Examining Senior Drivers Adaptation to Mixed Level Automated Vehicles: A Naturalistic Study

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Abstract

Advances in the development of advanced vehicle technologies (AVTs), such as blind spot alerts, lane keep assist, lane alert, and adaptive cruise control, can benefit senior drivers by reducing exposure to hazards and compensating for diminished cognitive abilities sometimes seen in this population. However, the degree to which such benefits can be realized in this vulnerable population depends largely on the degree to which senior drivers will accept, adopt, and adapt to these features. This study investigated how 18 seniors, aged 70–79, accepted, trusted, and used mixed-function AVTs when provided an AVT-equipped vehicle to drive as they desired for a 6-week period. Researchers assessed attitudes and the effect of exposure via before-and-after exposure surveys, brief weekly check-in surveys during the driving exposure period, and focus group sessions conducted after the conclusion of the driving exposure period. Analyses revealed that seniors prefer technologies that inform, such as blind spot alert, over those that assert independent control over the vehicle, such as lane keep assist. Increased confidence in and willingness to use AVTs correlated positively with exposure, with adequate time for orientation and appropriate user documentation emerging as key factors determining senior drivers' acceptance.

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Introduction

The aging of society is one of the most significant social transformations and challenges we face in this century, impacting housing, health care, and transportation. The population has aged substantially in recent years, and this trend is expected to accelerate. The number of seniors aged 65 and over is predicted to reach 94.7 million in 2060, constituting 23.5% of the U.S. population [1]. There are currently approximately 42 million licensed drivers aged 65 and over, representing around 18% of drivers [2].

The expected increase in the number and proportion of senior drivers raises concerns about potential negative impacts on traffic safety. Aging can bring cognitive and/or physical impairments that affect driving ability. Vehicles equipped with advanced vehicle systems (AVTs) have the potential to assist senior drivers by compensating for age-related declines [3] [4]. However, some features may prove less beneficial than anticipated, in part because drivers don't use them [5]. Compared to other age groups, seniors seem more reluctant [3] and sometimes even resistant to adopting innovative technologies [6]. However, with adequate exposure and training, seniors have also shown the propensity to use advanced features at the same rate as younger drivers [7].

Background

Literature Review

Senior Drivers and Age-Related Function Declines

Aging is often accompanied by declines in one or more physical, visual and/or cognitive abilities that may negatively influence driving safety [8]–[11]. Driving research has investigated the safety implications of various age-related declines [12] and improvements potentially afforded by various AVTs [13] [14]. Table 1 outlines the likely correlation between driving problems due to age-related declines and safety solutions offered by AVTs.

Table 1. AVTs Mitigating Driving Problems Associated with Age-Related Decline Based on [12] [13] [14]

Domain	Age-related Decline	Associated Potential Driving Problems	Potential Assistive AVTs
Visual/Perception	Anatomical changes (e.g., presbyopia, neural changes) that negatively affect visual perception: e.g., [15], declines in saccadic: e.g., [16] and pursuit eye movement ability [17]; and maximum extent of gaze with head movement [18]–[20].	Difficulty seeing objects nearby, such as the dashboard, for seniors with presbyopia.	In-vehicle signs (e.g., speed limits) and warnings, night vision enhancement.
Visual/Perception	Slower rate of dark adaptation [21]–[23].	Increased risk driving at night.	In-vehicle signs (e.g., speed limits) and warnings, night vision enhancement.
Visual/Perception	Decreased sensitivity to light at night: e.g., [22], [24].	Increased risk driving at night.	In-vehicle signs (e.g., speed limits) and warnings, night vision enhancement.
Visual/Perception	Increased glare recovery time [25] and greater debilitating effects after being glared [26].	Increased risk driving at night.	In-vehicle signs (e.g., speed limits) and warnings, night vision enhancement.
Visual/Perception	Declines in static [27] and dynamic visual acuity: e.g., [28].	Increased difficulty reading road signs at a distance; increased difficulty reading signs during driving.	In-vehicle signs (e.g., speed limits) and warnings, night vision enhancement.
Visual/Perception	Declines in contrast sensitivity for high frequency gratings [29], [30].	Difficulty reading road signs or seeing objects through the windshield.	In-vehicle signs (e.g., speed limits) and warnings, night vision enhancement.
Visual/Perception	Shrinkage in the size of Useful field of view (UFOV): e.g., [31].	Difficulty noticing an object or pedestrian appearing in the peripheral vision.	In-vehicle signs (e.g., speed limits) and warnings, night vision enhancement.
Visual/Perception	Deficient perception of depth (stereopsis): e.g., [33]–[35].	Reduced ability to estimate the distance to the lead vehicle or following distance in traffic.	Forward collision waring, adaptive cruise control.
Visual/Perception	Reduced sensitivity of perceiving motion: e.g., [36] [37].	Reduced ability to estimate the distance to the lead vehicle or following distance in traffic.	Forward collision waring, adaptive cruise control.

Domain	Age-related Decline	Associated Potential Driving Problems	Potential Assistive AVTs
Cognitive	Declined divided attention [38]	Difficulty driving in complex scenarios, such as intersections or congested traffic.	Forward collision warning, adaptive cruise control, in-vehicle signs and warnings, forward collision warning, in –vehicle signs and warnings.
Cognitive	Declined selective attention: e.g., [39]	Difficulty driving in complex scenarios, such as intersections or congested traffic.	Forward collision warning, adaptive cruise control, in-vehicle signs and warnings, forward collision warning, in –vehicle signs and warnings.
Cognitive	The duration of short term memory is shorter [40] and short term memory processing times are significantly longer (about 1.5) [41]. Difficulty in transmitting information from long term memory: e.g. [42]; difficulty retrieving information from long term memory: e.g., [43].	Longer time to perceive or react to hazards on the road. Longer time to recall traffic rules or comply with signs.	Navigation assistance/route guidance driver condition monitoring, adaptive cruise control, lane departure warning
Psychomotor	Strength loss.	Difficulty maneuvering the vehicle.	Blind spot alert, rear collision warning, lane departure warning, lane change assist/merge warning system, forward collision warning, adaptive cruise control.
Psychomotor	Increased simple reaction [44] and choice reaction time [45].	Longer time to respond a signal or a hazard.	Blind spot alert, rear collision warning, lane departure warning, lane change assist/merge warning system, forward collision warning, adaptive cruise control.
Psychomotor	Decreased flexibility [42], limited range of motion, and less accuracy in movement [46]–[49].	Difficulty turning head to scan the blind spot.	Blind spot alert, rear collision warning, lane departure warning, lane change assist/merge warning system, forward collision warning, adaptive cruise control.

Large-Scale Survey Studies on Opinions from All Populations

Many researchers have conducted large-scale surveys on views towards AVTs with drivers from all age groups (e.g., [51], [61]–[64]). According to these studies, seniors, relative to younger drivers, are:

- less interested in AVTs [61];
- less willing to spend for such technologies [54]–[56], [58], [59];
- less likely to embrace the concept of driverless cars [62], [64];
- more concerned about riding in self-driving vehicles or highly automated vehicles [54]; [56], [61], [63], [65];
- less inclined to use AVTs [54], [65].

Most senior drivers would like to test drive a self-driving car but are disinclined to purchase one, even at a similar price to a regular car [47]. In addition, age was found to be inversely correlated with perceived usefulness, affordability, social support, lifestyle fit, and conceptual compatibility of self-driving cars [57]. Furthermore, age negatively correlates with technology interest and experience variables [57]. More detailed findings from these large-scale surveys on senior drivers' attitudes toward AVTs are found in Appendix A.

Surveys collecting opinions from general populations tend to lack detail on the reasons why seniors exhibit reluctance to accept AVTs. Further, the absence of experience with or exposure to AVTs for some respondents results in an incomplete picture of how seniors might react when driving vehicles equipped with AVTs. Most participants responded to survey questions based upon their imaginations or information obtained from media rather than actual use.

Senior Drivers Studies

A few studies have focused on seniors' perceptions of and experiences with AVTs. These primarily relied on focus groups or interviews to explore senior drivers' attitudes towards AVTs and their perception of safety, reliability, and comfort levels.

Researchers in Australia surveyed 1,070 senior drivers online and conducted eight in-depth interviews to investigate senior drivers' perceptions and acceptance of AVTs [66]. The study also investigated factors affecting seniors' purchasing decisions, perception of ATVs' safety of and awareness of safety technologies. Generally, senior drivers displayed positive attitudes toward AVTs but lacked awareness of current automated technologies, such as adaptive cruise control (ACC), lane keep assist (LKA), blind spot alert (BSA) and lane alert (LA). When given the opportunity to elaborate on the contribution of AVTs to safety, seniors most commonly mentioned traditional and standard equipment, such as anti-lock brakes and airbags. Researchers also found that senior drivers preferred to rely upon their own personal experience or that of close friends in forming opinions about AVTs [66].

Researchers from the University of Iowa conducted a literature review and focus groups to identify the AVTs perceived by seniors as most beneficial to safety based on two criteria: ability to reduce hazards by compensating for the effects of aging and drivers' acceptance of AVTs

[67]. The study revealed that systems providing alerts only (e.g., BSA) had the highest acceptance rating from seniors. Whereas systems providing control interventions (e.g., LKA) had the lowest acceptance rating. In combined consideration with other criteria from past literature, alert systems were found to benefit senior drivers the most among all assessed systems.

Consistent with these findings, researchers at the Hartford and the MIT AgeLab recruited 302 drivers aged 50–69 to examine mature drivers' willingness to accept AVTs [51]. A video introducing AVTs was played for participants. Participants expressed the greatest willingness to use BSA and back-up cameras, both of which can be categorized as in-vehicle alert or information systems. Participants recognized the safety benefits but remained concerned about over-reliance on the technologies.

In a recent study, 35 senior drivers who owned a vehicle with at least two AVTs were interviewed about their motivation for purchasing the vehicle and asked about their perceptions of AVTs [68]. The study showed that cognizance of age-related decline is not a major motivation for seniors in purchasing vehicles with AVTs. However, senior participants who had used AVTs did value the technologies for improving safety and considered them "convenient devices" that improved their driving experience.

Research Questions

This study centered on the question of how senior drivers adapt to a vehicle with AVTs over a 6-week period driving a test vehicle in a naturalistic setting. Specifically, this research effort was designed to investigate the following questions:

- How do senior drivers' acceptance of AVTs change after extended use?
- How do senior drivers' attitudes change over a period of exposure to a vehicle equipped with AVTs?
- How do senior drivers perceive the safety benefits of AVTs?
- How do senior drivers adapt to and learn to use AVTs?
- How do senior drivers' trust and satisfaction change with accumulated AVT use?
- What do senior drivers like most and like least about AVTs?

Method

Human Subjects Protection

The study protocol and consent form were reviewed and approved by the Virginia Tech Institutional Review Board (IRB #17-1192). During the study period, three modifications to the protocol were submitted and approved. The informed consent form and a description of specific changes associated with each amendment are included in Appendix B and Appendix C.

Sample Design

Eighteen drivers between 70 and 79 years of age were recruited in the Blacksburg, VA area. Participants were assigned to one of three cohorts and provided with one of four vehicle models

to drive for a 6-week period. A demographic breakdown of the study sample by cohort and vehicle assignment is included in Appendix D.

Structuring of Study Experience

Recruitment and Screening

Virginia Tech Transportation Institute's (VTTI's) Recruitment Group handled recruitment and screening of potential participants. The Recruitment Group identified potential participants from VTTI's recruitment database, called prospective participants to conduct eligibility screening according to the eligibility criteria in Appendix E, and scheduled interested and eligible individuals for study intake. The telephone screening was conducted using an eligibility screening script (Appendix F).

Study Intake

Upon arrival at the VTTI research facility, participants were asked to present their driver's licenses and proof of liability insurance as a final eligibility screening. Participants were informed about all aspects of the study and advised that the Commonwealth of Virginia would cover expenses incurred due to vehicle damage. Participants then completed a demographic/driving history questionnaire and a survey collecting their attitudes toward AVTs and underwent a visual field assessment and Clock Drawing test to measure cognitive status. These instruments are included in Appendices G through J.

