and Adaptive Cruise Control will disengage.

AutonoDrive is a powerful self-driving feature that works reliably under most limited-access highway conditions. AutonoDrive reduces your workload and frees your hands to do other things. With safety and innovation at its core, AutonoDrive offers the greatest luxuries of all – trust, confidence, and peace of mind.

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## Appendix C: Post-Training Questionnaire

**AutonoDrive Post-Training Questionnaire**

| **1.** For each situation below, indicate whether or not you expect AutonoDrive to successfully control vehicle speed and keep the vehicle in its lane without the driver doing anything. If you're not sure, take your best guess. If you feel like you have no way of even guessing, you may select "I have no idea." **Mark one response for each row.** | **Definitely will** | **Probably will** | **Probably will not** | **Definitely will not** | **I have no idea** |
|---|---|---|---|---|---|
| **a.** Driving in a work zone where lanes have shifted from their usual location | ☐ | ☐ | ☐ | ☐ | ☐ |
| **b.** Driving in heavy rain | ☐ | ☐ | ☐ | ☐ | ☐ |
| **c.** Driving in heavy snow | ☐ | ☐ | ☐ | ☐ | ☐ |
| **d.** Driving at night without street lights | ☐ | ☐ | ☐ | ☐ | ☐ |
| **e.** Driving into direct sun glare at sunset | ☐ | ☐ | ☐ | ☐ | ☐ |
| **f.** Driving where lane lines are badly faded | ☐ | ☐ | ☐ | ☐ | ☐ |
| **g.** Changing lanes to pass a slower vehicle in your lane | ☐ | ☐ | ☐ | ☐ | ☐ |
| **h.** Exiting onto a ramp from one freeway to another freeway | ☐ | ☐ | ☐ | ☐ | ☐ |
| **i.** Driving in stop-and-go traffic due to a traffic jam | ☐ | ☐ | ☐ | ☐ | ☐ |
| **j.** Reduce speed on a tight curve where the current set speed is too fast | ☐ | ☐ | ☐ | ☐ | ☐ |
| **k.** Bring the vehicle to a stop if the driver loses consciousness due to a medical emergency | ☐ | ☐ | ☐ | ☐ | ☐ |
| **l.** Driving on an undivided highway with no median or barrier separating traffic traveling in the opposite direction | ☐ | ☐ | ☐ | ☐ | ☐ |
| **m.** Drive through a toll booth with a 10 mph speed limit to pay an electronic (E-ZPass) toll | ☐ | ☐ | ☐ | ☐ | ☐ |
| **n.** Merging one lane to the left when the right lane ends | ☐ | ☐ | ☐ | ☐ | ☐ |
| **o.** Reducing speed when the speed limit drops from 65 mph to 55 mph | ☐ | ☐ | ☐ | ☐ | ☐ |
| **p.** Keeping a safe distance from a truck with a pole extending 15 feet out from the back of the truck | ☐ | ☐ | ☐ | ☐ | ☐ |
| **q.** Driving down a steep hill | ☐ | ☐ | ☐ | ☐ | ☐ |
| **r.** Driving through a one-mile-long tunnel | ☐ | ☐ | ☐ | ☐ | ☐ |

*Participants assigned to DriveAssist training group received otherwise-identical questionnaire with "DriveAssist" in place of "AutonoDrive."

**2.** Which of the following statements best reflects your understanding of your role when using AutonoDrive?

- ○ I have to keep my hands on the wheel and feet on the pedals to help guide AutonoDrive
- ○ I can take my hands off the wheel and feet off the pedals, but I need to pay attention to the road and be ready to steer or use the pedals at all times
- ○ I can take my hands off the wheel and feet off the pedals, and I only need to occasionally glance at the road
- ○ I can take my hands off the wheel and feet off the pedals, and I don't need to look at the road unless I get a notification from AutonoDrive

