Driver Training Research and Guidelines for Automated Vehicle Technology

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16. Abstract
The advent of advanced driver-assistance systems presents the opportunity to significantly improve transportation safety. Complex sensor-based systems within vehicles can take responsibility for tasks typically performed by drivers, thus reducing driver-related error as a source of crashes. While there may be a reduction in driver errors, these systems fundamentally change the driving task from manual control to supervisory control. A significant challenge, given this fundamental change in the driving task, is that there are no established methods to train drivers on the use of these systems, which may be counterproductive to safety improvements. The aim of the project was to develop training protocol guidelines that could be used by advanced driver-assistance system trainers to optimize driving safety. The guidelines were developed based on the results of three activities that included the development of a taxonomy of the knowledge and skills necessary to operate advanced driver-assistance systems, a driving simulator study that examined the effectiveness of traditional training protocols, and a test track study that examined the efficacy of a vehicle-based training protocol. Results of both studies suggest that differing training protocols are most beneficial in terms of driver cognitive load and visual scanning as opposed to short-term changes in performance.

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Abstract

The increasing prevalence of advanced driver-assistance systems presents the opportunity to improve significantly transportation safety and comfort. Complex sensor-based systems within the vehicles can take responsibility for tasks typically performed by drivers, thus reducing driver-related error as a source of crashes. A significant challenge is that there are no established methods to train drivers on the use of these systems, which may be counterproductive to safety improvements. The aim of the project was to develop training protocol guidelines that could be used by stakeholders to train operators of vehicles with partial driving automation to optimize driving safety and comfort. The guidelines were developed based on the results of three activities that included the development of a taxonomy of the knowledge and skills necessary to operate advanced driver-assistance systems, a driving simulator study that examined the effectiveness of traditional training protocols, and a test track study that examined the efficacy of vehicle-based training protocol. Results of both studies suggest that differing training protocols are most beneficial in terms of driver cognitive load and visual scanning as opposed to short-term changes in performance.

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Introduction

It was estimated that in 2016 approximately 94% of serious crashes were attributable to human error, including errors related to distraction, impairment, or drowsiness (National Highway Traffic Safety Administration, 2017). Advanced driver assistance systems (ADAS) are technologies that assist drivers by helping to control vehicle acceleration, vehicle deceleration, and lane position. In contrast, automated vehicles (AVs) provide similar vehicle control functionality but do not require assistance by the driver. ADAS have the potential to significantly improve safety by relieving drivers of tasks. By removing drivers' vehicle control responsibilities, human errors may also be removed and the rate of crashes may be reduced on our roadways.

A critical aspect of ADAS is educating the public on their operational characteristics and use. Without proper training, drivers are more likely to be unaware of the system's strengths, weaknesses, and potential unanticipated or unintended responses (Parasuraman, 2000). Therefore, it is important to establish methods to train drivers on the use of ADAS. Within the context of this work, we refer to training as a continuous and systematic process that teaches individuals a new skill or behavior to accomplish a specific task (Salas, Wilson, Priest, & Guthrie, 2006). Ideally, training should promote permanent behavioral changes that support an optimal relationship between humans and the systems they operate. In the case of the current project, the purpose of training is to reduce driver workload, confusion, and unsafe behaviors. A successful training program will promote the necessary knowledge, skills, and attitudes (KSA) related to ADAS and, ultimately, safer driving.

Research Study Approach

The aim of this project was to develop training protocol guidelines that can be used by ADAS trainers to optimize driving safety. Three activities were conducted to achieve this goal: (1) the development of a taxonomy of the knowledge and skills required to operate National Highway Traffic Safety Administration (NHTSA) Level 2 vehicles; (2) a driving simulator study at the Texas A&M Transportation Institute (TTI) to determine and test ADAS training protocols; and (3) an instrumented vehicle study at the Virginia Tech Transportation Institute (VTTI) to determine how to best adapt ADAS training protocols into an *in situ* training program. Driver training guidelines were then developed and disseminated to various professional organizations involved with driver training. This report is structured into sections that summarize the three activities, the training guidelines, additional project products, and references.

Knowledge and Skills Taxonomy

The first activity within the project was to develop a knowledge and skills taxonomy indicating those items that should be included in ADAS training protocols. The taxonomy acted as a starting point for researchers to frame the experimental design and support the development of the subsequent research efforts. Figure 1 provides a summary of recommended skills and knowledge that drivers should be trained on to safely drive and operate a vehicle with ADAS features.

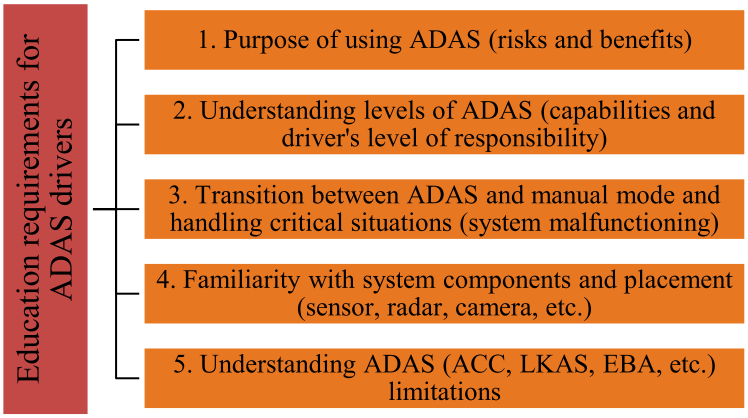

Figure 1. Knowledge and skills taxonomy for ADAS-equipped vehicles.

1. Purpose of ADAS. Several factors such as operators' attitudes toward automation, mental workload, level of trust in the system, confidence in self-skills, and level of risk influence drivers' decisions on using an automation system. Drivers should be made aware of the consequences of ADAS-related decisions.

2. Understanding ADAS. Education on the differences between levels of automation is probably the most important requirement of a training program. A lack of understanding of the differences between automation levels may lead to drivers being confused about their level of responsibility while transitioning between different levels of automation—when switching to another vehicle with a different level of automation or turning an automated subsystem on and off in the same vehicle (Marinik et al., 2014). The issue becomes more problematic when a driver overly relies on the system at lower levels of automation.

3. Transition between ADAS and Manual Mode. The transition between ADAS and manual control and how drivers behave when they receive a takeover request from the system is an important. In this regard, drivers' performance and behavior in reassuming control of the vehicle may vary based on driver characteristics such as age. Considering the variation in takeover behaviors among drivers could help with the development of specific training materials tailored toward different groups of drivers.

4. Familiarity with System Components and Placement. Drivers need to be familiar with the main components of the ADAS where they are located on the vehicle. For instance, many ADAS features utilize data collected from sensors and cameras to adjust speed or apply the brakes. If these sensors or cameras are blocked, they could produce inaccurate information.

5. Understanding of Driver Assistance Systems. There is low level of knowledge among drivers, not only about emerging safety technologies (e.g., adaptive cruise control [ACC], forward collision

warning [FCW]), but also about commonly featured technologies (e.g., anti-lock braking and tire pressure monitoring systems) (McDonald et al., 2015, 2016). While drivers' familiarity with ADAS operation is important, that alone is not sufficient. Drivers need to understand the capabilities and limitations of such systems as well. Many ADAS function properly only in certain conditions (e.g., ACC limitations on winding and hilly roads).

Traditional Training Protocol Evaluation

Introduction

The development and evaluation of ADAS training programs can be informed by both practical and theoretical considerations. Practically, the criteria for selecting one or more training programs could include compatibility with the training objectives (see Taxonomy in previous section), suitability to the anticipated training environment, available resources, and intended audience. The selection of training programs may also be associated with driver-related factors. For example, Sable (2017) found that younger drivers preferred self-led technology-based methods such as online videos or "game-ified" hands-on training, while older drivers tended to prefer more traditional instructor-led demonstrations. These findings have important real-world implications as the automotive and training industries grapple with whether the use of ADAS technology should be taught through online videos, such as My Car Does What, YouTube, dealer-provided videos, or taught by professional driving instructors, such as members of the American Driver and Traffic Safety Education Association (ADTSEA) and Driving Schools Association of the Americas.

A number of theoretical frameworks have been developed to guide the science of design, delivery, and evaluation of training systems (Branson, Rayner, Cox, Furman, & King, 1975; Tannenbaun, Cannon-Bowers, Salas, & Mathieu, 1993; Thayer & Teachout, 1995; Burke & Hutchins, 2008; Bell & Kozlowski, 2008). These frameworks do not rate the relative effectiveness of specific training methods, so it is difficult to select one that might be applied to various training approaches for ADAS. However, elements of these theories can be applied to the understanding of the video and demonstration-based approaches identified by Sable (2017).