Training

After study intake, an experimenter introduced the participant to the assigned study vehicle and provided instruction on its advanced features (Appendix K). The training consisted of two sessions: an introductory session, which was performed in the study vehicle while parked, and an on-road test driving session, which was performed under practical driving conditions. While the vehicle was parked, the experimenter first pointed out all components of the data acquisition system (DAS), advising the participant not to block the cameras and sensors while driving and not to disconnect the OBD-II cable, which was tucked under the dashboard. The experimenter then proceeded to introduce the basic vehicle features (e.g., vehicle start procedure, gauges, and windshield wipers) followed by the four advanced features (ACC, LKA, BSA and LA). The participant was given the opportunity to ask questions about the vehicle and its AVTs functions as well as the DAS prior to the test drive portion of the training session. The on-road test driving portion of the training was then conducted in order to train participants in the proper use of AVTs under practical on-road operating conditions. The experimenter first drove the vehicle to show the participant how to activate, deactivate, and properly respond to the AVTs. After demonstrating basic understanding, the participant drove the vehicle. The experimenter was in the passenger seat and instructed the participant to operate each system to ensure that he or she understood the functionality and was able to properly use, interpret, and respond to the AVTs. The on-road sessions occurred on town roads and highways in the Blacksburg area, and was designed to last around 45 minutes. After the test drive training, the participant signed the

training checklist (Appendix L) and the vehicle condition checklist (Appendix M), the latter of which was augmented by photographs of the vehicle.

Naturalistic Driving Experience

Following the intake session, each participant was free to drive the study vehicle as he or she would have driven his or her personal vehicle for a period of 6 weeks. Researchers performed an initial data review after the first week to identify any potential safety issues.

Weekly Phone Surveys

The research team called participants each week to conduct a brief interview (Appendix N). The weekly interviews collected updates about the participants' experience and attitudes towards the AVTs as well as any safety concerns.

Participant Exit Session

Upon return of the study vehicle to the research facility, participants again completed the Opinions on Autonomous Vehicles questionnaire (Appendix H) to measure their attitudes towards the AVTs after 6 weeks of driving the study vehicle.

Focus Group

Participants in each cohort attended a focus group session at VTTI approximately one week after completing the naturalistic driving experience. Researchers conducted three focus group sessions; each included six participants.

The focus groups provided opportunities for participants to share their thoughts and opinions about the AVTs through a series of questions, activities, and discussions on how they felt about the features, how their feelings changed with exposure, what features they liked best and least, and their perspectives on the safety of AVTs. Each session was led by a trained focus group facilitator. Appendix O documents the complete focus group guide, including questions used by the moderator and associated activities. The focus groups, designed to last no more than 90 minutes, were recorded (audio and video) for subsequent transcription and analysis.

AVTs Examined in the Study

This study specifically examined four AVTs: ACC, LKA, BSA and LA, all of which are included on many commercially available vehicles. Table 2 below summarizes the purpose(s) of and driver responsibilities for these four AVTs.

Table 2. General Description of AVTs Examined in the Study

	ACC	BSA	LKA	LA
Purpose	• Maintain the driver pre-set maximum speed if no lead vehicle detected within the safe distance. • Slow down automatically if detects a vehicle ahead, and maintain safe following distance relative to lead vehicle. • Speed up to the set maximum speed after the lead vehicle leaves the lane.	• Deliver information about vehicles located in the driver's blind spot via visual, sound or haptic alerts.	• Maneuver vehicle back into the lane when the system detects an unintended deviation.	• Alert driver to unintended deviations from the traffic lane.
Driver's responsibilities	• Pre-set the maximum speed. • Pre-select the safe distance to the lead vehicle. • Maintain awareness of the driving environment.	• Maintain awareness of the driving environment. • Respond promptly to alerts. • Do not encroach into occupied lane	• Maintain awareness of driving environment.	• Maintain awareness of driving environment. • Respond promptly to alerts. • Signal before changing lane.

Study Vehicles and Instrumentation

The fleet included eight vehicles equipped with four AVTs of interest: ACC, LA, BSA, and LKA. The differences in the four features' settings across the four manufactures are included in Appendix P. All study vehicles were instrumented with DAS equipment that collected video and sensor-based naturalistic driving data continuously and automatically every time the vehicle was driven. DAS details are included in Appendix Q.

Results

Pre- and Post-Experiment Opinions on Autonomous Vehicles

The responses of 18 participants to the Opinions on Autonomous Vehicles questionnaires collected at the intake session were compared to those collected at the end of the study. Paired-t and Wilcoxon signed-rank tests were used for statistical comparisons for normally and non-normally distributed data, respectively. Appendix R lists the descriptive and inferential statistical outcomes for all 18 items in the questionnaire.

The results revealed a significant positive attitude change on the *lane control features* based on comparison of participant responses at the intake session and after a 6-week data collection period based on the t-statistics on items in the questionnaire (Appendix R, questions 1–7):

(1) Participants perceived decrease in false alarms [t(17) = 2.61 , p = 0.02]
(2) Participants felt more familiar with the lane control features [t(17) = 4.25, p < 0.001]
(3) Participants felt safer [t(17) = 2.61, p = 0.02]
(4) Participants felt greater confidence in the lane control features [t(17) = 2.29, p = 0.03]

A similar positive attitude change was evident on the *acceleration and braking features* based on comparison of participant responses at the intake session and after a 6-week data collection period based on the t-statistics on items in the questionnaire (Appendix R, questions 8–16):

(1) Participants perceived decrease in false alarms [t(16) = 3.73, p < 0.01]
(2) Participants felt more familiar with the acceleration and braking features [t(17) = 3.43, p < 0.01]
(3) Participants perceived increased levels of safety [t(17) = 2.11, p = 0.05]
(4) Participants had greater confidence in the acceleration and braking features [t(17) = 2.33, p = 0.03]

Weekly Survey

The 18 participants responded to weekly phone surveys collecting data on usage frequency, factors affecting driving experience, trust, and satisfaction. Figure 1 presents frequency of use of the study vehicle; participants self-reported driving the vehicle 4–5 days each week.

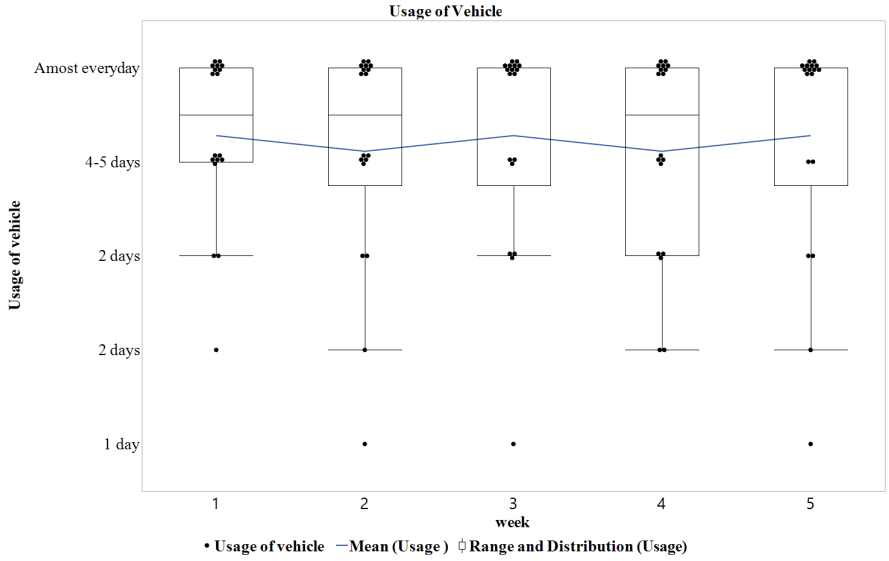

Figure 1. Box plots of study vehicle usage frequency.

Table 3 presents the frequency of use for individual AVT features. Most participants reported driving the study vehicle "almost every time," while the average usage was "4–5 days a week." BSA was the most frequently experienced of the four AVTs in this study, with 73% of participants reporting having experienced this feature "almost every time" they drove the vehicle. Participants reported consistent activation of the LA and LKA features 49% of the time and 44% of the time, respectively. ACC was consistently experienced least frequently, meriting further investigation.

Table 3. Overall Usage Frequency of AVT Features

	BSA	ACC	LA	LKA
Almost every time	73.3%	24.4%	48.9%	43.8%
More than half the time	10.0%	15.6%	8.9%	12.4%
Less than half the time	2.2%	15.6%	11.1%	11.3%
Rarely or never	8.9%	23.3%	11.1%	25.8%
About half the time	5.6%	21.1%	20.0%	6.7%
Total	**100%**	**100%**	**100%**	**100%**

The average ratings of participants' trust in and satisfaction with the four AVTs from each weekly phone survey are listed in Appendix S. Figure 2–Figure 5 illustrate the usage frequency, trust, and satisfaction ratings for four AVTs each week. The average usage frequency for all four features across all participants was between "about half the time" and "more than half the time" they drove the test vehicles. The average trust rating on all four features across all participants was between moderate and high. The average satisfaction rating for all four features across all participants was also between moderate and high. There appeared to be no significant change in trust and satisfaction level according to the repeated measure analysis of variance test (for statistical results see Appendix R).

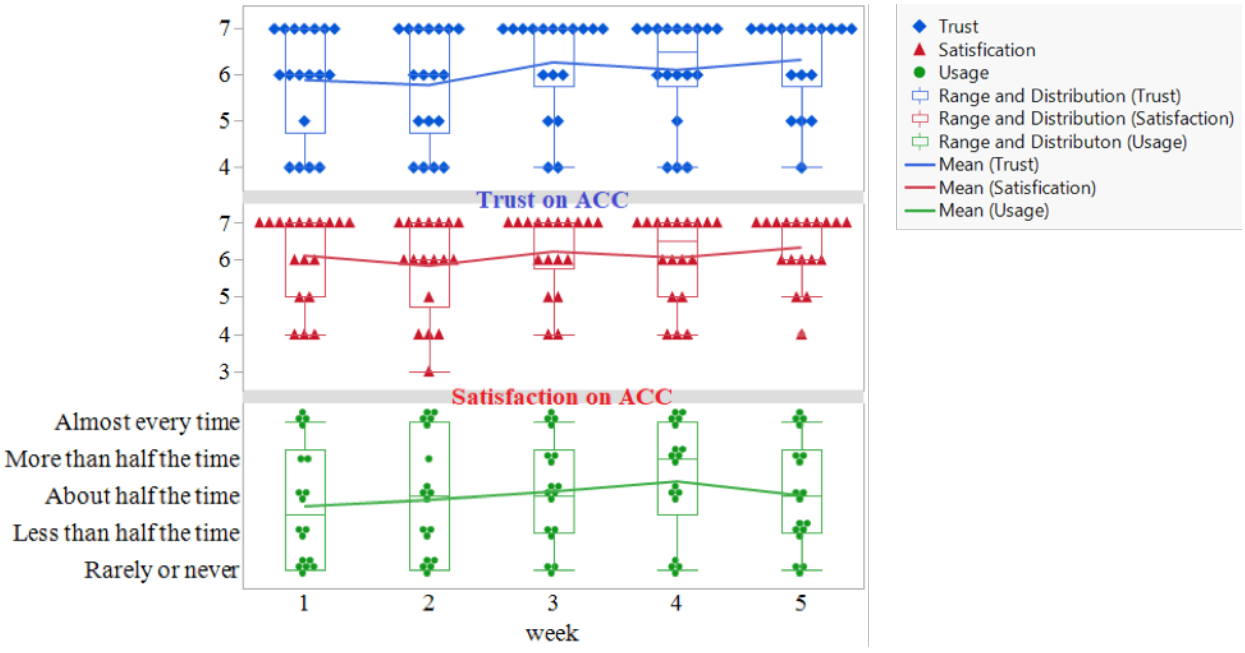

Figure 2. Usage frequency over time, trust and satisfaction ratings on ACC (1 = strongly disagree, 7 = strongly agree).