| **3.** For each situation below, please indicate whether or not you expect AutonoDrive to take action (brake and/or steer) and avoid a collision, without the driver doing anything. If you're not sure, take your best guess. If you feel like you have no way of even guessing, you may select "I have no idea." **Mark one response for each row.** | **Definitely will** | **Probably will** | **Probably will not** | **Definitely will not** | **I have no idea** |
|---|---|---|---|---|---|
| **a.** Approaching a bed mattress lying in your lane | ☐ | ☐ | ☐ | ☐ | ☐ |
| **b.** Car in lane directly next to you starts changing into your lane | ☐ | ☐ | ☐ | ☐ | ☐ |
| **c.** Slower-moving vehicle in lane next to you changes lanes in front of you, leaving a very small gap | ☐ | ☐ | ☐ | ☐ | ☐ |
| **d.** Car in front of you in your lane suddenly brakes hard | ☐ | ☐ | ☐ | ☐ | ☐ |
| **e.** Approaching a highway construction worker standing in your lane | ☐ | ☐ | ☐ | ☐ | ☐ |
| **f.** Approaching a slower moving motorcycle ahead in your lane | ☐ | ☐ | ☐ | ☐ | ☐ |
| **g.** Approaching stopped traffic ahead due to a traffic jam | ☐ | ☐ | ☐ | ☐ | ☐ |
| **h.** Approaching a deer that is on the roadside, but walking toward your lane | ☐ | ☐ | ☐ | ☐ | ☐ |

**4.** In what areas around the vehicle does AutonoDrive detect and respond to other vehicles? **Mark all that apply.**

- ☐ In front of vehicle
- ☐ Behind vehicle
- ☐ Left and right sides of the vehicle

**5.** What must happen before AutonoDrive will begin steering? **Mark all that apply**.

- ☐ Vehicle must be on a limited access highway
- ☐ Vehicle's speed must be over 40mph
- ☐ Vehicle must be centered in the lane
- ☐ Another vehicle must be present in the same lane ahead
- ☐ Lane lines must be visible on the roadway

**6.** How does AutonoDrive notify the driver when AutonoDrive is activated (actively steering and controlling speed)? **Mark all that apply**.

- ☐ Icon on instrument cluster/dashboard
- ☐ Light on top of steering wheel
- ☐ Beeping sound
- ☐ "AutonoDrive on" voice message
- ☐ Seat vibration

**7.** How does AutonoDrive notify the driver when it gives steering control back to the driver? **Mark all that apply**.

- ☐ Icon on instrument cluster/dashboard
- ☐ Light on top of steering wheel
- ☐ Beeping sound
- ☐ "AutonoDrive off" voice message
- ☐ Seat vibration

**8.** If a driver is using AutonoDrive, what happens after the driver presses the brake pedal?

- ○ Vehicle resumes AutonoDrive when driver releases brake
- ○ Vehicle switches to Adaptive Cruise Control
- ○ Vehicle gives full control of speed and steering to driver

**9.** If a driver is using AutonoDrive, what happens after the driver presses the accelerator pedal?

- Vehicle resumes AutonoDrive at original set speed
- Vehicle resumes AutonoDrive at new higher speed
- Vehicle switches to Adaptive Cruise Control
- Vehicle gives full control of speed and steering to driver

**10.** If a driver is using AutonoDrive, what happens after the driver uses a turn signal and changes lanes (without pressing any pedals)?

- Vehicle resumes AutonoDrive
- Vehicle switches to Adaptive Cruise Control
- Vehicle gives full control of speed and steering to driver

**11.** If a driver is using AutonoDrive, what happens after the vehicle leaves the area mapped in the AutonoDrive database?

- Vehicle remains in AutonoDrive
- Vehicle switches to Adaptive Cruise Control
- Vehicle gives full control of speed and steering to driver

| | 12. How willing would you be to drive in the following situations while using AutonoDrive, compared to driving a vehicle without AutonoDrive? **Mark one response for each row.** | Much less likely | Somewhat less likely | No difference | Somewhat more likely | Much more likely |
|---|---|---|---|---|---|---|
| **a.** | Driving while drowsy | ☐ | ☐ | ☐ | ☐ | ☐ |
| **b.** | Driving with back or shoulder pain | ☐ | ☐ | ☐ | ☐ | ☐ |
| **c.** | Taking a six-hour drive to another state | ☐ | ☐ | ☐ | ☐ | ☐ |
| **d.** | Driving after having three alcoholic drinks | ☐ | ☐ | ☐ | ☐ | ☐ |
| **e.** | Driving after taking a medication that warns you not to drive | ☐ | ☐ | ☐ | ☐ | ☐ |
| **f.** | Driving while having a hands-free cell phone conversation (for example: using Bluetooth headset or connection to car) | ☐ | ☐ | ☐ | ☐ | ☐ |
| **g.** | Driving while having a handheld cell phone conversation (for example: holding the phone to your ear) | ☐ | ☐ | ☐ | ☐ | ☐ |
| **h.** | Driving while having a text message conversation | ☐ | ☐ | ☐ | ☐ | ☐ |
| **i.** | Driving while eating | ☐ | ☐ | ☐ | ☐ | ☐ |
| **j.** | Driving faster than you usually do | ☐ | ☐ | ☐ | ☐ | ☐ |
| **k.** | Driving with a severe headache | ☐ | ☐ | ☐ | ☐ | ☐ |