Video-based training is supported by the interactivity principle (Arguel & Jamet, 2009), which posits that a participant can control the pace of information by starting, stopping, and reviewing part or all of a video. This process allows for information to be chunked into a more efficient mental model (Arguel & Jamet, 2009). A second element that can be applied to video-based learning relates to the cognitive load theory of multimedia learning (Mayer, 2003), which posits that multimedia instructional formats lead to better acquisition of information and foster deeper learning than a purely visual or verbal instructional format (Mayer, 2003; Arguel & Jamet, 2009).

In contrast, demonstration-based training is instructor-led and occurs in the working environment (i.e., in-vehicle in the case of training on ADAS). Demonstration provides an opportunity to observe and practice the behaviors needed to perform a task, which facilitates the establishment and reinforcement of the neural pathways employed with those actions, ultimately reducing the mental effort needed (Torriero, Oliveri, Koch, Caltagirone, & Petrosini, 2007). It should be noted that neither of these training protocols nor the theories that help define them have been assessed relative to learning ADAS. The purpose of the current study was to determine the effectiveness of two different training protocols on drivers' use of and interaction with an ADAS. The comparison provides a mechanism to establish the effectiveness of the two training approaches, which has immediate practical implications for those who develop training materials and for the students who must learn and use ADAS. It was hypothesized that superior learning would be observed for drivers who received demonstration-based training due to stronger neural pathway development.

Method

Participants

Thirty adults, aged 55 and older, were recruited from the Bryan/College Station, Texas, metropolitan area (see Table 1). To reduce biases that may influence study results, participants did not own or operate a vehicle with ADAS driving technologies, were not taking medications that would impair driving performance or decision-making, and possessed normal or corrected-to-normal vision via corrective lenses. Each participant read and affirmed their consent using the approved Texas A&M University Institutional Review Board (IRB) consent form.

Table 1. Texas A&M Study Participant Demographics

	No Training		**Video-based**		**Demonstration-based**	
Gender (No. of Participants	Male n=5	Female n=5	Male n=5	Female n=5	Male n=5	Female n=5
Age (Stan. Dev.)	63.80 (5.40)	62.40 (6.58)	64.75 (5.37)	62.20 (6.30)	63.00 (5.79)	61.80 (4.66)

Apparatus

This study was conducted in the Texas A&M Transportation Institute's driving environment simulator, which was manufactured by Realtime Technologies, Inc. The driving environment simulator consisted of a single vehicle seat placed in front of three screens that subtended 165- and 35-degree horizontal and vertical fields of view, respectively. Drivers controlled their virtual vehicle through a force feedback steering wheel, accelerator pedal, and brake pedal. A Level 2 ADAS was represented by an ACC and a lane keep assist system (LKAS). Eye-glance metrics were collected using a Seeing Machines Incorporated single-camera Fovio system.

Procedures

Each participant completed a background survey to collect information on driving history, caffeine and nicotine consumption, and video game experience (Appendix A), as well as a knowledge assessment of ADAS (Appendix B). The survey and questionnaire information were used to verify homogeneous participant characteristics across experimental conditions. Participants then completed a five-minute practice drive to eliminate simulator learning effects during the study.

Each participant was randomly assigned to one of three conditions, which differed only in the type of ADAS training protocol provided. Participants in the video-based training protocol condition watched instructional videos describing the operation and characteristics of the ACC and LKAS systems and how they operated together to create a Level 2 ADAS. This protocol was analogous to online training. Participants in the demonstration-based training protocol condition received identical instructions that were delivered by a trainer/instructor and were provided with a demonstration, a method that is analogous to typical behind-the-wheel driver-training approaches. Participants in the no instruction training protocol were not provided with instructions, which was analogous to drivers who learn vehicle-based systems through exploration.

Participants completed three drives, each composed of eight driving segments that alternated between roadway conditions requiring manual control (i.e., driver responsible for all driving actions) and conditions suitable for ADAS control (i.e., when participants could use the combined ACC and LKAS). Throughout each drive, participants performed a car-following task in which they were instructed to follow a lead vehicle that randomly changed both speed and speed amplitude at a close and consistent distance at all times. Participants reported Rating Scale Mental Effort (RSME) scores four times per drive, after the second and fourth ADAS control segments, and after the second and fourth manual control segments (Appendix C). RSME scores ranged from 0 to 150, with the latter indicating maximum mental effort. Participants completed the Knowledge Assessment of Automated Vehicle Technologies questionnaire after the third drive. At the conclusion of the study session, participants were compensated $50 for their participation.

Experimental Design

Performance, defined as mean time headway (MTH) between the participant and the lead vehicle for the second, third, and fourth manual drive segments, was subjected to a 2 × 3 × 3 multivariate analysis of variance (MANOVA) with Gender (Female, Male) and Training Protocol (No Training, Video-Based, Demonstration-Based) as between-subject factors and Drive (One, Two, Three) as a within-subjects repeated measure. MTH indicated the extent to which there were any positive or negative carryover effects from autonomous to manual driving.

Glance Location Proportion (GLP) defined our measure of attention allocation and was calculated as the percentage of time participant glances occurred in each of four areas of interest that included the dash (containing icons with ADAS system status), side touch screen (ADAS controls were located on the right side touch screen), forward roadway, and none (gaze not detected) for each of the manual and ADAS segments. Since glance patterns at the beginning and end of each segment would be erratic due to the control transition, the first and final 15 seconds of each segment were not included in GLP. The GLPs for the four areas of interest were independently subjected to a 2 × 3 × 3 MANOVA with Gender (Female, Male) and Training Protocol (No Training, Video-Based, Demonstration-Based) as between-subject factors and Drive (One, Two, Three) as a within-subjects repeated measure.

RSME was used to define driver mental workload. Two RSME scores were computed per drive, one that represented ADAS driving segments and one that represented manual driving segments. A 2 × 2 × 3 × 3 repeated measures MANOVA was conducted with task (Manual, ADAS) and Drive (One, Two, Three) as within-subject repeated measures and training protocol (No Training, Video, Demonstration) and Gender (Female, Male) as between-subject variables. Data were only included in each analysis when participants activated both LKAS and ACC. Bonferroni adjustments were employed for all post hoc tests.

Results

Mean Time Headway

Results indicated a Gender by Training Protocol by Drive interaction, $F(4, 24) = 3.105, p = .034, \eta^2 = .341$. Time headway was significantly greater for female participants compared to males (Figure 2), but this was only seen during Drive 1 in the control group. Training protocol post hoc comparisons did not reach significance.

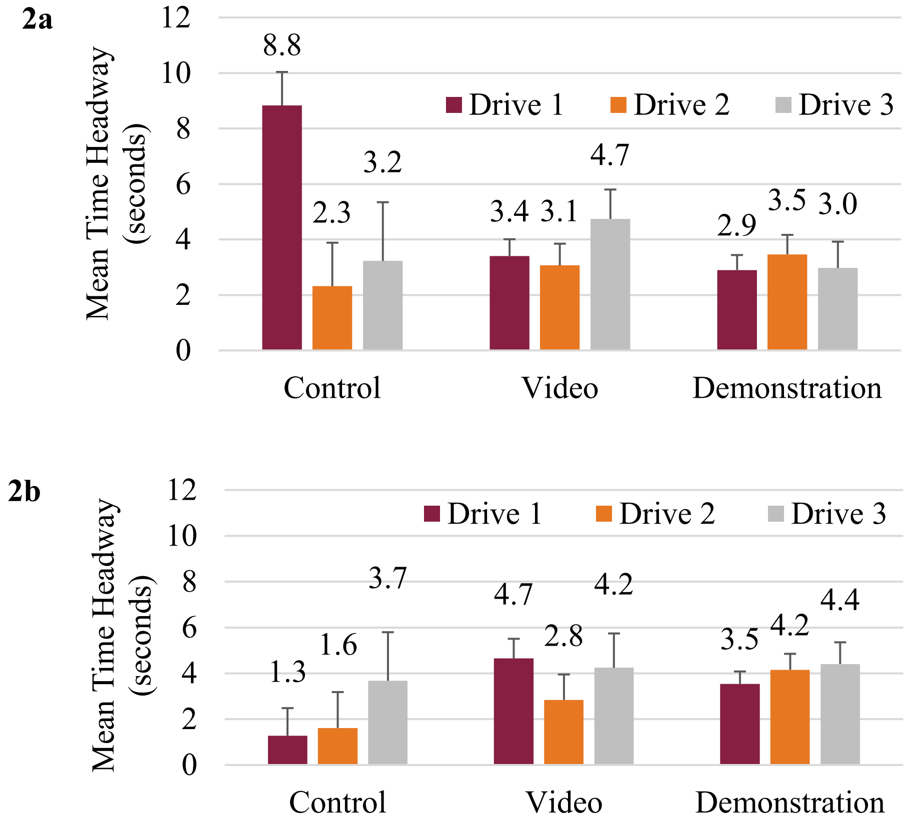

Figure 2. MTH by drive for females (2a) and males (2b). Error bars represent standard error.