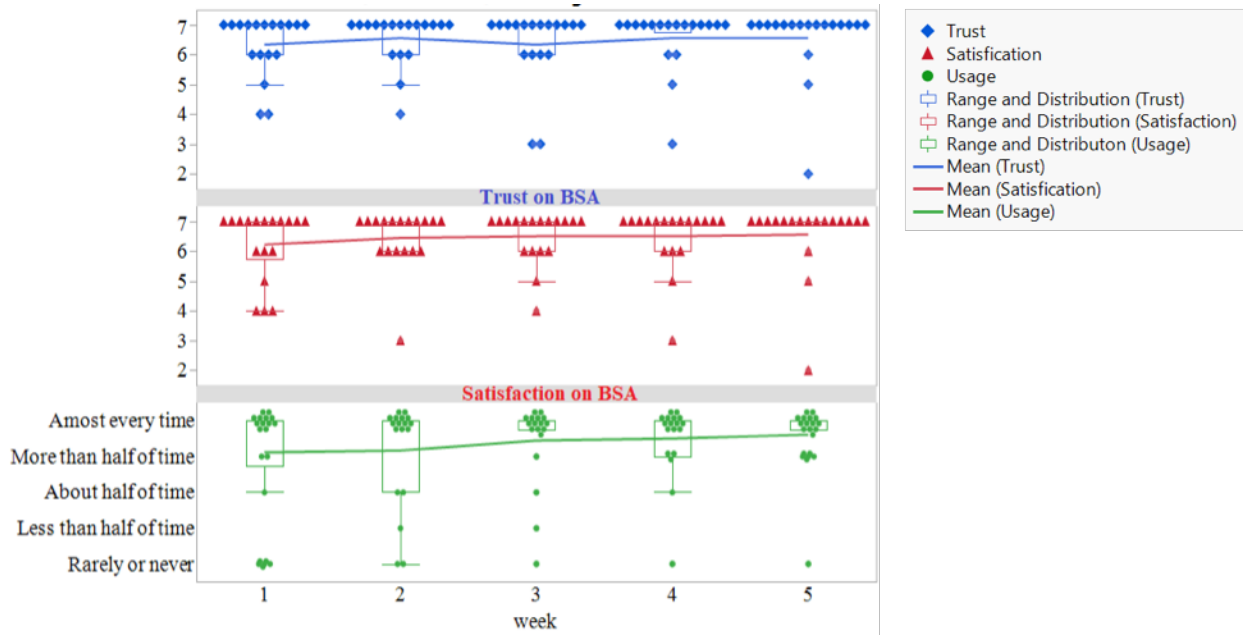

Figure 3. Usage frequency over time, trust and satisfaction ratings on BSA (1=strongly disagree, 7 = strongly agree).

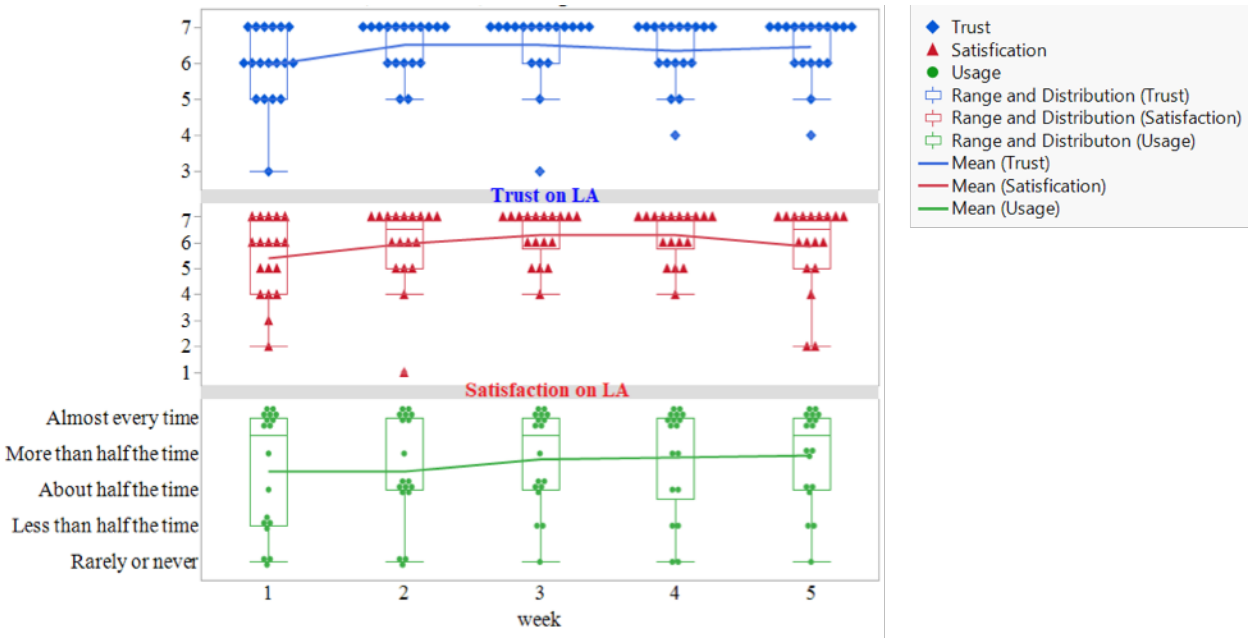

Figure 4. Usage frequency over time, trust and satisfaction ratings on LA (1 = strongly disagree, 7 = strongly agree).

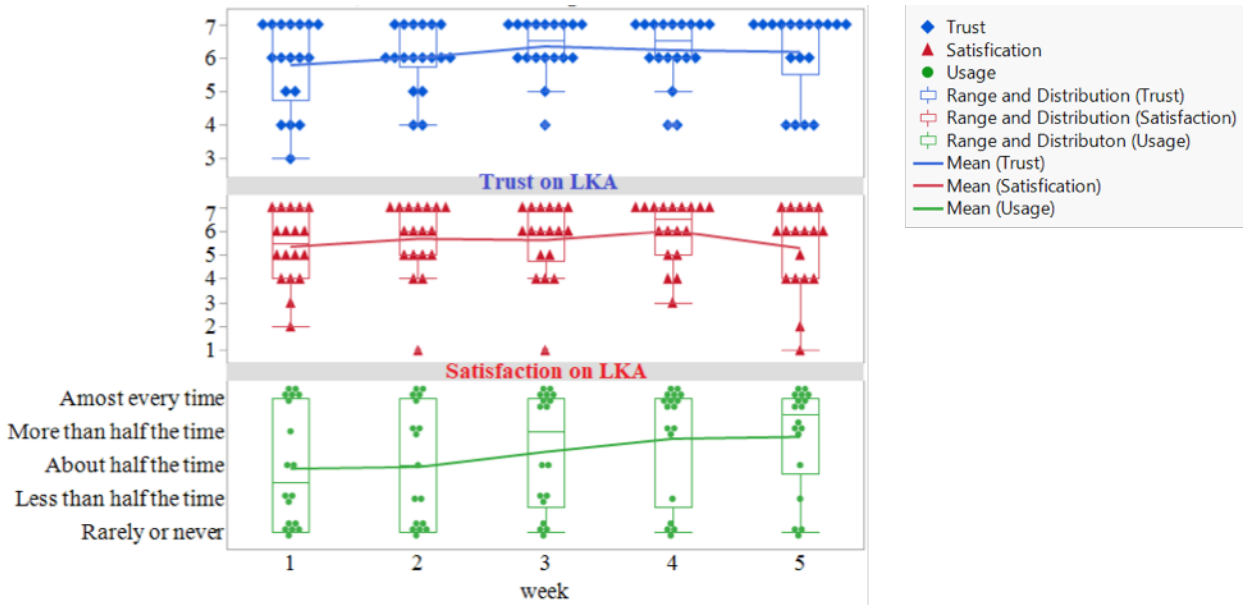

Figure 5. Usage frequency over time, trust and satisfaction ratings on LKA (1 = strongly disagree, 7 = strongly agree).

One-way repeated analyses of variance were conducted to reveal the effect of number of weeks (i.e., week 1 to week 5) using the AVTs on trust and/or satisfaction ratings. The results of these analyses are presented in Appendix S. The test results did not indicate any significant differences between the number of weeks using the AVTs for either rating, contrary to the hypothesis that participant satisfaction and trust would change with increased exposure to AVTs over the naturalistic driving study period.

Focus Group

This subsection summarizes participant responses to questions posed during focus group sessions on three topics: attitude change, likes/dislikes, and safety. The nine findings are summarized following. Participants…

1. exhibited negative initial attitudes towards the AVTs;
2. exhibited positive post-exposure attitudes towards the AVTs;
3. improved attitude with usage experience;
4. improved attitude by reading vehicle manuals;
5. expected better training;
6. expected more intuitive control;
7. liked BSA most;
8. liked LKA least; and
9. agreed that the four AVTs could improve safety.

Question 1: What one word describes how you felt about the advanced features in your vehicle when you began the study? What one word describes how you feel about the advanced features in your vehicle now, at the end of the study?

Figure 6 characterizes participant responses to focus group question 1, where green indicates positive responses, white denotes neutral responses, and red denotes negative responses. When it came to a word with uncertain sentiment orientation, such as "OK" and "unsure," the moderator asked the participants to further explain their selected words. The classification is based on the participants' explanation. The numbers in parentheses indicate the number of participants selecting that word.

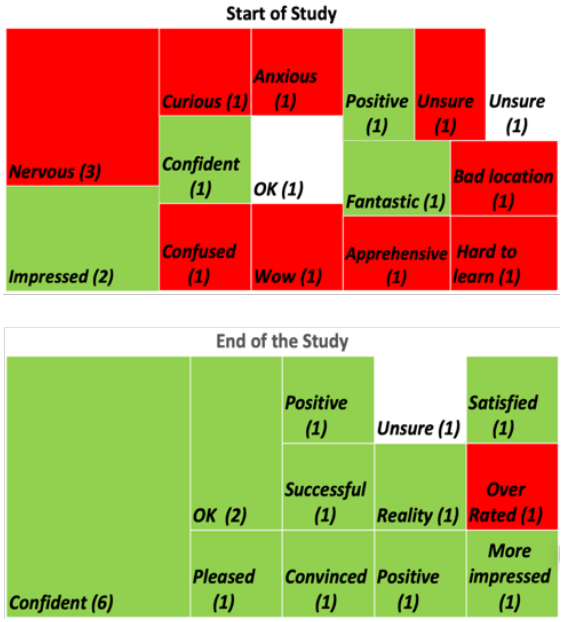

Figure 6. Words selected by participants to describe their feelings towards AVTs.

Finding 1: Negative initial attitudes towards AVTs. Ten out of 18 participants used negative words (e.g., "confused," "unsure") to describe their impression of the AVTs when they began driving the study vehicles. For example, a male participant who responded with the word "anxious" noted that he was, "Anxious in just how things worked, when it would work, when it wouldn't work. Not…fully understanding it. [It was] something brand new."

Finding 2: Positive post-exposure attitudes towards the advanced features. Fourteen out of 18 participants used positive words (e.g., "pleased," "satisfied") to describe their feelings about AVTs at the end of the study. A participant who responded with "confident" further explained: "I knew when I could use it and when I couldn't and so I just felt…good about all that."

Question 2: What caused your feelings to change or remain the same?

Finding 3: Experience improves attitudes. Fourteen of 18 participants mentioned that their attitudes towards AVTs changed with "experience" or a related expression (e.g., "using the system," "driving a lot"). Participants indicated that they became more familiar with operating the features as well as their limitations. In the words of one participant, "Just experience and time to play with [the technology]. Trying it, you know like trying to see if I could get onto 460 and

put on the lane control, see if I could drive out to Lowes without using my hands. [Participants laugh]. Didn't work."

Finding 4: Reading the owner's manual improves attitudes. In addition to "experience," the second most frequently mentioned reason behind an increased positivity toward AVTs was reading the manual, which was reported as helping participants become familiar with the vehicle, thereby improving their attitude towards the advanced features.

Question 3: What would make you feel more comfortable with these features?

This question generated a lot of discussion among the participants. The factors pertinent to making the participants more comfortable with these features are better training and an intuitive user interface.

Finding 5: Better training. Twelve of 18 participants mentioned better training in response to Question 3. With regards to the content of training, some participants suggested training on each function (e.g., turning on/off the heat, using GPS) in the vehicle, not just the AVTs. One participant indicated that the non-safety related features (e.g., radio, GPS, vehicle climate control) are difficult to set, distracting from the driving task. They expected to learn how to use those non-safety features in a training session. Some participants expected training sessions from a car dealer, while one participant noted that he would be more comfortable asking for help from family or friends familiar with the technology.

Some suggested that a "re-orientation" session after the first few weeks of driving would help them answer the questions raised during their driving experience. For example, a male participant said, "If I was buying a new car like this, I would really appreciate being able to go back and have somebody ride with me [the other two participants agree] to not just explain it, but see if I'm using it to the best advantage of how I drive and it would probably take."