**13.** How confident are you that AutonoDrive will work as it was described to you today?

- ○ Completely confident
- ○ Mostly confident
- ○ Somewhat confident
- ○ Slightly confident
- ○ Not at all confident

**14.** Overall, how much do you trust AutonoDrive to maintain your lane position and speed?

- ○ Completely trust
- ○ Mostly trust
- ○ Somewhat trust
- ○ Slightly trust
- ○ Do not trust at all

**15**. Overall, how much do you trust AutonoDrive to avoid conflicts with other vehicles?

- Completely trust
- Mostly trust
- Somewhat trust
- Slightly trust
- Do not trust at all

| **16**. Please indicate whether you agree or disagree with each of the following statements about your expectations for your upcoming trip using AutonoDrive. **Mark one response for each row.** | **Strongly disagree** | **Somewhat disagree** | **Neutral/ No opinion** | **Somewhat agree** | **Strongly agree** |
|---|---|---|---|---|---|
| **a.** I expect that AutonoDrive will increase my safety | ☐ | ☐ | ☐ | ☐ | ☐ |
| **b.** I expect that AutonoDrive will reduce my stress | ☐ | ☐ | ☐ | ☐ | ☐ |
| **c.** I expect that AutonoDrive will improve my physical comfort | ☐ | ☐ | ☐ | ☐ | ☐ |
| **d.** I expect that AutonoDrive will be scary to use | ☐ | ☐ | ☐ | ☐ | ☐ |
| **e.** I expect that AutonoDrive will be fun to use | ☐ | ☐ | ☐ | ☐ | ☐ |

**17**. How comfortable are you about using AutonoDrive on the road today?

- Completely comfortable
- Mostly comfortable
- Somewhat comfortable
- Slightly comfortable
- Not at all comfortable

**18**. Now that you have learned about AutonoDrive, are you willing to try using it on the road today?

- Yes
- No → **If no, please inform the experimenter now**

# Appendix D: Final Questionnaire

**AutonoDrive Final Questionnaire**

| | | Definitely will | Probably will | Probably will not | Definitely will not | I have no idea |
|---|---|---|---|---|---|---|
| **1.** | For each situation below, indicate whether or not you expect AutonoDrive to successfully control vehicle speed and keep the vehicle in its lane without the driver doing anything. If you're not sure, take your best guess. If you feel like you have no way of even guessing, you may select "I have no idea." **Mark one response for each row.** | | | | | |
| **a.** | Driving in a work zone where lanes have shifted from their usual location | ☐ | ☐ | ☐ | ☐ | ☐ |
| **b.** | Driving in heavy rain | ☐ | ☐ | ☐ | ☐ | ☐ |
| **c.** | Driving in heavy snow | ☐ | ☐ | ☐ | ☐ | ☐ |
| **d.** | Driving at night without street lights | ☐ | ☐ | ☐ | ☐ | ☐ |
| **e.** | Driving into direct sun glare at sunset | ☐ | ☐ | ☐ | ☐ | ☐ |
| **f.** | Driving where lane lines are badly faded | ☐ | ☐ | ☐ | ☐ | ☐ |
| **g.** | Changing lanes to pass a slower vehicle in your lane | ☐ | ☐ | ☐ | ☐ | ☐ |
| **h.** | Exiting onto a ramp from one freeway to another freeway | ☐ | ☐ | ☐ | ☐ | ☐ |
| **i.** | Driving in stop-and-go traffic due to a traffic jam | ☐ | ☐ | ☐ | ☐ | ☐ |
| **j.** | Reduce speed on a tight curve where the current set speed is too fast | ☐ | ☐ | ☐ | ☐ | ☐ |
| **k.** | Bring the vehicle to a stop if the driver loses consciousness due to a medical emergency | ☐ | ☐ | ☐ | ☐ | ☐ |
| **l.** | Driving on an undivided highway with no median or barrier separating traffic traveling in the opposite direction | ☐ | ☐ | ☐ | ☐ | ☐ |
| **m.** | Drive through a toll booth with a 10 mph speed limit to pay an electronic (E-ZPass) toll | ☐ | ☐ | ☐ | ☐ | ☐ |
| **n.** | Merging one lane to the left when the right lane ends | ☐ | ☐ | ☐ | ☐ | ☐ |
| **o.** | Reducing speed when the speed limit drops from 65 mph to 55 mph | ☐ | ☐ | ☐ | ☐ | ☐ |
| **p.** | Keeping a safe distance from a truck with a pole extending 15 feet out from the back of the truck | ☐ | ☐ | ☐ | ☐ | ☐ |
| **q.** | Driving down a steep hill | ☐ | ☐ | ☐ | ☐ | ☐ |
| **r.** | Driving through a one-mile-long tunnel | ☐ | ☐ | ☐ | ☐ | ☐ |