Glance Location Proportion

A main effect of Gender for GLP to the dash was observed, $F(1, 9) = 5.628, p = .042, \eta^2 = .385$, in which males (mean = 7.38%) exhibited greater glance proportion toward the dash compared to females (mean = .98%).

Results indicated a Gender main effect, $F(1, 9) = 5.985, p = .037, \eta^2 = .399$, for GLP to the side touchscreen with males viewing the screen a significantly higher proportion of the time compared to females. A Gender by Training Protocol interaction, $F(2, 9) = 4.708, p = .040, \eta^2 = .511$, indicated that males exhibited a significantly greater glance proportion towards the side touch screen compared to females; however, this relationship was only observed in the no training group compared to the demonstration and video training groups (Figure 3). Post hoc tests for the training protocol did not reach significance.

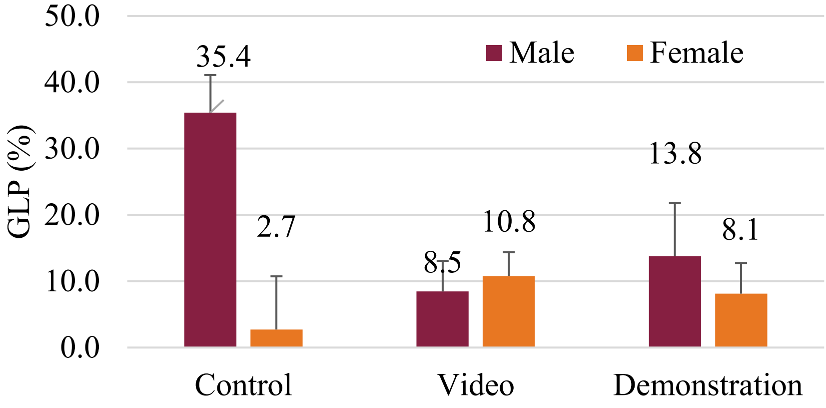

Figure 3. Side touch screen GLP training condition by gender interaction. Error bars represent standard error.

Rating Scale of Mental Effort

Participants reported significantly greater mental effort during the manual drive segments (mean = 67.50) compared to the ADAS drive segments (mean = 58.16), $F(1, 24) = 15.712, p = .001, \eta^2 = .369$.

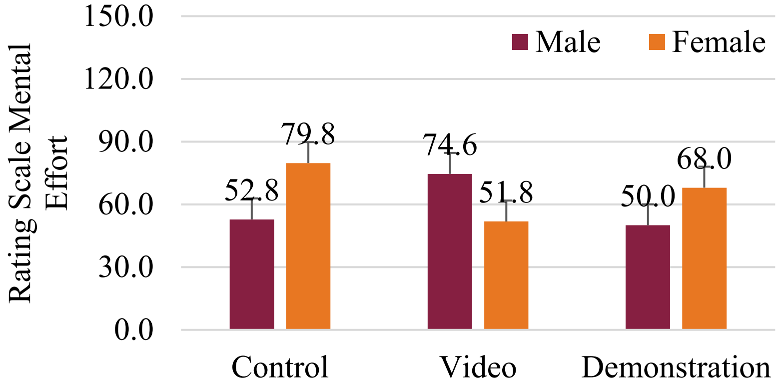

Figure 4. RSME training condition by gender interaction. Error bars represent standard error.

The Gender by Training Protocol interaction, $F(2, 24) = 3.483, p = .047, \eta^2 = .225$, indicated that females reported greater mental effort compared to males in both the no training and the demonstration-based training conditions; however, the opposite relationship was observed in the video-based training protocol group, with males reporting greater mental effort compared to females (Figure 4). Post hoc tests for the Training Protocol did not reach significance.

Discussion

ADAS training is intended to improve driving performance, attention allocation, workload, and knowledge of the system. Specifically, demonstration-based training that provides for more experiential learning and subsequent neural pathway development was hypothesized to result in the greatest improvements. This study demonstrated that the different types of training protocols can have differential effects on a range of driving metrics.

Driving performance results did not support the primary hypotheses that training type would influence MTH performance. The performance results did indicate that females, specifically in the control condition, exhibited greater MTH compared to males, which would suggest that under normal conditions (i.e., without training) females adopted a safer driving strategy. However, after either training protocol, MTH, and subsequently safety margins, was reduced for females to approximately that of males.

The current work also demonstrates that driver gender and training protocol can significantly influence attention allocation. Research results examining attention allocation to the forward roadway indicated comparable results between genders, with females and males looking at the road ahead 78% and 60% of the time, respectively. This finding demonstrates a trend for females to allocate their attention to the most important visual area while driving. It is also important to determine where attention is being allocated when not focusing on the forward scene. Results indicating that male participants viewed the side touchscreen and dash significantly more often than their female counterparts provides initial evidence that males not only attend to the forward scene less often but that glances to other areas are more varied than females. As a reminder, the DASV features were controlled on the side touchscreen, and system status (i.e., enabled or disabled) could be confirmed in the dash or on the side touchscreen. These results strongly suggest that male participants allocated more attention to checking the status of the ADAS, but while this may be informative, it may also be counterproductive to safety due to the increased proportion of time that males did not look at the forward scene.

ADAS training protocols may also reduce driver mental workload by virtue of reducing the amount effort required to understand and operate the system. Consistent with allied research (Young & Stanton, 1997; Young & Stanton, 2007; de Winter, Happee, Martens, & Stanton, 2014), results of the current work reaffirmed that the mental effort associated with manual driving was significantly greater compared to ADAS driving. The current work extends these results by finding that females reported greater mental effort compared to males but only for the no training and demonstration-based training conditions. An opposite trend was found in the video-based training condition. While there is limited research pertaining to specific types of training protocols and their influence on workload, some work has evaluated gender differences in perceived workload. Specifically, females report greater workload on spatial tasks, such as driving, compared to males, and females found spatial tasks to be frustrating, mentally challenging, and requiring significant effort when compared to their male counterparts (Warm, Dember, and Ricks, 2001). Given this finding, it is not surprising that females reported significantly greater mental effort in the control and demonstration groups; however, this trend would be expected to carry over to the video-based group as well. This result should be accepted cautiously because the control condition had relatively few data points (a small proportion of participants activated both LKAS and ACC systems, which was a condition for including data in the analyses), which may result in scores that are not fully representative of a larger pool of participants.

Overall, results of this research indicate that performance and attention allocation relative to ADAS can all be impacted in different ways by training protocol but that the effects are intertwined with other factors such as gender. The practical implications suggest that there are no performance advantages as a result of providing either ADAS vehicle training protocol to drivers. In fact, for females the provision of each protocol resulted in the adoption of less-safe driving performance, albeit not worse than males. This finding must be considered in parallel with the notion that levels of mental effort for females were also higher after the provision of some training protocols. A positive finding is that attention allocation to the road ahead was increased by either training protocol. These combined results suggest that a "one size fits all" approach to ADAS training protocols will likely not be effective and that, instead, ADAS training protocols should be tailored to specific driver demographics.

Vehicle-Based Training Protocol Evaluation

Background

Literature in the area of driver training for vehicle automation is still relatively sparse; one previous study explored the use of demonstrations and review of owner's manuals, methods that are likely to increase the driver's general or verbal understanding. A University of Iowa study aimed to understand how a driver's first exposure to five advanced ADAS affected their knowledge and attitudes about the systems. The study evaluated two conventional learning methods (owner's manual and demonstration) and found that knowledge scores on written assessments of ADAS technologies increased among all participants regardless of which conventional training method they experienced initially (McDonald, Reyes, Roe, & McGehee, 2017).

However, the McDonald et al. study and previous studies related to training and comprehension of automated driving systems have some important limitations. While verbal or general understanding may help a subject pass certain information-focused tests, it does not necessarily facilitate problem-solving or indicate true comprehension. Constructivism is an educational philosophy which states that learning takes place in context and that learners form or construct much of what they learn and understand as a function of their experiences (Schunk, 2012). Studies of how drivers learned to use the technologies in their vehicles indicate that the majority of owners learn by reading the operator manual or through "trial-and-error" (Abraham, Reimer, Seppelt, Fitzgerald, & Coughlin, 2017; Mcdonald, Carney, & Mcgehee, 2018). Abraham et al. (2017) found that 35% of car owners surveyed would have preferred to learn how to use their in-vehicle technologies "by the car teaching them." This finding indicates that a constructivist-based approach to training is what drivers want in their next vehicle purchase and will possibly facilitate a deeper understanding of in-vehicle systems.