Finding 6: More intuitive user interface. Five of 18 participants complained of difficulties controlling the AVTs. Two specific usability issues were locating the controls and using the touchscreen. Five of the participants responded that buttons to access AVTs features were difficult to locate. Some participants found the touch screen insensitive to their input.

Question 4: What is one thing you liked best about these features? What is one thing you liked least about the features?

***F*inding 7: Liked BEST BSA**. Nine out of 18 participants liked BSA best. Participants strongly perceived the safety benefits from driving with BSA. Many found the BSA increased their confidence when merging or changing lanes.

Finding 8: Liked LEAST LKA. When ranked in descending order of safety and usefulness, LKA was ranked last by seven out of 18 participants, ACC was identified as least safe and useful by three participants, and LA and BSA were so identified by one. Lack of trust and too many limitations on LKA were the most frequently mentioned reasons. Participants claimed that they

could not trust LKA, and that their experience of false alerts and malfunction of the LKA exacerbated this mistrust. LKA was reported not to have functioned well in construction areas and on highway exit ramps. One participant spoke about his experience driving on a highway exit ramp with LKA: "Well in the lane keeping, my Audi, number one when you came to an exit ramp, it would get totally confused." One participant who mainly drove on rural roads or mountainous areas preferred to turn off LKA to avoid annoyance due to frequent alerts.

Question 5: Suppose a friend is considering purchasing a car with these features and they ask you if you think if they improve driving safety or not. What would you say?

Figure 7 characterizes participant responses to Question 5, where green indicates positive responses, yellow denotes neutral responses and red indicates negative responses**.**

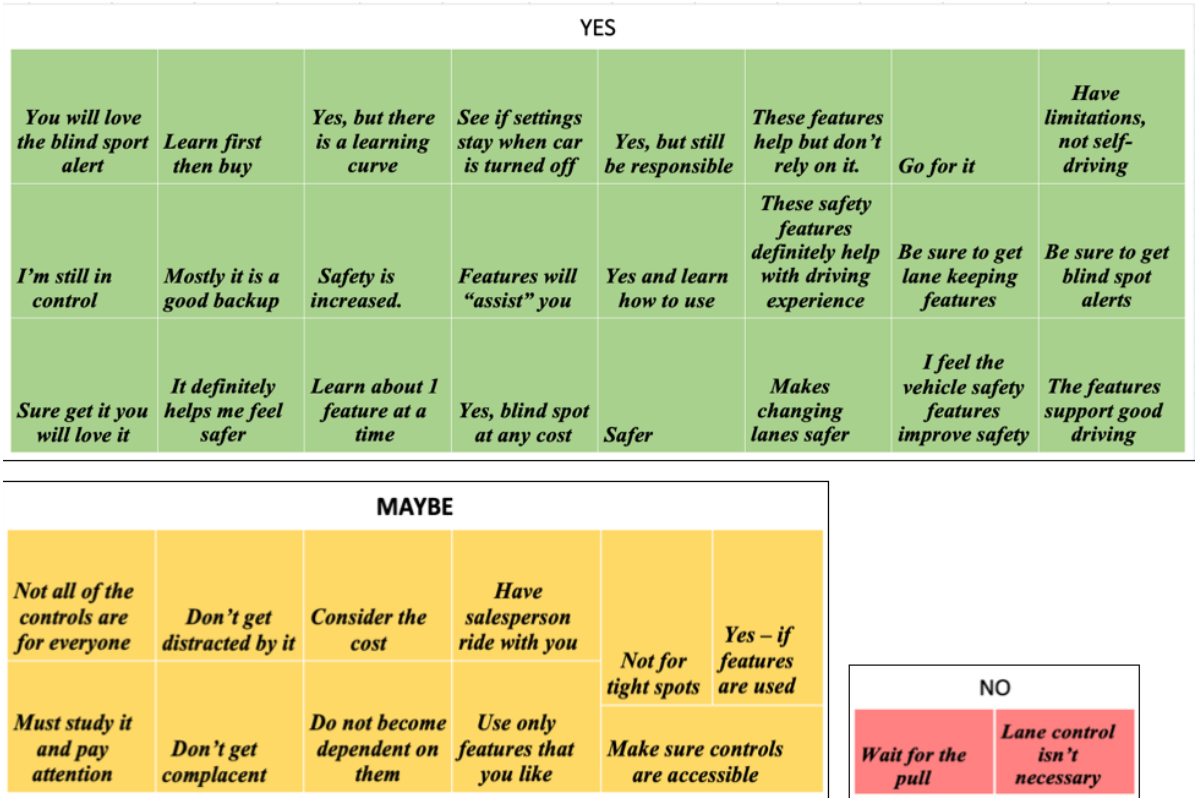

Figure 7. Participant's responses assuming that a friend is asking if AVTs improve safety.

Finding 9: Most participants agreed that the features improve safety. Most responses showed that participants perceived the advanced features as improving driving safety. However, they further indicated the necessity of an extended learning period to realize the safety benefits. Though safety was believed to improve, many would recommend that their friends "learn first then buy," as they all experienced a steep learning curve. Participants noted that they would also share their concerns about over-reliance on AVTs with a friend.

Discussion

Attitudes Towards AVTs Improve with Exposure

We examined seniors' attitudes towards AVTs using three self-reported methods: intake and exit questionnaires, weekly interviews, and focus group. Though the weekly interview did not show statistically significant results of the changes in attitudes (trust and satisfaction) over the weeks, questionnaires and focus groups produced consistent results, showing that participants' attitudes toward AVTs grew more positive over the course of the study, suggesting a positive association between attitude and exposure. Specifically, participants voiced less concern about false alarms and felt more familiar with the features over time. They also reported higher levels of trust in the effectiveness of advanced features with regard to safety. The focus group results mirrored the findings of the questionnaires. Most participants in the focus group discussions responded with positive attitudes towards AVTs at end of the study. Together, these results suggest that senior drivers' attitudes toward automated features could improve with adequate exposure.

Weekly Attitude Change

Weekly surveys tracked participants' usage of the study vehicle and AVTs, as well as participants' trust and satisfaction. Participants reported that they drove the study vehicle 4–5 days each week on average. ACC, LA and LKA were reported as being activated around half of the time, and BSA was activated over half of the time. Given the reported relatively high-frequency of usage, participants did not show any obvious resistance to driving with AVTs activated. However, reported AVT activation did not increase over the course of the study. Along with stable usage frequency, participants' trust and satisfaction towards all AVTs barely changed, remaining always at slightly above the neutral rating. The plateau of participants' attitudes from the weekly interview suggests a quick adaptation process. A study conducted in the past found that trust in ACC from drivers without prior experience reached a plateau after 3.5 hours of exposure to the system [69], but the weekly interviews in this study were likely unable to capture such a rapid change in attitude.

Preferred Learning Methods for Senior Drivers

During focus groups, participants indicated that they expected better training before using AVTs and preferred a more intuitive interface. Their expectations may reflect two major barriers in the adoption rate of AVTs amongst seniors: AVTs' steep learning curve and usability. With regards to learning, seniors prefer to read the vehicle manual; young and middle-aged drivers prefer to learn through trial and error [56] [71]. For instance, one study in which owners of recently introduced AVTs were interviewed found that seniors were more likely to learn ACC through via the manual than those of other age groups [70]. Thus, owner's manuals must be designed with senior drivers and readers in mind, and also thoroughly tested with all users, particularly seniors.

Touchscreen User Interface for Senior Drivers

AVTs user interfaces must be intuitive and easy to navigate. Compared to their younger counterparts, seniors may not have as much experience using electronic devices (e.g., iPad, smartphone) with a touch screen. This may explain participants' complaints about navigating a touchscreen during focus group sessions. Considering seniors' age-related declines while designing the touch screen interface could potentially address these usability issues. Touchscreen design guidelines have been proposed that specifically consider seniors' needs [80]. The guidelines include target size, target distance, the angle of the line from the starting point to the target, and click position. Unlike virtual buttons on a touchscreen, physical buttons are easier to locate and press due to their fixed location and tactile feedback. Drivers can complete the button press or inputs without taking their eyes off the road. Touchscreens, on the other hand, have the advantages of greater contextual sensitivity and combining more controls into less space, and thus manufacturers have increasingly been employing touchscreens for the in-vehicle user interface. The tradeoff between physical and virtual buttons has long been a design challenge, considering seniors' decreased visual ability [18]–[20], poorer divided attention (e.g., [73]) and decreased accuracy of movement [46]–[49].

Most and Least Liked Features

Participants identified BSA as their most liked feature, confirming prior findings from survey studies [67] [51]. Both survey studies rated BSA as the feature senior drivers are most willing to accept and adopt. LKA was the least liked feature. Usage limitations of LKA could be one reason for this negative impression. Quality of lane markings, weather, road design, and environment all may potentially affect LKA's functionality and performance. Usage limitations may also influence drivers' perception of LKA's usefulness. In addition, many participants reported receiving false LKA alerts, which may have significantly influenced participants' confidence in the system [69] [70]. Participants may not have fully understood the limitations and capabilities of LKA and attempted to use it beyond its intended operational parameters. For instance, participants in the focus group sessions mentioned that they received false alerts from LKA when driving in construction areas and on highway ramps, two environments for which LKA is not designed. In order to minimize such scenarios, drivers must be knowledgeable regarding the system's functional limitations and purpose (i.e., have a well-developed mental model of system functionality and capability), so their confidence can be correctly calibrated to AVT capabilities [76] [72]. Seniors who have little knowledge of AVTs emerging in the market and limited understanding of the limitations of specific vehicle technologies are more inclined to use AVTs in ways incompatible with driving conditions [66]. Providing this information base in a robust, meaningful, and reliable manner can help drivers develop appropriate expectations. Going forward, designers should consider ways to prevent drivers from engaging AVTs outside of their intended capabilities.

Future Study Plans

The planned Phase II of this study will analyze the naturalistic driving data collected during Phase I. These data include acceleration, speed, lane position, time to collision, etc., and driver behavior recorded by five cameras. Analysis of these data has the potential to reveal senior drivers' behavioral adaptation using AVTs. Through comparison with the subjective data collected in Phase 1, these planned analyses will also examine whether driving behaviors and performance change concomitantly with the subjective data. Additionally, data from the Second Strategic Highway Research Project, which included little in the way of AVTs, present an ideal control group. Thus, planned Phase II analyses will examine how AVTs can influence senior drivers' performance and driving behavior in real-world driving.

Conclusions and Recommendations

AVTs have tremendous potential to mitigate age-related declines in cognitive and motor-related abilities, and senior drivers demonstrate an increasing acceptance of these technologies with experience. They also show a preference for technologies that provide information in a timely manner compared with those that exert actual control over the operation of the vehicle. It is recommended that new owners be provided adequate orientation time, preferably over multiple sessions, and that owner's manuals be written in a clear, streamlined manner and be thoroughly tested with the senior driver in mind. In addition, user interface design elements should be informed by a consideration of seniors' preferences and capabilities in order to optimize the safety benefits of these technologies for this growing segment of our population.

Additional Products

The Education and Workforce Development (EWD) and Technology Transfer (T2) products created as part of this project can be downloaded from the project page on the Safe-D website. The final project data are available on the Safe-D Collection of the VTTI Dataverse.

Education and Workforce Development Products

This project resulted in the following education and workforce development products:

First, the project sponsored one graduate student for one year in carrying out the research for a Ph.D. degree. Senior researchers mentored the student in scientific research on transportation automation and safety, particularly as these relate to the growing senior population. The graduate student received training on collecting data in naturalistic driving studies, analyzing qualitative and quantitative data, and presenting scientific results to audiences at scientific/professional conferences. The project provided professional and scientific graduate training that will prepare this student to contribute to research and applications in transportation safety. Specifically, it is expected that the student will use the subjective as well as continuous video and time series naturalistic driving data to develop her dissertation topic.

Second, the graduate student presented preliminary results at the 7th Naturalistic Driving Research Symposium in September 2018. The graduate student also presented the project work via a poster session at a ribbon-cutting ceremony hosted by VTTI for the Automation HUB in November 2018.