*Participants assigned to DriveAssist training group received otherwise-identical questionnaire with "DriveAssist" in place of "AutonoDrive."

2. Which of the following statements **best** reflects your understanding of your role when using AutonoDrive?

- ○ I have to keep my hands on the wheel and feet on the pedals to help guide AutonoDrive
- ○ I can take my hands off the wheel and feet off the pedals, but I need to pay attention to the road and be ready to steer or use the pedals at all times
- ○ I can take my hands off the wheel and feet off the pedals, and I only need to occasionally glance at the road
- ○ I can take my hands off the wheel and feet off the pedals, and I don't need to look at the road unless I get a notification from AutonoDrive

| **3.** For each situation below, please indicate whether or not you expect AutonoDrive to take action (brake and/or steer) and avoid a collision, without the driver doing anything. If you're not sure, take your best guess. If you feel like you have no way of even guessing, you may select "I have no idea." **Mark one response for each row.** | **Definitely will** | **Probably will** | **Probably will not** | **Definitely will not** | **I have no idea** |
|---|---|---|---|---|---|
| **a.** Approaching a bed mattress lying in your lane | ☐ | ☐ | ☐ | ☐ | ☐ |
| **b.** Car in lane directly next to you starts changing into your lane | ☐ | ☐ | ☐ | ☐ | ☐ |
| **c.** Slower-moving vehicle in lane next to you changes lanes in front of you, leaving a very small gap | ☐ | ☐ | ☐ | ☐ | ☐ |
| **d.** Car in front of you in your lane suddenly brakes hard | ☐ | ☐ | ☐ | ☐ | ☐ |
| **e.** Approaching a highway construction worker standing in your lane | ☐ | ☐ | ☐ | ☐ | ☐ |
| **f.** Approaching a slower moving motorcycle ahead in your lane | ☐ | ☐ | ☐ | ☐ | ☐ |
| **g.** Approaching stopped traffic ahead due to a traffic jam | ☐ | ☐ | ☐ | ☐ | ☐ |
| **h.** Approaching a deer that is on the roadside, but walking toward your lane | ☐ | ☐ | ☐ | ☐ | ☐ |

4. In what areas around the vehicle does AutonoDrive detect and respond to other vehicles? **Mark all that apply.**

- ☐ In front of vehicle
- ☐ Behind vehicle
- ☐ Left and right sides of the vehicle

| **5.** How willing would you be to drive in the following situations while using AutonoDrive, compared to driving a vehicle without AutonoDrive? **Mark one response for each row.** | **Much less likely** | **Somewhat less likely** | **No difference** | **Somewhat more likely** | **Much more likely** |
|---|---|---|---|---|---|
| **a.** Driving while drowsy | ☐ | ☐ | ☐ | ☐ | ☐ |
| **b.** Driving with back or shoulder pain | ☐ | ☐ | ☐ | ☐ | ☐ |
| **c.** Taking a six-hour drive to another state | ☐ | ☐ | ☐ | ☐ | ☐ |
| **d.** Driving after having three alcoholic drinks | ☐ | ☐ | ☐ | ☐ | ☐ |
| **e.** Driving after taking a medication that warns you not to drive | ☐ | ☐ | ☐ | ☐ | ☐ |
| **f.** Driving while having a hands-free cell phone conversation (i.e., using Bluetooth headset or connection to car) | ☐ | ☐ | ☐ | ☐ | ☐ |
| **g.** Driving while having a handheld cell phone conversation (i.e., holding the phone to your ear) | ☐ | ☐ | ☐ | ☐ | ☐ |
| **h.** Driving while having a text message conversation | ☐ | ☐ | ☐ | ☐ | ☐ |
| **i.** Driving while eating | ☐ | ☐ | ☐ | ☐ | ☐ |
| **j.** Driving faster than you usually do | ☐ | ☐ | ☐ | ☐ | ☐ |
| **k.** Driving with a severe headache | ☐ | ☐ | ☐ | ☐ | ☐ |