The purpose of this study was to determine the effectiveness of two training protocols on drivers' knowledge and perceived familiarity with vehicle automation, as well as on drivers' monitoring of the forward roadway during system use. To test this, one of the most prevalent forms of mass training (self-study with the vehicle manual) was compared with an experimental multimedia training protocol (Appendix D. Vehicle-Based Training Protocols). It was hypothesized that participants who experienced the experimental training protocol would demonstrate superior knowledge of the ADAS and drive more safely than recipients of the conventional protocol.

Method

Participants

Forty participants from southwestern Virginia volunteered for this research effort. The two target age ranges for volunteers were 18 to 25 years old and 55 to 75 years old (Table 2). Participants who owned a primary vehicle that had advanced systems such as ACC, LKAS, or automatic emergency braking were not eligible to participate in the study. Participants affirmed their consent using the approved Virginia Tech IRB human subjects consent form. A Snellen eye test (corrected visual acuity of 20/40 or better) and basic hearing test were administered. All participants passed the pre-drive test. The study session consisted of one two-hour visit; volunteers were compensated $60.00 for their time.

Table 2. VTTI Participant Demographics and Training Group Assignment

	Conventional Training	**Multimedia Training**	**Total**
Younger Participants (18–25)	10 (*M* = 21.4, *SD* = 1.58)	10 (*M* = 21.1, *SD* = 1.37)	20 (*M* = 21.25, *SD* = 1.45)
Older Participants (55–75)	10 (*M* = 59.7, *SD* = 5.64)	10 (*M* = 66.2, *SD* = 7.63)	20 (*M* = 62.95, *SD* = 7.33)
Total	20 (*M* = 40.55, *SD* = 20.06)	20 (*M* = 43.65, *SD* = 23.74)	40 (*M* = 42.1, *SD* = 21.75)

Apparatus

Participants were randomly assigned to one of two training groups prior to their arrival for the experimental session. Training modules were completed in the parked research vehicle, without the experimenter present. The research vehicle for this study was a 2016 Tesla Model S with Autopilot Software v8.1. A DAS was used to accurately record all relevant kinematic driver performance data.

Procedures

Intake

After completing the informed consent, participants completed pre-drive questionnaires, which assessed participant driving history, psychometric measures, and familiarity with ADAS and other forms of technology. After completing the intake procedure and questionnaires, participants were escorted to the research vehicle where they were to complete their randomly assigned training protocol after a brief orientation to the vehicle.

Training

Both training modules, for the control and experimental groups, consisted of specific topics from the Tesla Model S operator's manual (Appendix F. Vehicle-Based Training Topics).

The control group received conventional training on how to use driver assistance systems (Traffic-Aware Cruise Control and Autosteer) by reading the specified section of the operator's manual. The goal was to provide participants with an experience similar to how much of the motoring public learns to use in-vehicle technologies.

The experimental group received training via an interactive multimedia module. The multimedia training was divided into three distinct components: Overview, Traffic-Aware Cruise Control, and Autosteer. As part of the training, the video instructed participants to manipulate controls and interact with the system to promote interactive learning and to facilitate a better understanding of the system.

After finishing the training program, participants completed a post-training questionnaire. This questionnaire assessed their knowledge of vehicle automation systems, attitudes toward the systems, and attitudes toward the training program. Following the completion of the post-training questionnaire, participants were escorted to the Virginia Smart Road to begin the closed test track portion of the study.

Test Track

The Virginia Smart Road is a closed-access, two-lane roadway built to federal highway specifications and located at VTTI. This study used a section of the Smart Road that was approximately 1.3 miles long. Participants completed six laps on the Smart Road and were instructed to stop the vehicle at a specified point for questions and additional instructions. A VTTI researcher was in the front seat during the test track portion of this study, and a confederate vehicle, driven by a VTTI researcher, accompanied the research vehicle on to the Smart Road. Participants were instructed that the maximum speed limit for the study was 35 mph, that they should obey all traffic laws, and that they should maintain their current lane and a 2-second following distance when there was a vehicle in front of them.

Secondary tasks were completed on two 0.3-mile sections of the Smart Road bisected by a 0.3-mile transition area. While in the transition area, secondary tasks were not to be continued and the confederate lead vehicle drove at a constant speed in front of the subject vehicle.

Independent Variables

The independent factors used in this study are described in Table 3.

Table 3. VTTI Study Independent Variables

Independent Variables	Definition & Levels
Age Group (Between-subjects)	Depending on subject's age on day of experimental visit, participants were placed in one of two categories. • Younger: 18–25 years old • Mature: 55–75 years old
Training (Between-subjects)	Participants were randomly assigned to one of two training groups prior to their arrival for the experimental session. • Conventional: Control group, received training by reading the operator's manual. • Multimedia: Experimental group, completed multimedia training. Protocols are described on page 11.
Automation (Within-subjects)	Automation state is a binary indicator of whether the human operator or the driving automation system had active control of the vehicle's lateral and longitudinal motion. During half of the laps of the test track session, participants were asked to activate the ADAS. • ON: Driving automation system had active control of vehicle's lateral and longitudinal motion. • OFF: Human operator had active control of vehicle's lateral and longitudinal motion.
Secondary Task (Within-subjects)	After completing the initial baseline laps, participants were asked to engage in secondary tasks. • No Task: Participants were not completing secondary tasks. • Task: Participants were continuously performing visual or visual-manual tasks.
Exposure Period (Within-subject)	Measure of participant exposure to the ADAS system. Each exposure period consisted of one lap with automation on and one lap with automation off. • Early: Laps 1 & 2 • Middle: Laps 3 & 4 • Late: Laps 5 & 6
Admin Time (Within-subject)	Questionnaires were administered to participants at specific points during the study. • Pre-Training: Response given prior to receiving training. • Post-Training: Response immediately after receiving training. • Post-Drive: Response after receiving training and driving the research vehicle.

Dependent Measures

ADAS Knowledge

Participants filled out multiple-selection knowledge questionnaires after completing their assigned training protocol and after driving the vehicle (post-training and post-drive). Participant responses to questions were marked as correct or incorrect; no partial credit was given. Questions covered three knowledge areas: operational design domain, system limitations, and system components.

Eye-glance Behavior

The average duration of glances away from the forward roadway (mean glance duration) was used as a behavior metric for environmental monitoring. Trained data reductionists manually coded participants' glances for each frame of the specified secondary task events and predetermined baseline and transition scenarios. On-road glance locations consisted of glances to the forward roadway.

Attitude toward ADAS

The trust scale used in this study was the six-item trust scale that was used by Vasquez et al. (2015). Responses to statements used a 7-point Likert-type scale with options ranging from “1” (strongly disagree) to “7” (strongly agree).

Results

A variety of analyses were employed to assess the effects of training type on driver knowledge, eye-glance behavior, and attitudes toward ADAS. For all analyses, statistical significance was evaluated at $\alpha = 0.05$.

ADAS Knowledge

Logistic regression was used to estimate the odds ratios (ORs) of a correct response by each main effect: age (Younger, Mature), training protocol (Conventional, Multimedia), and administration period (Post-training, Post-drive).

Operational Design Domain

Drivers in the mature age group were 2.89 times as likely to correctly identify when it would be appropriate to use ACC compared to drivers in the younger age group (OR: 2.89, CI [1.058, 7.915]). Drivers in the mature age group were 3.35 times as likely to correctly identify when it would be appropriate to use LKAS compared to drivers in the younger age group (OR: 3.35, CI [1.194, 9.392]).

System Limitations

For ACC, only four participants post-training and two participants post-drive were able to identify all situations where ACC may not work as expected. Similarly, for lane keeping, participants were unable to identify all situations where the system may not work as expected. Only one driver in both the post-training and post-drive questionnaires responded correctly.

System Components

For ACC, no main effects were significant. Approximately 80% of subjects were able to correctly identify the forward-looking camera and radar as essential components of the ACC system after training (76% overall). When asked about the LKAS system, there was a significant difference in the training effect. Participants who received multimedia training were more likely to report all sensors required for system function as specified by the training correctly nearly three times as often as those who received conventional training (OR=2.97, CI [1.079, 8.225]).