Third, senior researchers in this project from both the Department of Industrial and Systems Engineering (ISE) at Virginia Tech and VTTI collaboratively developed a seminar on aging in transportation safety. This seminar covered current knowledge about driving issues associated with seniors and current research challenges in addition to the research methods and findings specific to this project. The ISE faculty on the team, Dr. Nathan Lau, presented the seminar in the course of ISE 3614 Intro to Human Factors, which enrolled over 200 students.

Technology Transfer Products

This project generated two key products. First, there were actionable outcomes derived from the subjective questionnaire and focus group data:

- How do seniors feel about AVTs?
- Will seniors use AVTs when provided a vehicle which incorporates such?
- How does exposure and usage change those perceptions, if at all?
- What can be gleaned from the current study to help motivate and provide support to seniors so that they are better prepared and equipped to avail themselves of the safety and mobility benefits of AVTs?

As the population of senior drivers continues to grow over the next several decades, it is imperative that various stakeholders be equipped with data to make well-informed decisions. Key stakeholders in the transportation arena include federal and state-level governmental agencies, OEMs, safety and/or senior advocacy groups, and the research community. We are well positioned to engage these types of organizations directly with the products of this project, as the National Surface Transportation Safety Center for Excellence (NSTSCE) has provided substantial matching funds to support this research effort. NSTSCE Stakeholders represent major players in several of the categories noted above: GM (OEM), FMCSA (federal government), Virginia Department of Transportation (state-level government), Travelers (insurance industry), the National Safety Council (Advocacy Group), and VTTI (research institute). Progress has been reported to these stakeholders and feedback solicited on how best to package the deliverables and products for ease of use by all players in their respective fields. The products of this report included a final report, one or more presentations at key conferences and/or symposia (e.g., TRB, HFES, NDRS as well as other venues). Also, as noted in the Education and Workforce Development Plan above, the research team presented these results to students in a variety of settings, not only expanding their educational horizons, but also helping to disseminate key project findings to the next generation of stakeholders in the transportation sphere.

Second, in Phase II of this research, a database of naturalistic driving data will be productized and marketed to the NSTSCE Stakeholder group (and others) as a leveraged opportunity for further quantitative analyses of real-world driving behaviors. Data will be specifically productized for consumption by different stakeholder audience groups (e.g., OEMs or transportation safety researchers).

As detailed above in the Education and Workforce Development Plan, one of the key audiences is the population of senior drivers. Plans to reach them with study products include webinars and in-person appearances at senior physical or virtual gathering places (e.g., AARP).

Data Products

The efforts described herein have resulted in a robust dataset replete with subjective data related to participants' attitudes toward AVTs and the effects of extended exposure on those attitudes. In addition, objective assessments of visual field and cognitive abilities were collected using the Clock Drawing instrument and Useful Field of View assessment tool. The dataset also includes transcripts of the three focus groups conducted in the course of this research. These transcripts include images of artifacts from the focus group sessions. The dataset is available at https://doi.org/10.15787/VTT1/VUXYYM.

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Appendices

Appendix A. Findings from Selected Survey Studies

Source	Sample	Method	Finding related to senior drivers
[7]	1019 respondents, 392 among them born 1946-1964 251 born 1929-1945	Telephone questionnaire survey	• Seniors born 1929-1945 reported least comfort with and acceptance of the advanced in-vehicle technology, however they tended to use them. • Senior generation were less interested in non-safety systems than younger generation. • Smaller percentage of senior generation felt comfortable with CVS compared to younger generations' • Smaller percentage of senior generation reported would accept the CVS on the roads compared to younger generations'
[50]	384 respondents	Questionnaire study	• Showed higher intention of using the driverless vehicle • Have positive attitudes towards the advanced in-vehicle features • Compared to other travel modes, driverless vehicles were rated as having a lower degree of effectiveness
[51]	302 respondents 50-69 years old	Survey A small group discussion	• Most senior drivers would like to "test-drive" a driverless car, while the purchase intention was relatively low even assuming the driverless car does not differ in price with regular cars
[53]	183 respondents 29% aged 61-70 17% aged over 71	Mail survey	• No significant differences by drivers' age on opinions about AVTs
[54]	347 respondents 21-70 years old	Survey requests distributed by email	• Less interested in connected and automated vehicles (CAV) and shared autonomous vehicles • Lower willingness to buy AVs • Less frequently use AVs • Have trust issues about the technologies
[55]	1088 respondents aged 21-69	First phase distributed the questionnaires through a professional survey company, followed through online survey	• Less willingness to spend on these technologies • Senior drivers' adoption rate may depend on their friends' adoption rate
[57]	1756 respondents	Online survey	• Perceived usefulness, affordability, social support, lifestyle fit and conceptual compatibility were identified as significant

	17.2% born 1946-1954 13.7% born on or before 1945		predictors of acceptance of self-driving cars across the ages • Attitude was identified as the predictor of behavioral intention to use • Age was negatively associated with the predictors of acceptance, which means senior drivers were less accepting of self-driving cars • Age was negatively associated with technology experience factors, which were strongly related to acceptance.
[58]	17400 respondents	Not found	• Only 9% of aged 57-65 (18-25:37%, 26-37: 29%, 38-56: 13%) would consider purchasing fully autonomous driving functions based on a market price of $3000
[60]	336 people: 178 female, 158 males Aged between 19 to 65 years	Online survey	• Compared to younger ages, 36-65 age groups have more positive attitudes towards the technologies • Compare to younger ages, 36-65 age groups have higher intention of using the technologies.
[61]	1533 respondents 7.4% aged 60-69 0.2% aged over 70	Online survey	• Showed less interest in the vehicle technologies than younger groups • Greater concerns about riding in self-driving vehicles compared to youngers • Showed more concerns about completely self-driving vehicles than partially self-driving vehicles • Less optimistic about the benefits the self-driving car may bring to drivers and society
[62]	505 respondents 26.9% 60 or older	Online survey	• Less likely to embrace the concept of driverless cars • Prefer voice commands • Greater concern about riding in self-driving vehicles compared to younger people • Showed more concerns about completely self-driving vehicles than partially self-driving vehicles
[63]	2038 respondents	Online survey	• No age difference reported on willingness to pay for automation • Showed slightly more concerns about riding in self-driving car compared to younger people
[64]	1001 respondents aged 16 to 76	Not found	• Lower percentage of older respondents found driverless technology important compared to younger ones • Less likely to embrace the concept of driverless cars than younger drivers
[65]	1001 respondents aged 65 and older	Online Survey	• Prefer to drive by themselves, would not like to be driven by the car • Would be uncomfortable riding in a fully autonomous vehicle
[77]	2954 respondents 52% aged over 55	Online survey	a. Have we done that in the past? b. Why or under which auspices is he signing it? •

[78]	421 respondents m=40.2 aged 19 to 73 SD=15.9	Online questionnaire	• Less likely to pay for such technology, but show higher acceptance
[79]	5000 respondents across 109 countries	Online questionnaire survey	• No strong age differences found on purchase intention

Appendix B. Consent Form

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants of Investigative Projects

Examining Senior Drivers Adaptation to Mixed Level Automated Vehicles: A Naturalistic Study

INVESTIGATORS: Jon Antin, Nathan Ka Ching Lau, Dan Liang, Stephanie Baker, Kelly Stulce, Lisa Eichelberger, Brian Wotring, Jessica Rardin, Virginia Tech Transportation Institute (VTTI)

WHAT IS THE PURPOSE OF THIS RESEARCH?

This study will look at how senior drivers use vehicles with automated technologies. 18 drivers aged 70 -79 will participate. Participants will fill out surveys and take tests, take part in interviews and focus groups. Participants will also be given an instrumented vehicle to drive for 6 weeks.

WHAT SHOULD I KNOW BEFORE DECIDING TO PARTICIPATE?

1. The main focus of this study is to learn about your thoughts and feelings about certain automated vehicle technologies.
2. We will give you a vehicle with one or more automated vehicle technologies to drive for a six-week period. We encourage you to use these features, but you will never be required to do so.
3. The vehicle will be set up with sensors and cameras. The cameras will take video of your face, the steering wheel/dashboard, the forward roadway and the roadway behind the vehicle. No audio will be collected.
4. The video and other data that tell who you are, or could be used to tell who you are, will be held under a high level of security. Your data will be linked with a code rather than your name.
5. Only qualified researchers will be allowed to have access to data that could be used to identify you. The level to which they have access will be based on their level of authorization.
6. We will do our best to not collect identifying video information on passengers in the vehicle; however, passengers sitting right behind the driver will be the most vulnerable to being seen on video.
7. You are giving permission for us to collect data (including video) whenever the study vehicle is used. We ask that you not let anyone else to drive the study vehicle. If, when we look at the data, we find trips where someone else is driving, we will delete those data as soon as we are sure that you are not the driver.
8. If you are in a crash, follow the steps listed on the yellow envelope in the glove box. When it is safe to do so, you should call us at **540-231-1045** to let us know about the crash.

9. You may leave the study at any time. If you do wish to leave the study before your scheduled end date, please tell us right away so we can arrange for you to return the vehicle. We will not keep any data collected after you contact us, but we will keep and use any data collected after the date you sign the consent form and before the date you notify us of your wish to leave.

WHAT DO I HAVE TO DO IF I CHOOSE TO PARTICIPATE?

The study includes a 6-week driving experience during which you will drive a study vehicle with a data collection system containing sensors and cameras to record a variety of driving measures. As a participant, you will complete the following activities:

1. **Attend a study intake session.** During this session:
    a. You will be asked to show the researcher your U.S. driver's license.
    b. A member of the study team will review this informed consent form with you, answering any questions you might have.
    c. The researcher will take you to the parking lot and show you the study vehicle you would be driving as part of the study.
    d. If you choose to be in the study, we will ask you to sign two copies of this form. You will take one copy with you and we will keep the other copy in a locked cabinet at the research facility.
    e. You will complete an intake survey and forms related to compensation.
    f. You will undergo a series of tests used to collect data about you. These include tests to measure your visual field and a clock drawing test. Like the video and driving data described earlier, these will be kept confidential. Results of these tests will be associated with a numerical code rather than your name.
    g. A member of the research team will take your picture using a digital camera.
    h. The intake session should last no longer than two hours.
2. **Attend a vehicle training session.**
    a. We are happy to set up transportation for you to this session to avoid any inconvenience to you.
    b. During this session, we will give you an introduction to the study vehicle you will be driving. We will show you how to use the advanced features, like lane keeping and braking assist.
    c. We will also show you the cameras and other data collection equipment in the vehicle and tell you whom to contact if you are in a crash, have any problems with the vehicle or notice any maintenance issues with the data collection equipment (for example, the device comes loose).
    d. During the vehicle training session, we will offer to help you pair your cell phone with the vehicle so that you can use the hands-free technology. This is entirely optional; you don't have to do this if you don't want to.
    e. After completing the vehicle training, we will go on a test drive so you can ask any questions about the vehicle features before you take possession. The route will include town roads, highway and freeway driving in the New River Valley. First, the researcher will drive and show you how to use the vehicle features.

Then, you will drive the vehicle and try out the features, asking any questions you may have. We will show you where to find the owner's manual in the glove box.

f. We will ask you to sign a training checklist after the test drive. The list will show that you have received information about the vehicle and its features.
g. You will drive the study vehicle home from this session. We will give you a full tank of gas at the beginning of your driving period. You will be responsible for fueling the vehicle and paying for gas during your driving period. You do not have to bring the vehicle back with the gas tank full.
h. This session should take no more than 3 hours.

3. **Participate in a naturalistic driving experience.** You will drive the instrumented study vehicle for a period of six weeks.
4. **Participate in a weekly phone interview.** Each week during your driving experience, a member of the study team will call you to ask questions about your experience with the study vehicle. This should take no more than 15 minutes. We will plan this call at a time that is convenient for you when you are not driving.
5. **Complete an exit survey.** When you bring the study vehicle back to the research facility at the end of your driving experience, we will ask you to fill out a brief exit survey. We are happy to help you with a ride home after you've returned the study vehicle. This final session should last no more than thirty minutes.
6. **Attend a focus group discussion**. Following your driving experience, you will return to VTTI for a focus group session and answer questions about your experience. This will last no more than ninety minutes.

WHAT DO I DO DURING THE NATURALISTIC DRIVING EXPERIENCE?