| **6.** Please indicate whether you agree or disagree with each of the following statements about your experience using AutonoDrive today. **Mark one response for each row.** | **Strongly disagree** | **Somewhat disagree** | **Neutral/ No opinion** | **Somewhat agree** | **Strongly agree** |
|---|---|---|---|---|---|
| **a.** AutonoDrive increased my safety | ☐ | ☐ | ☐ | ☐ | ☐ |
| **b.** AutonoDrive reduced my stress | ☐ | ☐ | ☐ | ☐ | ☐ |
| **c.** AutonoDrive improved my physical comfort | ☐ | ☐ | ☐ | ☐ | ☐ |
| **d.** AutonoDrive was scary to use | ☐ | ☐ | ☐ | ☐ | ☐ |
| **e.** AutonoDrive was fun to use | ☐ | ☐ | ☐ | ☐ | ☐ |

**IMPORTANT: Please give this questionnaire to the researcher now. The researcher will ask you the rest of the questions and write down your answers.**

**The following questions are to be asked by the researcher. Do not fill them out on your own.**

**7.** Overall, how would you rate the performance of AutonoDrive? Would you say…

- Excellent
- Very good
- Fair, or
- Poor

**8.** Overall, how did AutonoDrive perform compared to your expectations just before you started the drive? Would you say…

- Much better than your expectations
- Somewhat better than your expectations
- Met your expectations
- Somewhat worse than your expectations, or
- Much worse than your expectations

**9.** In what ways did AutonoDrive perform worse than you expected?

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

**10.** In what ways did AutonoDrive perform better than you expected?

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

**For these next questions, please think about the training you received before using AutonoDrive**

**11.** How useful was this training in understanding how to activate AutonoDrive? Would you say…

- Very useful
- Somewhat useful
- Slightly useful, or
- Not at all useful

**12.** How accurate was this training in describing the **capabilities** of AutonoDrive, or what it **can** do? Would you say…

- ○ Completely accurate → **SKIP TO Q14**
- ○ Very accurate
- ○ Somewhat accurate
- ○ Slightly accurate, or
- ○ Not at all accurate

**13.** In what ways was the training **in**accurate in describing the capabilities of AutonoDrive?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

**14.** How accurate was this training in describing the **limitations** of AutonoDrive, or what it **cannot** do? Would you say…

- ○ Completely accurate → **SKIP TO Q16**
- ○ Very accurate
- ○ Somewhat accurate
- ○ Slightly accurate, or
- ○ Not at all accurate

**15.** In what ways was the training **in**accurate in describing the limitations of AutonoDrive?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

**16.** Overall, how well did the training you received before using AutonoDrive reflect the actual capabilities of AutonoDrive? Would you say…

- ○ AutonoDrive was **much more capable** than the training made it seem
- ○ AutonoDrive was **somewhat more capable** than the training made it seem
- ○ AutonoDrive was **as capable** as the training made it seem
- ○ AutonoDrive was **somewhat less capable** than the training made it seem, or
- ○ AutonoDrive was **much less capable** than the training made it seem

**For these final two questions, I'm going to ask you about the name of the technology you experienced today.**

***17.*** What do you think of the name AutonoDrive? *Probe if necessary:*

- **a.** What thoughts first come to mind when you hear the name AutonoDrive?
- **b.** Is the name a good fit for the system you experienced on the road?

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

**18.** How accurately does the name AutonoDrive reflect the capabilities of the technology you experienced on the road today? Would you say the name AutonoDrive makes the technology sound…

- ○ More capable than it is?
- ○ Less capable than it is?, or
- ○ Would you say the name AutonoDrive accurately reflects the capabilities of the technology?

**Session summary notes (to be completed by researcher after session)**

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