Eye-glance Behavior

A linear mixed model analysis and Tukey post hoc adjustments were used to investigate operator behavior under secondary task conditions and during transition epochs.

Eye-glance during Secondary Tasks

Epochs in which participants were marked as attempting the secondary task when prompted were included in this analysis. The effects of age (Younger, Mature) and training (Conventional, Multimedia) were examined as between-subjects factors and automation (On, Off), and secondary task (Task, No Task) as a within-subjects factors.

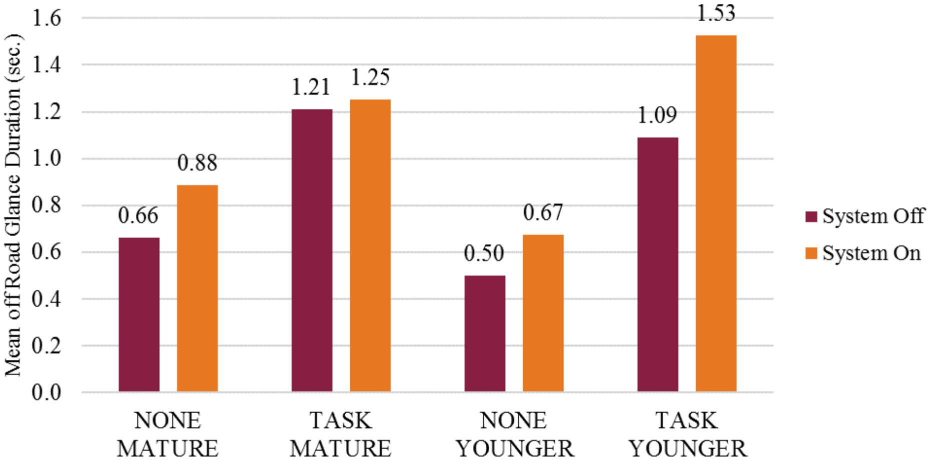

Figure 5. The interaction between age, automation, and secondary task had a significant effect on mean off-road glance duration. Younger participants' MGOR was approximately a half second longer during secondary tasks when systems were active compared to when systems were inactive.

The three-way interaction between age, automation, and secondary task had a significant effect on mean off-road glance duration, $F(1,336) = 9.28$, $p = 0.0025$ (Figure 5). Mature drivers showed no difference in mean glance duration when completing secondary tasks regardless of whether or not the vehicle automation was active ($M = 1.25$ s, $SD = 0.72$) or inactive ($M = 1.21$ s, $SD = 0.47$). However, for younger participants mean glance off roadway (MGOR) was approximately a half second longer during secondary tasks when systems were active ($M = 1.53$ s, $SD = 0.87$) compared to when systems were inactive ($M = 1.09$ s, $SD = 0.42$).

Eye-glance during Transitions

Eye-glance analysis during transitions was performed on the downhill segments of the first and last two laps on the Smart Road. During transitions, no secondary tasks were performed and the confederate lead vehicle drove at a constant speed in front of the subject vehicle. All transition epochs were approximately 30 seconds long ($M = 30.53$, $SD = 1.02$). The independent factors used to assess eye-glance behavior during transitions were age (Younger, Mature), training protocol (Conventional, Multimedia), automation (On, Off), and exposure period (Early, Late). There were age-related effects on mean glance duration for transition events, $F(1, 36) = 9.91$, $p = 0.0033$. Mature drivers had mean off-road glances that were longer ($M = 0.76$ s, $SD = 0.31$) than those of younger drivers ($M = 0.59$ s, $SD = 0.25$). Automation state had a significant effect on mean glance duration during transitions, $F(1, 111) = 14.22$, $p = 0.0003$. When the ADAS was actively controlling the vehicle, mean glance duration was longer ($M = 0.74$ s, $SD = 0.29$) than when ADAS systems were inactive ($M = 0.6$ s, $SD = 0.28$). The interaction of automation and exposure period had a significant effect on mean glance duration, $F(1,111) = 13.13$, $p = 0.0004$. The mean off-road glance duration when vehicle automation was off and the exposure period was early was significantly different from all other factor levels (Figure 6).

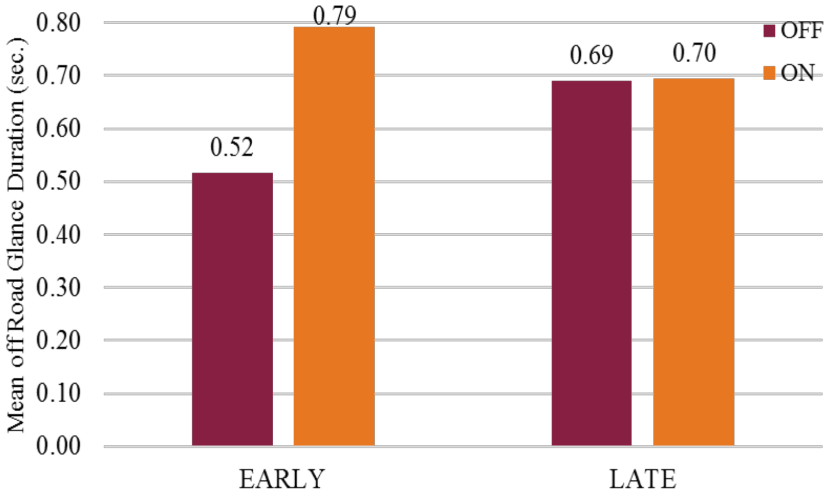

Figure 6. The mean off-road glance duration when vehicle automation was off and the exposure period was early was significantly different from all other factor levels.

Attitude toward ADAS

A linear mixed model analysis and Tukey post hoc adjustments were used to investigate participant trust scores. The factors used to assess participant trust were age (Younger, Mature), training protocol (Conventional, Multimedia), and administration period (Pre-training, Post-training, Post-drive).

Administration period had a significant effect on participants' perceived familiarity with vehicle automation, $F(2, 72) = 31.76$, $p < 0.0001$. Participants were more inclined to agree with the statement, "I am familiar with vehicle automation," after driving the vehicle ($M = 4.95$, $SD=1.01$) compared to both pre-training ($M = 3.43$, $SD = 1.58$) and post-training ($M = 3.48$, $SD = 1.36$).

The interaction between participant age and time (Figure 7) also had a significant effect on perceived familiarity with vehicle automation, $F(2, 72) = 11.80$, $p < 0.0001$. Mature participants had higher agreement with the statement, "I am familiar with vehicle automation," before receiving training ($M = 4.2$, $SD = 1.15$) compared to younger participants ($M = 2.65$, $SD = 1.6$). After receiving training, there was no difference in the responses between the two age groups. Neither group was particularly confident or unconfident ($M_{\mathrm{Y}} = 3.65$, $SD_{\mathrm{Y}} = 1.14$; $M_{\mathrm{M}} = 3.3$, $SD_{\mathrm{M}} = 1.56$). After driving the vehicle, participants' average response increased again, there was no difference between the age groups for the post-drive response, and their scores were significantly higher than post-training response ($M_{\mathrm{Y}} = 5.05$, $SD_{\mathrm{Y}} = 1.23$; $M_{\mathrm{M}} = 4.85$, $SD_{\mathrm{M}} = 0.75$).

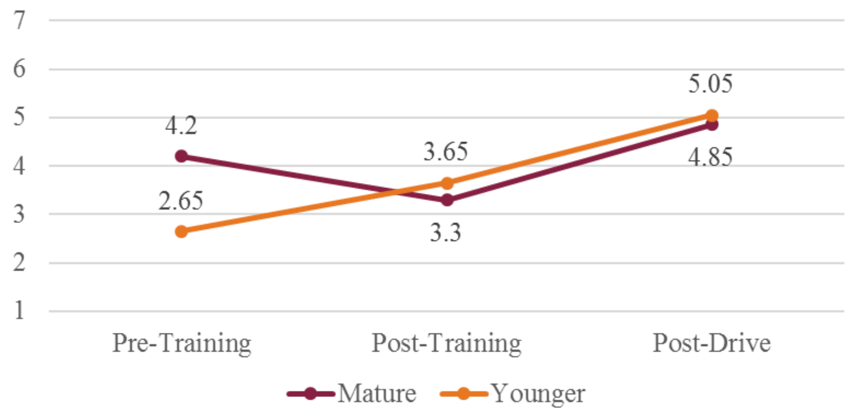

Figure 7. Participants' perceived familiarity with vehicle automation changes with experience.

Discussion

In this study, we examined if the training mode would have an influence on driver knowledge of vehicle automation, behavior during system use, and attitudes toward the ADAS systems. The results of this study demonstrate that:

- Training mode elicits limited differences in knowledge scores and no difference in driver behaviors or attitudes.
- Behaviors and attitudes were influenced by time and experience with the driving automation system while knowledge of the vehicle systems remained unchanged.