1. Drive as you normally would.
2. After one week of driving, we will need to retrieve the data drive from the data collection equipment. This will involve bringing the vehicle back to the research facility. This appointment will last up to one hour, and you will receive a $25 inconvenience fee.
3. If you have any problems with the vehicle or notice any maintenance issues with the data collection equipment, please call us right away at **540-231-1045.**
4. If you are in a crash, we ask you to seek emergency help as you normally would. Please call us at **540-231-1045** as soon as it is convenient to do so. We will want to get the vehicle back from you to make any needed repairs. In addition, we will also want to talk to you about the crash. We would like for this conversation to occur soon after the crash, but only when it is safe and comfortable for you.
5. Let VTTI researchers get into the study vehicle (at your home, work, or other mutually agreed upon location) if necessary to do maintenance on the vehicle or the data collection system. This may include taking the vehicle back to the research facility to do maintenance (such as oil changes) or may require an experimenter to open the trunk and get into the interior of the vehicle. You do not need to be present, nor do you need to leave the vehicle unlocked (the researcher will have a key to the vehicle).
6. While you are driving the study, we ask that you not drive the vehicle into any areas where cameras are not allowed, including any international border crossings, military bases, or similar facilities.

WHAT HAPPENS WHEN THE STUDY IS OVER?

1. After your driving experience ends (six weeks), you will be asked to bring the vehicle back to the research facility. We will ask you to fill out an exit survey. This should take no more than thirty minutes.

2. When you leave the study, we will ask you if we can keep your contact information to contact you about future follow-on studies. This will be optional, and if you do not agree, we will delete your contact information one year after data collection is complete.

3. Video collected during the study may be shown at conferences or other research-related proceedings. At no time will personally identifying information, such as your name, be linked with this video.

WHAT ARE THE RISKS OF PARTICIPATING IN THIS STUDY?

There are non-driving risks resulting from participation. Cameras will be placed in the vehicle. If you drive into an area where cameras are not allowed, such as international border crossings, military and intelligence locations, and certain manufacturing plants, there is a risk that you may be stopped or arrested or that the vehicle may be held. For this reason, by signing this Informed Consent and thereby agreeing to be in the study, you also are agreeing not to drive into any such areas while you are in this study.

Throughout the study, we will take all possible steps to protect your privacy and keep confidential your role in the study and the confidentiality of information that identifies you. However, the researchers may be required by law to report matters such as child abuse, or a participant's threatened or actual harm to self or others. In terms of a vehicle, this could also include items such as driving under the influence of drugs or alcohol, allowing an unlicensed minor to drive the vehicle, or habitually running red lights at high speed. Such behaviors may result in your removal from the study and reporting of the behavior to the appropriate authorities. In the event of a crash, it may not be possible to prevent the equipment and the data from falling into the hands of the police; if this happens, however, the data are still encrypted; these individuals cannot access or read the data.

You are also responsible for protecting your privacy. Do not post or tell about your participation on any public forum, including websites, Facebook, newspapers, radio and television. Protect your role in the study the same way that you protect other personal and private information. If you do not keep confidential your role in the study, there is a risk that some of the data collected during the study, including information that identifies you, may be used against you in a court case or other legal proceeding.

The operation or drivability of the vehicle should not be affected by the equipment, and thus carries a similar risk as when you drive a vehicle normally. However, if you violate state or local driving laws (such as driving under the influence, going over posted speed limits, or driving

while distracted), the equipment could record evidence of these violations. This has the potential to pose greater than minimal risk of legal harm. A variety of strategies and procedures have been developed to reduce the potential for legal or economic harms. These strategies include making the data obtained by sensors and cameras unreadable until it is processed at our facility and using a code number to identify you with the code key kept in a secure location. More details on these steps are provided below.

The risk of filling out the surveys is minimal and similar to doing office paperwork, although some questions may make you uncomfortable. Likewise, the risk of participating in interviews is minimal; you are free to decline to answer any question for both questionnaires and interviews.

There is a risk that you may feel uncomfortable stating your opinions in a group with other people during the focus group session.

The following steps will be taken to minimize the risk to you:

a) You may decide not to be in the study or to leave the study at any time.
b) Any current driver could buy/lease/rent a vehicle similar to those used in the study. The systems are not changed for use in this experiment in any way.
c) The vehicle has a driver's side and passenger's side airbag, side airbags for both front passengers, curtain airbags for first and second row occupants, and a supplemental restraint system.
d) All data collection equipment is placed such that, to the greatest extent possible, it is not expected to pose a danger to you.
e) You will be given training about the available features. The vehicle owner's manual will be in the glove box. This further describes features and their limitations. You should never fully rely on the onboard systems, but you should always use normal caution when operating the vehicle.
f) The vehicles will be maintained by the research team, including routine maintenance, to ensure they are safe to operate.
g) If you do have your cell phone paired, we will delete any downloaded contacts or other information from the vehicle at the end of your driving experience.

WHAT ARE THE BENEFITS OF PARTICIPATING IN THIS STUDY?

While there are no direct benefits to you from this study, you may find it interesting. No promise or guarantee of benefits is being made to encourage your participation. Participation will help to improve in-vehicle advanced technologies. Participation may also help us design safer vehicles in the future.

HOW WILL MY DATA BE KEPT CONFIDENTIAL AND SECURE AND WHO WILL HAVE ACCESS TO MY DATA?

Any data collected during this study that could be used to identify you will be protected. Your data will not be linked to your name, but rather to a number (for example, Driver 0011). The raw data collected while you drive the vehicle will be made unreadable from the moment they are

collected until they are moved to a secure server at VTTI. Your name also will be separated from any data about you, either given by you when we talk to you to see if you are eligible to be in the study or gathered by researchers during the study, and will be replaced by the same driver number (for example, Driver 0011).

Several types of information and data about you will be collected during the study:

1. **Contact information** includes your name, address, email address, phone numbers, and similar information used to get in touch with you when needed. It will be stored securely in electronic form during the course of the study and destroyed after the study is complete (unless you give permission for us to keep your contact information when the study is over). This information will not be linked to or mingled with your study data, and will not be used in any research or analysis.
2. **Auxiliary study information** includes your Social Security Number and similar information. This information is used to verify your identity and to compensate you for your participation. This information will be stored securely at VTTI and destroyed after the study is complete. This information will not be linked to or mingled with your study data, and will not be used in any research or analysis.
3. **Driver data** includes your answers to surveys and in weekly interviews and focus groups. Focus groups will be recorded, including both audio and video. These recordings will not contain your name or any other information that tells who you are and will be used in analyses, both on their own and in combination with the driving data, vehicle data, and additional crash data. This data will be stored securely in electronic form throughout the lifetime of the data (defined below).
4. **Driving data** includes the data we collect from the study vehicle while you are driving, including video and sensor data. This will contain video of your face and GPS coordinates of your trips, both of which could be used to tell who you are. These data will be stored in an unreadable format from the moment of their creation until they are downloaded from the vehicle, moved to a secure server at VTTI, and verified. From this point on they will be made readable on as as-needed basis for each analysis. These data will be used for analysis, both on their own and in combination with driver data and vehicle data. These data will be stored securely in electronic form throughout the lifetime of the data (defined below).
5. **Additional crash data** includes items we may collect after a crash, including answers to an interview with one of our researchers. These data will not contain your name or any identifying information and will be used in analyses, both on their own and in combination with the driver data, vehicle data, and driving data. These data will be stored securely in electronic form throughout the lifetime of the data (defined below).

It is possible that an authorized Institutional Review Board (IRB) may view this study's collected data for auditing purposes. An IRB is responsible for the oversight of the protection of human subjects involved in research.

The study sponsors or investigators will be required to maintain the security and confidentiality of any data that personally identifies study participants or that could be used to personally identify study participants.

While driving the vehicle, a camera will record your face with some added space around the head to handle any head movements. An example is shown in Figure 1 below. Also, video cameras will take views of the forward roadway, the driver's foot well, your hands on the steering wheel, a rear view, and a dashboard view. From time to time, a camera will also take a permanently blurred snapshot of the inside of the vehicle that will let researchers count the number of passengers and make rough estimates of age, gender, and seatbelt use. Researchers will not be able to be identify passengers from these blurred snapshots. All video will be captured and stored in digital format (no tape copies will exist).

Video views.

There will also be a sensor that is capable of detecting the presence of alcohol in the passenger compartment under certain conditions. It may not be able to tell whether the alcohol was drunk or applied (as in hand sanitizer or perfume), and it will be unable to tell whether it is coming from the driver or a passenger.

During the data collection phase of this study, all data collected from the vehicle will be made unreadable to anyone who does not have the key from the time of their creation and then stored in a specific password-protected project folder on a secure server; the driving data will only be made readable once it has been stored in this folder. At the end of the collection phase of this study, the driver data, vehicle data, driving data, and additional crash data will be permanently kept at Virginia Tech's highly secure data storage facility.

All data collected by this project will be uploaded and archived in a Safe-D UTC data repository maintained by Virginia Tech Transportation Institute. Researchers external to VTTI, as well as the general public, will be able to access the de-identified study data through a data access website.

Qualified researchers external to VTTI will be provided with identifiable data with the approval of an IRB and under the terms of a data sharing agreement or contract that at a minimum provides the participant with the same level of confidentiality and protection provided by the consent form. These external researchers will only be able to look at identifiable data, including face video, identifying GPS data, and identifying crash data in a secure data area.

VTTI researchers may be provided with identifying or de-identified data with Virginia Tech IRB approval and within the confines of VTTI"s secure computing environment.

Project personnel, the project sponsor, and qualified, authorized research partners may show specific clips of video at research conferences. Your name and other personally identifying information will never be associated with the showing of these video clips. Identifying location information will not be shown in association with these video clips.

If you are involved in a crash while participating in this study, the data collection equipment in the study vehicle will likely capture the events leading up to the event. You are under NO LEGAL OBLIGATION to voluntarily mention the data collection equipment or your participation in this study at the time of a crash or traffic offense. We have provided a letter which you should keep in the glove box for these cases. The letter describes the vehicle's role in the study without identifying you as a participant in the study.

WILL I RECEIVE COMPENSATION FOR PARTICIPATING IN THIS STUDY?

Total maximum compensation for full participation in this study is $250. At your intake session, you will be given a MasterCard, and funds will be loaded onto the card as follows:

1. After you have been enrolled in the study, signed the consent form and done intake surveys and tests, $25 will be loaded onto a MasterCard. After your vehicle training session we will load another $25 onto your card.
2. $50 will be loaded onto the card after you take part in the focus group session.
3. After three weeks of driving, $50 will be loaded onto your card to cover the cost of buying premium fuel for the study vehicle. If you leave the study before completing the first three weeks of driving, you will not receive this compensation.

4. An additional $100 will be loaded to your MasterCard when you bring the vehicle back at the end of your six-week driving period.
5. If we ask you to bring the study vehicle back to the research facility for a maintenance visit, you will receive $25 for each maintenance visit at the research facility. If a VTTI researcher comes to you to do repairs, you will not receive any extra compensation. This $25 compensation is not included in the total amount above.
6. Please allow one full business day for the card to be activated. Once activated, this card cannot be used past its expiration date. As stated in the ClinCard documentation you receive, the issuing bank will begin subtracting a monthly service fee of $4.50 after three months of inactivity.
7. If you leave the study before the end of the six-week driving period, by your own choice or because you are asked to leave by someone on the study team, $2.38 will be loaded onto the card for each day that you drove the study vehicle.

Insurance

In the event of an accident or injury in an automobile owned or leased by Virginia Tech, the automobile liability coverage for property damage and personal injury is provided. The total policy amount per occurrence is $2,000,000. This coverage (unless the other party was at fault, which would mean all expense would go to the insurer of the other party's vehicle) would apply in case of an accident for all volunteers and would cover medical expenses up to the policy limit. For example, if you were injured in an automobile owned or leased by Virginia Tech, the cost of transportation to the hospital emergency room would be covered by this policy. Any coverage of the participant is limited to the terms and conditions of the insurance policy.

Participants in this study are considered volunteers, regardless of whether they receive compensation for their participation; under Commonwealth of Virginia law, worker's compensation does not apply to volunteers; therefore, if not in the automobile, the participants are responsible for their own medical insurance for bodily injury. Appropriate health insurance is strongly recommended to cover these types of expenses. For example, if you were injured outside of the automobile owned or leased by Virginia Tech, the cost of transportation to the hospital emergency room would be covered by your insurance.

AM I FREE TO WITHDRAW FROM THIS STUDY AT ANY TIME?