These findings highlight the deficiencies of current training materials. Current training content is not sufficient to teach operators how systems work, particularly when it comes to system limitations. Drivers need to be better educated about the capabilities and limitations of ADAS. Brief experience with the system after training does not sufficiently alter misconceptions about the boundaries of system operational design domain. Drivers may become more aware of system limitations with prolonged exposure; however, previous studies have shown that safety critical misunderstandings of system limitations persist over time (Kyriakidis, et al., 2017; Larsson, 2012; Llaneras, 2006).

Operator behavior during system activation indicates a willingness to disengage from the task of monitoring the roadway during periods of ADAS driving. Our findings are consistent with previous research indicating that drivers are prone to becoming disengaged during ADAS driving conditions, which may lead to poor performance when driver takeover is required (Banks, Eriksson, O 'donoghue, & Stanton, 2017; Merat, Jamson, Lai, & Carsten, 2012; Stanton, Young, & McCaulder, 1997). This is particularly worrisome given this study's findings of increased mean off-road glance duration for younger drivers when ADAS is active during secondary tasks.

Furthermore, participants' reported familiarity peaked after they gained experience with vehicle automation. Llaneras (2006) found that driver trust and reliance on in-vehicle systems tends to increase over time and is tied to system use. It is critical for operator trust to be calibrated according to the capabilities of the technology to avoid misuse of automation (Lee & See, 2004). User expectations of vehicle automation limitations and operator predilections to secondary task engagement need to be calibrated through clear and engaging training that is distributed over time, not as a mass protocol. This could occur through continuous driver monitoring and providing the operator with periodic performance feedback.

Further research on driver interaction with vehicle automation over time (short term and long term) to determine how driver proficiency changes with system interaction as a result of unstructured self-guided learning needs to be considered. In advance of developing new training materials, naturalistic or live road data should be mined to identify prevalent operator missteps and misconceptions about ADAS that may not have been anticipated by system designers or vehicle manufacturers and that may not be covered in current training materials. Finally, the development and assessment of training protocols that aim to educate drivers about operator-based errors in addition to machine-centered failures will lead to a training program that is holistic and encompasses the strengths and occasional deficiencies of both human and machine.

It is important to note that these findings do not identify whether lack of differences in training were due to the training material (i.e., what materials were used to train drivers), the delivery methods (i.e., how drivers were trained), or both. Subsequent research efforts should consider investigating these issues as the results can directly inform the development and delivery of driver training for ADAS content.

Overall Discussion

These results corroborate previous findings that suggest that any type of ADAS training prior to driving will improve trust and performance compared to no training at all. However, this study design did not find knowledge, trust, or performance differences based upon the type of training participants received. Future research needs to be conducted to further assess this result as the training paradigms in this study primarily replicated the same information for both training modes (the simulator study used demonstration and video-based training, whereas the test track study used multimedia and reading a manual). Additionally, each type of training positively impacted drivers' attention allocation in that drivers with no training had a tendency to look at the ADAS displays. While all participants in the test track study received some form of training, it was observed that drivers did look away from the forward roadway during non-secondary task periods and many of those glances were toward displays.

There were some measurable differences in driving performance with ADAS between males and females as well as between younger and older drivers. These differences suggest that multiple types of training may be required to reach different driver demographics. This also suggests that all stakeholders should take part in potential solutions and that training is an issue that cannot fall on only one stakeholder to solve.

Training with the addition of experience appears to impact drivers' self-reported understanding of ADAS and their trust in ADAS. This result strongly suggests not only the importance of training but also the importance of solid human factors design principles when designing ADAS systems and human-machine interfaces. The promises of ADAS vehicle technology will not be realized unless human-centered design is implemented along with efficient and useful training.

ADAS Training Guidelines

Results from the TTI and VTTI studies were used as the basis for the development of training guidelines for ADAS. The guidelines were distributed to the ADTSEA and the Driving Schools Association of the America. It is recommended that drivers of vehicles with ADAS be trained on the following items:

- Purpose of using ADAS systems (risks and benefits)
- Understanding levels of automation (capabilities and limitations)
- Transition between ADAS and manual mode and handling critical situations (system malfunctions)
- Familiarity with system components and placement (sensor, radar, camera, etc.)
- Understanding limitations of driver assistant systems (ACC, LKAS, AEB, etc.)

Training protocols should address:

- The need for drivers to focus their attention on the roadway at all times but particularly during ADAS use.
- Potential differences between men and women in terms of attention allocation and mental effort when using ADAS.

It is recommended that training programs be designed and implemented using a variety of techniques, cover the requisite material, and be broadly available from many different stakeholders for voluntary use by drivers.

Additional Products

The Education and Workforce Development (EWD) and Technology Transfer (T2) products created as part of this project can be downloaded from the Safe-D website here. The final project dataset is located on the Safe-D Dataverse, as described below.

Education and Workforce Development Products

The Education and Workforce Development (EWD) Plan for this project included several components, each of which are described below.

1. Graduate Students – A total of three graduate students were hired as members of the research team. A graduate student in the Department of Civil, Construction, and Environmental Engineering at San Diego State University supported the identification of

driver knowledge and skills. He leveraged his experience to gain full-time employment within the civil engineering field. Two graduate students directly supported study design, data collection, and data analysis in the simulation and test track studies conducted at TTI and VTTI. The TTI graduate student was able to use this experience to gain full-time employment in psychophysiological data collection in Michigan while the VTTI student continues here graduate work.

2. Teaching Module – The study objectives, methods, data collection procedure, and analysis were used to develop a teaching module on driver training and behavior modeling. The preliminary version of the module was taught in the "CIVE 781 Seminar in Transportation" course at the SDSU Department of Civil, Construction, and Environmental Engineering in Spring 2018. The full module will be added to the CIVE 781 curriculum in the next offering of the course in Spring 2019. This module includes a main component (PowerPoint with notes), Class Activities (Word documents), and an End of Class quiz (Word document).

3. Driver Training Guidelines for Advanced Driver-Assistance Systems - Driver training guidelines were developed from the results of the identification of necessary knowledge and skills for advanced driver assistance systems, the simulation and instrumented vehicle studies, and from discussion with key stakeholders. The guidelines could be used by advanced driver assistance system trainers and training protocol developers to optimize driving safety.

Technology Transfer Products

The Technology Transfer (T2) Plan for this project included four components. The technology transfer products are summarized below and are available on the project page of the Safe-D website.

1. Guidelines Dissemination – The research team disseminated the Driver Training Guidelines for Advanced Driver-Assistance Systems to the primary driver training organizations in the United States including AAA, American Driver and Traffic Safety Education Association, the Driving School Association of the Americas, and to major automotive manufacturers.

2. Partnerships – The research team leveraged project activities to attract partnerships to facilitate further research efforts by TTI, VTTI, and SDSU. The research team developed key partnerships through personal contact with manufacturer research staff and driver training organizations that included Toyota Center for Collaborative Safety Research, the American Driver and Traffic Safety Education Association, and the Driver School Association of the Americas. In addition, we received enquiries from driver trainers in Germany, United Kingdom, and Saudi Arabia.

3. Publications – The project results have been accepted for conference paper publication and presentation at the 2019 Human Factors and Ergonomic Society Meeting.

4. Webinar – In lieu of a webinar, the research team met directly with key stakeholders to relay the project purpose, project activities, study results, guidelines, and practical application of the results which was consistent with the original goals of the webinar. In addition, we discussed future research avenues, reviewed methods to apply the results to products in development and, discussed the application of the results to current driver training protocols. The research team conducted these meetings with the following key stakeholders.

   - American Automobile Association
   - American Driver Trainers and Safety Educations Association
   - Driving Schools Association of America
   - Driver Training and Qualifications (Dubai Government)
   - Gatik (USA)
   - Rapp Trans AG (Berlin)
   - TeamOne (China)

Data Products

The final data products for this project consist of two datasets that were generated from the traditional and the vehicle-based training protocol evaluations.