As a participant in this research, you can leave the study at any time without penalty. If you choose to leave the study, you will receive partial compensation as described in the Compensation section of this form. You **can choose not to answer any questions** without penalty. If you leave or are dismissed from the study, we will keep data collected before your withdrawal/dismissal, but delete any data collected in the time between when we become aware of the withdrawal/dismissal and before you bring the vehicle back. You will not receive your final compensation until the study vehicle has been returned.

PARTICIPANT'S RESPONSIBILITIES

If you voluntarily agree to participate in this study, you will have the following responsibilities:

1. To not remove, change, or tamper with any of the installed components.
2. To not block the forward or driver's face cameras and not to hang decorative ornaments on study components or the rear view mirror.
3. To tell research staff if you are involved in a crash, have any problems with the study vehicle or if you have questions.
4. To follow these rules about driving the study vehicle:
    a. You must not take the study vehicle into any facilities or areas that do not allow video recording devices.
    b. You must not let other people to drive the study vehicle.
    c. You must not use the study vehicle in a 'for hire' capacity such as a taxi, Uber, Lyft or other similar service.
    d. Wear your seatbelt at all times and make sure passengers use safety belts and child safety restraints properly.
    e. Not to use the vehicle to tow any form of trailer, or haul any material greater than what the vehicle was designed to carry. The vehicle cannot be used to transport flammable or hazardous materials (e.g., gasoline, acid, dynamite, lime).
    f. The vehicle cannot be driven off- road.
    g. You must not smoke or allow others to smoke in the vehicle.
    h. Please keep the interior clean and odor free.
    i. You should buy premium fuel for the study vehicle.

HAS THIS RESEARCH BEEN APPROVED?

Before this experiment begins, the research must be approved by the Institutional Review Board for research involving human subjects at Virginia Tech. You should know that this approval has been obtained and is valid through the date listed at the bottom of this form.

HOW DO I PROVIDE MY CONSENT?

I _____ (participant) have read this consent form and have had the opportunity to ask questions about the study, its risks, and the conditions of participation. My questions have been answered. I freely agree to participate and have not been coerced into participation. I understand that participation is voluntary and that I may withdraw at any time without penalty.

I _____ (participant) will allow VTTI to keep data from the screening survey I completed for analysis purposes. I understand that my name, phone number and email address will not be kept long-term unless I give permission to be contacted for possible follow-on studies.

_____ _____ _____

Participant (Print Name) Signature Date

_____ _____ _____

Experimenter (Print Name) Signature Date

==========

Should I have any questions about this research, I may contact:

Brian Wotring	Project Coordinator	(540) 231-1045
bwotring@vtti.vt.edu		
Jon Antin	Project Director	(540) 231-1579
jantin@vtti.vt.edu		

Should you have any questions or concerns about the study's conduct or your rights as a research subject, or need to report a research-related injury or event, you may contact:

Virginia Tech Institutional Review Board for the Protection of Human Subjects

Telephone: (540) 231-3732; Email: irb@vt.edu

The Participant Must Be Provided With A Copy Of This Consent Form.

Appendix C. Summary of Human Subjects Protection Activities

Item	Content	Date Submitted	Date Approved
Initial Protocol Submission	• Study protocol • Recruiting materials • Assessments • Consent form • Other participant forms and documentation	1/17/2018	1/23/2018
Amendment 1	• Add Co-Investigator • Change number of participants from 24 to 18 • Remove reference to driving history check in telephone screening script • Add question about vehicle selection to telephone screening script • Add a start and end time to Appendix J- Vehicle Orientation Checklist • Clarify that the participant will be afforded the opportunity to look at a study vehicle at the intake session prior to providing written informed consent • Alter the order of activities in the study protocol such that the focus group occurs after the participant has concluded his or her naturalistic driving experience • Adjust description of focus group protocol to allow for a revised number of participants and to clarify that images of the work products will be captured but that no still images of participants will be captured as part of the focus group. • Alter recruiting copy	1/24/2018	1/29/2018
Amendment 2	• Introduce $50 fuel supplement into compensation structure to be loaded onto ClinCards 3 weeks into the naturalistic driving period.	2/9/2018	2/26/2018
Amendment 3	• Revise focus group script to elicit more meaningful discussion among participants • Add safety-related questions to weekly interview script • Clarify the way in which the research team will respond to any safety-related concerns that come to light in the context of the weekly interview • Introduce drive swap one week into participants' naturalistic driving experiences	3/1/2018	3/6/2018

Appendix D. Demographics of Study Sample

Sample Demographics

	Cohort 1		Cohort 2		Cohort 3		
Year/Make/Model	**M**	**F**	**M**	**F**	**M**	**F**	**Total**
2015 Infiniti Q50	0	1	2	0	1	1	5
2016 Volvo XC90	0	1	0	2	1	0	4
2016 Mercedes E350	1	1	1	0	1	1	5
2017 Audi Q7	1	1	0	1	1	0	4
Total	2	4	3	3	4	2	18
Age Distribution	Mean= 73 Range:70-76		Mean= 72 Range:71-77		Mean= 75 Range:71-79		Mean= 74 Range:70-79

Appendix E. Participant Screening Criteria List

All participants must meet the following criteria:

- Must hold and able to present a valid U.S. driver's license at time of participation and have no history of license suspension.
- Must be willing to show proof of liability insurance at time of participation
- Must be between 70 and 79 years old
- Must be a U.S. citizen or eligible to work in the U.S.
- Must be willing to provide SSN or VT ID #.
- Must be able to drive an automatic transmission without assistive devices or special equipment.
- Must currently drive at least 2 days a week
- Must have insurance on their current vehicle
- Must not have more than two driving violations in the past 3 years.
- Must not have caused an injurious accident within the past 3 years.
- Must not smoke in the study vehicle
- Must not allow anyone else to drive the study vehicle
- Must not drive in areas where video recording is not allowed
- Must not use study vehicles to tow
- Preference for those who do not routinely wear sunglasses while driving
- Must not use study vehicles to haul flammable or hazardous materials
- Must not drive the study vehicle off road
- Must not use the study vehicle as a 'for hire' vehicle such as a taxi, Uber, Lyft or other similar service
- Preference for participants who plan to remain in the area for the next 18 weeks (3 waves of data collection, each taking 6 weeks, are planned. For ease of scheduling, preference will be given to individuals with the flexibility to be part of any one of the three cohorts.)
- Must not currently drive/own a vehicle with AVTs
- Preference for drivers who drive at least 3 days per week
- Preference for those who do not need to transport a child using a car safety or booster seat on a regular basis
- Must be able to fluently read, write, and speak English.

- Primary investigator will have discretion to adjudicate cases where a prospective participant has participated in other studies at VTTI.

Health-Related Criteria

- Cannot have a history of neck or back conditions which still limit their ability to participate in certain activities.
- Cannot have a history of brain damage from stroke, tumor, head injury, recent concussion, or disease or infection of the brain.
- A current heart condition that limits their ability to participate in certain activities may prove exclusionary at the primary investigator's discretion.
- Cannot have current respiratory disorders or disorders requiring oxygen.
- Cannot have had epileptic seizures or lapses of consciousness within the last 12 months.
- Cannot have chronic migraines or tension headaches (averages no more than one per month).
- Cannot have current problems with motion sickness, inner ear problems, dizziness, vertigo, or balance problems.
- Cannot have uncontrolled diabetes (have they been recently diagnosed or have they been hospitalized for this condition, or any changes in their insulin prescription during the past 3 months)
- Must not have had any major surgery within the past 6 months (including eye procedures).
- Cannot have advanced osteoporosis (softening or weakness of the bones)
- Cannot currently be taking any substances that may interfere with driving ability (cause drowsiness or impair motor abilities).
- Must have normal (or corrected to normal) hearing and vision in both eyes.

Appendix F. Telephone Screening Script

Screening Date_____ **Screener**_____ **Screening #:** _____

<Senior Mixer>: Screening Questionnaire

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

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

Hello. My name is _____ and I'm with the Virginia Tech Transportation Institute, here at the Smart Rd, in Blacksburg, VA. We are currently recruiting people to participate in a research study to learn more about how people typically use some of the features found in today's newer vehicles.

Participation in this study involves driving our research vehicle instead of your own vehicle for a 6-week period. We will provide hands-on training on all key aspects of the research vehicle. The vehicle will be either an Audi, Infinity, Mercedes, or a Volvo. If you choose to participate, full details of what is required of you as a participant will be provided in writing for your review before any appointments would be scheduled. The research vehicle is instrumented with cameras which will collect video of the surrounding roadway and your face anytime the vehicle is turned on. The monitoring system will be unobtrusive; it won't affect your ability to drive safely and you won't have to interact with it at all. No one is allowed to drive the vehicle except the enrolled participant; and no smoking will be allowed inside the research vehicle. Also, you must agree that no hazardous materials, flammable materials, or illegal materials will be hauled using the research vehicle.

All collected data are kept completely secure and your name will never be associated with the recorded data. There will be some questionnaires and assessments to complete before you begin driving the vehicle, a short weekly interview during the study, and a survey to complete at the end of your participation. In addition, we will ask you to participate in a 90 minute focus group discussion of your driving experience along with other participants in this study. This focus group session will be recorded.

Each research vehicle will come with a full tank of fuel. Participants do not need to return the vehicle with a full tank of fuel. Participants will be compensated $200 with a MasterCard for full participation. You will receive a MasterCard loaded with $25 when you enroll in the study and

complete a series of surveys, another $25 when you receive training on the operation of the vehicle, $100 after completing six weeks of driving and participating in a short phone interview about your driving experience each week, and another $50 after you participate in a 90 minute focus group discussion of your driving experience, for a total possible maximum of $200.

Any questions yet?

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

Participants will also be asked to undergo a driving history check

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

Participant Eligibility Questions:

1. Do you currently hold, a valid U.S. driver's license, which you can present at the time of the study? YES _____ NO _____ If yes, how long have you held a U.S. license? _____

   Has your license ever been suspended? YES _____ NO _____
   If yes, how many times & when?
   _____
   Is your license valid now?
   _____

Criterion: they are ineligible to participate if unable to present a VALID U.S. driver's license at their appointment and they must be an experienced driver (at least 2 years). Can't include time with a Learner's Permit during the 2 years of experience. (Must be fully licensed for at least 2 years).

Must not have a history of license suspension during the past 7 years or have a history of multiple suspensions.

NOTE: They will be reminded that they must present a driver's license at their appointment if scheduled.

2. Does your current U.S. Driver's License have any restrictions? YES _____ NO _____
Criterion: Must present a driver's license with NO restrictions at their appointment if scheduled. For example, can't be restricted to only driving to and from work. Being a participant doesn't qualify as 'work'.

3. What is your current age? _____ YOB_____

Criterion: Must be between 70 and 79 years old to participate.

4. Are you a U.S. Citizen? YES ____ NO _____

If No, are you a permanent resident with a valid green card to work anywhere in the U.S.?

YES ____ NO _____

To clarify, Are you a Visa holder or do you have a *Valid Green Card with permanent resident status*? Visa ____ Green Card ____

If you have a Visa you will not be eligible to participate. Those with a Permanent Resident Green Card are eligible.

Notes:_____

_____

Criterion: Must be a U.S. citizen or permanent resident (green card holder able to work anywhere in the U.S. with NO restrictions such as limit on number of hours he or she can work each week or place he or she is allowed to work, for example, he or she can't be limited to only working at 1 company or VT only). Visa holders are not applicable.

5. On average, how many days do you drive your vehicle each week? _____

Comments:

_____

Criterion: Must drive at least 2 days per week. Preference will be given to those that drive 3 days a week.

6. Is your vehicle equipped with Adaptive Cruise Control?

YES _____ NO _____

Criterion: Must not drive/own a vehicle equipped with AVTs.

7. Is your vehicle equipped with lane keeping technology (e.g., Lane Departure Warning or Lane Keep Assist)?

YES _____ NO _____

Criterion: Must not drive/own a vehicle equipped with AVTs.

8. Is your vehicle equipped with a Blind Spot alert system?

YES _____ NO _____

Criterion: Must not drive/own a vehicle equipped with AVTs

a) Is your vehicle equipped with automated braking?

YES _____ NO _____

Criterion: Must not drive/own a vehicle equipped with AVTs.