1. Final Data Set – Traditional Training Protocol Evaluation – This dataset contains all objective and subjective data from the TTI-based driving simulator study (https://doi.org/10.15787/VTT1/T5RFJ3).
   - Task 3 – Design Spec 8-13-18.pdf (description of apparatus and experimental methods).
   - UTC Project 001-004 Driver Training Final Dataset_11-20.tab (aggregated questionnaire and driving simulator data).
2. Final Data Set – Vehicle-Based Training Protocol Evaluation Data – This dataset contains all objective and subjective data from the VTTI-test track study (https://doi.org/10.15787/H6VV-TS37). Descriptions of the data files can be found in the data dictionary file (data_Dictionary.docx).
   - data_dictionary.docx
   - Familiarity_Dataverse.tab (responses to multiple selections knowledge questionnaire in Appendix H of this report).
   - HeadUnitSpeed_Dataverse.tab (vehicle speed from the head unit).
   - Knowledge_Dataverse.tab (responses to question 5 from the trust questionnaire, “I am familiar with vehicle automation.”).
   - MGOR_V5_FC_Dataverse.tab (mean glance durations and event information for the study).

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Appendices

Appendix A. TTI Simulator Study Background Survey

1. Age: ________
2. Sex:
    - ☐ M
    - ☐ F
3. Marital Status:
    - ☐ Single
    - ☐ Married
    - ☐ Divorced
    - ☐ Widowed
4. Racial Background:
    - ☐ African-American
    - ☐ Asian or Pacific Islander
    - ☐ Hispanic
    - ☐ White:
    - ☐ Other: __________________
5. What is you highest education level completed?
    - ☐ High school/ Vocational School
    - ☐ Associates Degree
    - ☐ Bachelor
    - ☐ Masters
    - ☐ PhD
6. Please state your occupation: ____
7. What type of are do you live in:
    - ☐ City
    - ☐ Suburban
    - ☐ Rural
8. Make and model of vehicle normally driven: __________________________________
9. About how often do you drive nowadays?
    - ☐ Never
    - ☐ Hardly ever
    - ☐ Sometimes
    - ☐ Most days
    - ☐ Everyday

10. During the last three years, how many minor road accidents have you been involved in? (Minor accident is one in which no-one required medical treatment, AND cost of damage to vehicles and property were less than $1,000)

    Number of minor accidents _______ (if none, write 0)

11. During the last three years, how many major road accidents have you been involved in? (Major accident is one in which EITHER someone required medical treatment, OR cost of damage to vehicles and property were greater than $1,000, or both)

    Number of major accidents _______ (if none, write 0)

12. Have you had any caffeinated drinks to day and if so, how many?
    a. Yes; Number: ______
    b. No
13. Have you had any nicotine products today and if so, how many?
    a. Yes; Number: ______
    b. No
14. How often do you play driving-based computer or video games per week?
    a. 0 hours
    b. 0-1 hours
    c. 2-9 hours
    d. More than 10 hours

Appendix B. TTI Knowledge Assessment of Automated Vehicle Technologies

Please answer the questions below to the best of your ability. If you do not know the answer you can type "I don't know."

1. Define what vehicle automation means to you.

2. What is partial vehicle automation?

3. What does LKAS stand for?

4. What does LKAS do? What is purpose of this technology?

5. When can you use LKAS? (Select all that apply)

- When one lane marking is present
- When both lane markings are present
- Travelling at a speed below 25mph
- Travelling at a speed above 25mph
- Travelling at a speed below 90mph
- Travelling at a speed above 90mph
- When ACC is being used
- When there is a vehicle in front of your vehicle
- When there is no vehicle in front of your vehicle
- I don't know

6. When can you NOT use LKAS? (Select all that apply)

- When one lane marking is present
- When both lane markings are present
- Travelling at a speed below 25mph
- Travelling at a speed above 25mph
- Travelling at a speed below 90mph
- Travelling at a speed above 90mph
- When ACC is being used
- When there is a vehicle in front of your vehicle
- When there is no vehicle in front of your vehicle
- I don't know

7. What does ACC stand for?

8. What does ACC do? What is purpose of this technology?

9. When can you use ACC? (Select all that apply)

- When one lane marking is present
- When both lane markings are present
- Travelling at a speed below 25mph
- Travelling at a speed above 25mph
- Travelling at a speed below 90mph
- Travelling at a speed above 90mph
- When LKAS is being used
- When there is a vehicle in front of your vehicle
- When there is no vehicle in front of your vehicle
- I don't know

10. When can you NOT use ACC? (Select all that apply)

- When one lane marking is present
- When both lane markings are present
- Travelling at a speed below 25mph
- Travelling at a speed above 25mph
- Travelling at a speed below 90mph
- Travelling at a speed above 90mph
- When LKAS is being used
- When there is a vehicle in front of your vehicle
- When there is no vehicle in front of your vehicle
- I don't know

Please answer the questions below to the best of your ability. If you do not know the answer you can type "I don't know."

1. Define what vehicle automation means to you.

2. What is partial vehicle automation?

3. What does LKAS stand for?

4. What does LKAS do? What is purpose of this technology?

5. When can you use LKAS? (Select all that apply)

- When one lane marking is present
- When both lane markings are present
- Travelling at a speed below 25mph
- Travelling at a speed above 25mph
- Travelling at a speed below 90mph
- Travelling at a speed above 90mph
- When ACC is being used
- When there is a vehicle in front of your vehicle
- When there is no vehicle in front of your vehicle
- I don't know

6. When can you NOT use LKAS? (Select all that apply)

- When one lane marking is present
- When both lane markings are present
- Travelling at a speed below 25mph
- Travelling at a speed above 25mph
- Travelling at a speed below 90mph
- Travelling at a speed above 90mph
- When ACC is being used
- When there is a vehicle in front of your vehicle
- When there is no vehicle in front of your vehicle
- I don't know

7. What does ACC stand for?

8. What does ACC do? What is purpose of this technology?

9. When can you use ACC? (Select all that apply)

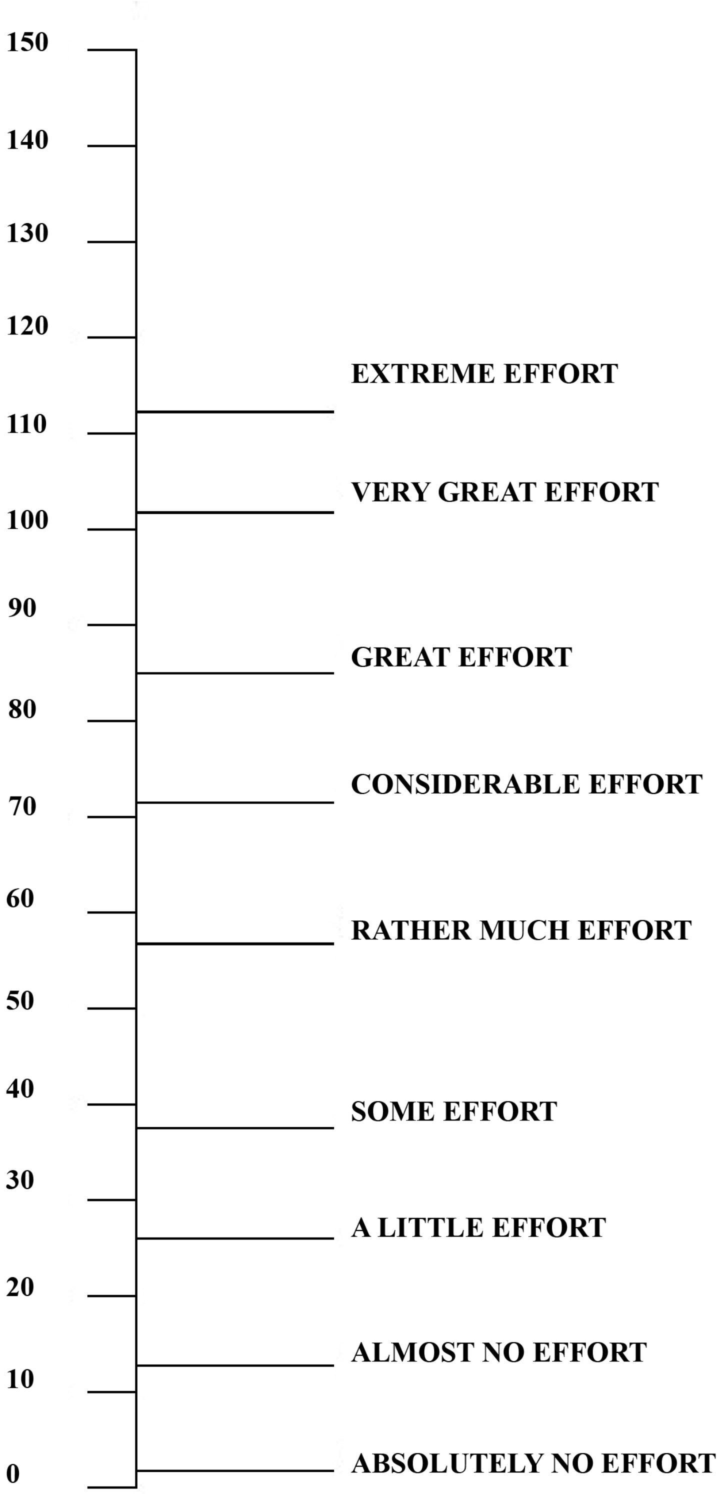
- When one lane marking is present
- When both lane markings are present
- Travelling at a speed below 25mph
- Travelling at a speed above 25mph
- Travelling at a speed below 90mph
- Travelling at a speed above 90mph
- When LKAS is being used
- When there is a vehicle in front of your vehicle
- When there is no vehicle in front of your vehicle
- I don't know

10. When can you NOT use ACC? (Select all that apply)

- When one lane marking is present
- When both lane markings are present
- Travelling at a speed below 25mph
- Travelling at a speed above 25mph
- Travelling at a speed below 90mph
- Travelling at a speed above 90mph
- When LKAS is being used
- When there is a vehicle in front of your vehicle
- When there is no vehicle in front of your vehicle
- I don't know

Appendix C. TTI Ratings Scale of Mental Effort

Please indicate, by making the vertical axis below, how much effort it took for you to complete the task you've just finished.



Appendix D. Vehicle-Based Training Protocols

Figure 8. Participants received one of two training protocols: a copy of the ADAS portion of the operator's manual in electronic form (left) or an interactive multimedia module (right).

Appendix E. VTTI DAS and Camera Set Up

The DAS was located out of participant view in an unobtrusive location. DAS hardware is wired to interface with the vehicle through Controller Area Network (CAN) protocols accessed by the Onboard Diagnostic II (OBD II) port and collects and records data streams asynchronously, allowing each sensor to operate at its optimal collection rate. The DAS records at millisecond precision at the rate native to each sensor or CAN variable.

Five camera views were collected while participants were in the research vehicle. The camera views included a view of the forward roadway, over-the-shoulder, the participant's face, the foot well/pedal, and the instrument panel. Data collected from the camera views were used in subsequent eye glance analyses and participant driving behavior analyses.

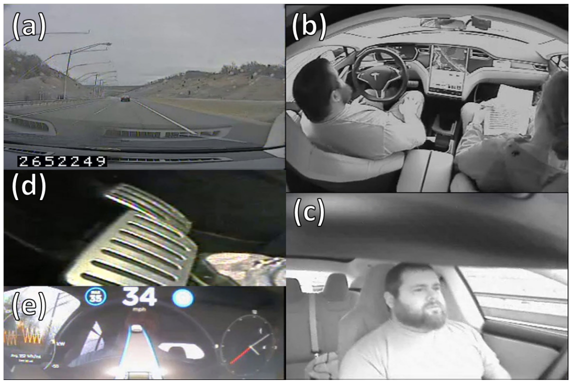


Figure 9. Camera views used while participants were in the research vehicle included: a) forward roadway, b) over-the-shoulder, c) participant face, d) foot well/pedal, e) instrument panel

Appendix F. Vehicle-Based Training Topics

Tesla Content Header	Sub-Header	Description
Driver Assistance Features	About Driver Assistance Features	Lists types of features
	Driver Assistance Components	Lists components used to actively monitor the roadway environment
	Limitations	Factors that can influence the performance of driver assistance components.
Traffic-Aware Cruise Control	Overview	The functional purpose of traffic aware cruise control and the operational design domain.
	Operating TACC	Instructions for operation (activation
	Adjust Following Distance	Instructions for adjusting the following distance
	Changing Set Speed	Instructions for adjusting the set speed
	Canceling/Resuming	Instructions for canceling/resuming adaptive cruise control
	Summary of Cruise Indicators	Summary of icons on the instrument panel
	Situations where TACC may not be available	Situations where Traffic-Aware Cruise Control may not operate as intended.
	Warnings and Limitations	
Autosteer	Overview	The functional purpose of Autosteer
	Operating Autosteer	How to activate Autosteer and change settings
	Restricted Speed	Functional limitation based on road environment
	Hold the Steering Wheel	Warning/alert
	Take Over Immediately	Warning/alert
	Canceling Autosteer	How to cancel Autosteer
	Warnings and Limitations	Situations where Autosteer may not operate as intended.

Content Excluded

Specific automated features were excluded from the training material due to system or test track constraints. The sections that were removed are listed below with the justification for their removal:

Cruising at the speed limit (Autosteer): The Smart Road is a controlled access facility and therefore does not have a uniformly applied speed limit. After the 2016 fatal Tesla crash in Williston, FL software updates in version 8.1 limit the speed top of Autosteer to 45 mph on roads where the speed limit cannot be detected.

Overtake acceleration (Autosteer): Participants will not be overtaking other vehicles in this study. This feature is outside of the performance specifications of a standard adaptive cruise control design and will not be covered in either training protocol.

Additional automated features available as part of the Autopilot 8.1 software package such as automatic lane change were disabled and not covered during the training protocol to prevent unintentional lane changes during the experimental session.

Automatic emergency braking and forward collision warning were not covered during the training session, however, the research team left these systems active as a safety measure.

Appendix G. VTTI Trust Questionnaire

1. I would rely on vehicle automation to function properly while I am doing something else.

1	**2**	**3**	**4**	**5**	**6**	**7**
Strongly Disagree			No Opinion			Strongly Agree

2. I would rely on vehicle automation to provide alerts when needed.

1	**2**	**3**	**4**	**5**	**6**	**7**
Strongly Disagree			No Opinion			Strongly Agree

3. Vehicle automation gives false alerts.

1	**2**	**3**	**4**	**5**	**6**	**7**
Strongly Disagree			No Opinion			Strongly Agree

4. Vehicle automations is dependable.

1	**2**	**3**	**4**	**5**	**6**	**7**
Strongly Disagree			No Opinion			Strongly Agree

5. I am familiar with vehicle automation.

1	**2**	**3**	**4**	**5**	**6**	**7**
Strongly Disagree			No Opinion			Strongly Agree

6. I trust vehicle automation.

1	**2**	**3**	**4**	**5**	**6**	**7**
Strongly Disagree			No Opinion			Strongly Agree

Administered: Pre-Training, Post-Training, and Post-Drive

Appendix H. VTTI Knowledge Questionnaire

1. Please select all roadway environments where it would be appropriate to use Adaptive Cruise Control (ACC, TACC).
   - ☐ Divided highways and roadways
   - ☐ Carpool/HOV Lanes
   - ☐ Roundabouts and traffic circles
   - ☐ Toll roads
   - ☐ Gravel Roads
   - ☐ Parking lots
   - ☐ Local roads and streets
   - ☐ Residential streets

2. Please select all situations where it would be appropriate to use Lane Keeping Assist (LKA, Autosteer).
   - ☐ Divided highways and roadways
   - ☐ Carpool/HOV Lanes
   - ☐ Roundabouts and traffic circles
   - ☐ Toll roads
   - ☐ Gravel Roads
   - ☐ Parking lots
   - ☐ Local roads and streets
   - ☐ Residential streets

3. Please select all situations from the following where Adaptive Cruise Control (ACC, TACC) may not work as expected.
   - ☐ Extremely hot or cold temperatures
   - ☐ Clear sunny days
   - ☐ Dusk and dawn
   - ☐ Heavy rain or snow
   - ☐ Poor tire traction
   - ☐ Sensors are obstructed
   - ☐ Windy roads
   - ☐ Straight roads
   - ☐ Roads with poor lane markings
   - ☐ Roads with no lane markings
   - ☐ Roads with clearly visible lane markings
   - ☐ Work Zones
   - ☐ Toll plazas

4. Please select all situations from the following where Lane Keep Assist (LKA, Autosteer) may not work as expected.

☐ Extremely hot or cold temperatures
☐ Clear sunny days
☐ Dusk and dawn
☐ Heavy rain or snow
☐ Poor tire traction
☐ Sensors are obstructed
☐ Windy roads
☐ Straight roads
☐ Roads with poor lane markings
☐ Roads with no lane markings
☐ Roads with clearly visible lane markings
☐ Work Zones
☐ Toll plazas

5. What sensor(s) is/are used by Adaptive Cruise Control (ACC, TACC)? Select all that apply.

☐ Forward Looking Camera
☐ Forward Looking Radar
☐ Ultra Sonic Sensors
☐ GPS
☐ Rearview camera

6. What sensor(s) is/are used by Lane Keeping Assist (LKA, Autosteer)? Select all that apply.

☐ Forward Looking Camera
☐ Forward Looking Radar
☐ Ultra Sonic Sensors
☐ GPS
☐ Rearview camera

Administered: Post-Training and Post-Drive