9. Do you understand and agree that no one other than you will be allowed to drive the research vehicle? YES_____ NO_____

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

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

YES _____ NO _____

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

11. Do you need to transport a child requiring a car safety seat or booster seat on a regular basis? YES_____NO_____

Criterion: Preference given to those who do regularly not transport a child who requires a car seat or booster seat. PI to make final decision.

b) Do you routinely wear sunglasses while driving?

YES_____NO_____

Criterion: Preference for those who do not routinely wear sunglasses while driving.

12. Do you have any events or plans that you know of over the next three to four months, such as birth of a child, planned surgeries, extended vacations, trips, or travel plans, which would impact your normal routine?

Notes:

_____

This question is not exclusionary, but instead designed to gather information that will help the PI make decisions about scheduling.

13. If you participate, you will not be allowed to haul any flammable or hazardous materials with the research vehicle. Are you okay with this? YES _____ NO _____

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

14. Do you agree to not smoke or allow any smoking inside the research vehicle? YES_____ NO_____

Criterion: Must agree to not allow any smoking or vaping inside the research vehicle.

15. If you participate, you will not be allowed to drive the vehicle off road on unpaved roads, dirt access roads, or long unpaved driveways. Are you okay with this? YES _____ NO _____

Comments:

_____

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

16. For research purposes, do you identify as Male, Female [pause], or Other?, (Circle one)

Criterion: The total number of participants will be gender balanced if possible.

17. If selected to participate in this study, will you provide your SSN or VT ID number, at the time of participation? *(for compensation documentation and tax recording purposes Va Tech will require them to complete a W-9)* YES _____ NO _____

Please note: VA Tech would never require your SS # or any personal banking information during a phone call. If scheduled to participate in any type of study, VT would send instructions whether you need to bring personal information for an appointment, in order to complete required paperwork at a study location.

Criterion: Must be willing to provide SSN or VT ID number for compensation purposes.

18. Do you (or the vehicle owner) have liability insurance on the vehicle you normally drive?
YES _____ NO _____

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

YES _____ NO _____

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

19. Do you use your primary vehicle for hire, such as Uber or taxi? YES _____ NO _____

If yes, please specify:_____

Criterion: Must not use their primary vehicle as a "for hire" vehicle, such as Uber driver, or taxi. If they use their primary vehicle "for hire" as a second job or on occasion, they agree they will not use the research vehicle while working "for hire". They must meet the miles traveled criteria while not doing "for hire" work.

20. Have you participated in any experiments or driving studies at the Virginia Tech Transportation Institute? YES _____ NO _____

If yes, describe the study:

_____

Participation in other VTTI studies will not be strictly disqualifying; primary investigator will have discretion to adjudicate these cases.

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

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

_____

_____

21. Do you have any mobility limitations which may cause you to require assistance getting in and out of the motor vehicle or walking to and from the building and out to the research vehicle? Yes____ No_____
    a. Are you able to drive an automatic transmission without assistive devices or special equipment? Yes____ No_____

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

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

If yes, please
explain:_____

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

23. Any Head Injury, Stroke, or illness or disease affecting the Brain? YES _____ NO _____
If yes, please
explain:_____

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

24. Current heart condition which limits your ability to participate in certain activities? YES _____ NO _____
If yes, please
explain:_____

Presence of a heart condition will not be strictly disqualifying. The primary investigator will have discretion to adjudicate these cases.

25. Current respiratory disorder/disease or any condition which requires oxygen? YES _____ NO _____ Notes:_____

Cannot have current respiratory disorder/disease or disorder/disease requiring oxygen.

26. Any epileptic seizures or lapses of consciousness within the past twelve months?

YES _____ NO _____
Notes:_____

Cannot have had an epileptic seizure or lapse of consciousness within the past 12 months.

27. Chronic migraines or tension headaches? YES _____ NO _____
If yes, do they occur more than once a month on average? YES _____ NO _____

Notes:
_____

Cannot have, on average, more than one migraine or severe headache per month during the past yr.

28. Current problems with motion sickness, inner ear problems, dizziness, vertigo, or balance problems? YES _____ NO _____

Cannot have current problems with motion sickness, inner ear problems, dizziness, vertigo, or balance problems.

29. Do you currently have uncontrolled diabetes? YES _____ NO _____

Cannot have uncontrolled diabetes (frequent low/high blood sugar levels that they are struggling to keep regulated). Cannot have been recently diagnosed or have been hospitalized for this condition or incurred any changes in their insulin prescription during the past 3 months.

30. Do you currently have advanced osteoporosis? YES _____ NO _____

Criterion: Cannot have advanced osteoporosis

31. Have you had any major surgery within the past six months, including any eye procedures?

YES _____ NO _____

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

32. Are you currently taking any long term medicines or substances that may cause drowsiness or impair your driving ability? YES _____ NO _____

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

33. Do you have normal, or corrected to normal, vision in both eyes? YES _____ NO _____

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

34. Are you comfortable reading, writing, and speaking English? YES _____ NO _____

NOTE: If the screener finds during the phone interview, the caller is struggling with their ability to communicate fluently in English or has a severe speech impediment (i.e. stuttering) that may affect their ability to communicate their perceptions of the system, the screener may determine the caller as ineligible.

Must be comfortable reading, writing, and speaking English

35. Do you regularly drive in areas where videotaping or audio recording is not allowed, for example, military installations, high-security facilities, etc.? YES _____ NO _____
Notes:_____
____

Criterion: Cannot drive in areas where videotaping/audio recording is not allowed.

36. Are you an identical twin? YES_____ NO_____

If yes, Does your twin live in your household? YES _____ NO _____

If no, Would you be willing to agree not to let your twin drive the vehicle for the duration of the study?

YES _____ NO _____

Criterion: Identical twins who share housing are not enrolled due to difficulties with driver identification. If participants have a twin, not living with them, they agree to not allow the twin to drive the vehicle at any time during the study.

How did you hear about this project? _____

If the individual is eligible:

Availability: _____

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

E-mail address: _____

Home Phone #: _____ Cell#_____ Work #_____

Home Address_____

City: _____ State_____ Zip_____

Work Address_____

City: _____ State_____ Zip_____

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

Scheduled on (date & time):_____

_____

Would you like to be contacted for future studies? Yes: _____ No: _____

If yes, collect the following:

Last Name: _____ First Name: _____Y.O.B. _____

Home Phone #: _____ Cell#_____ Work #_____

Town or city: _____ State: _____ Zip: _____

Specialty Driver's License_____
If CDL, endorsements: _____
Restrictions: _____
Make and Model of Primary Vehicle (light) _____

Appendix G. Intake Questionnaire

Pre-Drive Questionnaire

1. Demographic Questions and Background

1) Please specify your gender.

a) Male
b) Female
c) Other: _____
d) Prefer Not to Disclose

2) What is your current age? _____

3) What is the year, make and model of your primary vehicle?

Year:_____

Make: _____

Model:_____

4) With what ethnicity do you most closely relate yourself?

a) American Indian/Native American

b) Asian c) Black/African American

d) Hispanic/Latino

e) White/Caucasian

f) Pacific Islander

g) Other

5) Do you now have, or have you ever had, a disability that prevented you from driving?

a) Yes b) No

5a. if yes, please elaborate:

Disability: _____

About how many years ago? _____

Approximate duration of not being able to drive_____

6) What is your current level of employment?

a) Employed full time

b) Employed part time

c) Self employed

d) Unemployed/ Looking for work

e) Homemaker

f) Student

g) Retired

7) What is the highest level of education you have completed?

a) Less Than Middle School/No Education

b) Middle School

c) High School/GED

d) Associate's Degree

e) Bachelor's Degree

f) Master's Degree

g) Doctoral Degree

h) Professional Degree

2. Memory

Instructions: For the next several questions, please compare yourself to 5 years ago. **Response options: a) Yes b) No.**

8) Are other people telling you that you are more forgetful?

9) Is concentration and focusing more difficult than it was 5 years ago?

10) Are you being told that you are repeating yourself?

11) Do you forget names, where you have left things, or appointments more than 5 years ago?

12) Do you more frequently forget something you have just read compared to 5 years ago?

13) Do you lose your train of thought more frequently in conversation than 5 years ago?

14) Do you feel that you are not as sharp as you were 5 years ago?

15) Are simple everyday tasks like playing cards and balancing a checkbook more difficult than they were 5 years ago?

16) Do you have more trouble recalling words than you did 5 years ago?

3. Vision

Instructions: The next questions are about how much difficulty, if any, you have doing certain activities. If you wear glasses or contact lenses for that activity, assume that you are wearing them.

Response options:

1	2	3	4	5	6	7

No difficulty **Moderate Difficulty** **Extreme Difficulty**

17) How much difficulty do you have reading ordinary print in newspapers?

18) How much difficulty do you have doing work or hobbies that require you to see well up close, such as cooking, sewing, or repairing things around the house?

19) Because of your eyesight, how much difficulty do you have finding something on a crowded shelf?

20) How much difficulty do you have reading street signs or the names of stores?

21) Because of your eyesight, how much difficulty do you have seeing movies, plays, or sports events?

22) Because of your eyesight, how much difficulty do you have going down steps, stairs, or curbs in dim light?

23) Because of your eyesight, how much difficulty do you have noticing objects off to the side while you are walking along?

4. Physical Mobility Impairment

24) How easy is it to turn your head and neck?

1	2	3	4	5	6	7

Very easy Somewhat easy Somewhat difficult Very Difficult

25) How easy is it climb up and down one flight of stairs?

1	2	3	4	5	6	7

Very easy Somewhat easy Somewhat difficult Very Difficult

26) How easy is it to do heavy housework like scrubbing a bath- tub?

1	2	3	4	5	6	7

Very easy Somewhat easy Somewhat difficult Very Difficult

5. Medical conditions

27) Have you been diagnosed by a doctor or medical professional as having any of the following (please check all that apply)?

a) Alzheimer's disease or any other memory disorder
b) Arthritis
c) Diabetes
d) Osteoporosis
e) Hearing impairment? (If yes, do you use a hearing aid?)
f) Stroke
g) Heart attack
h) Other serious medical condition

6. Current driving

28) How many hours do you estimate you spend driving each week?

a) 0 hrs b)1-5 hrs c) 6-10 hrs d)11-15 hrs e)16-20 hrs f)More than 20 hrs

29) How enjoyable do you find driving?

1	2	3	4	5	6	7

Not Enjoyable **Very Enjoyable**

30) How old were you when you got your first license?

_____year/_____age

31) Have any restrictions been placed on your current license? If yes, please specify_____

32) Do you wear glasses or contact lenses when you drive? a) Yes b) No

33) Do you wear a seatbelt when you drive?

c) Always
d) Sometimes
e) Never

34) Which way do you prefer to get around?

a) Drive yourself
b) Have someone drive you
c) Use public transportation
d) Take a taxi
e) Use a rideshare service (e.g., Uber or Lyft)
f) Walking or Biking
g) Other_____

35) How fast do you usually drive compared with the general flow of traffic?

a) Much faster

b) Somewhat slower

c) Somewhat faster

d) Much slower

e) About the same

36) Has anyone suggested over the past year that you limit your driving or stop driving?

a) Yes b) No

36a. if yes, who made that suggestion to you? (check all that apply)

a.) spouse
b.) son/daughter
c.) friend
d.) physician
e.) other health care provider (e.g., physical or occupational therapist)
f.) other

37) How would you rate the quality of your driving?

h) Excellent
i) Good
j) Average
k) Fair
l) Poor

38) If you had to go somewhere and didn't want to drive yourself, what would you do?

a) Ask a friend or relative to drive you

b) Call a taxi or take the bus

c) Drive yourself regardless of how you feel

d) Cancel or postpone your plans and stay at home

e) Other (specify): _____

8. Accidents and Citations

39) How many accidents have you been involved in over the past year when you were the driver? Please list the number of all accidents, whether or not you were at fault.

____ accidents

40) How many accidents have you been involved in over the past year when you were the driver where the police were called to the scene?

____ accidents

41) How many times over the past year have you been pulled over by the police, regardless of whether you received a ticket?

____ times

42) How many times in the past year have you received a traffic ticket (other than a parking ticket) where you were found to be guilty, regardless of whether or not you think you were at fault?

____ times

9. Driving Avoidance

43– 53 How Often Do You Avoid Driving?

Response options coded as: always or often avoid it, rarely or never avoid it.

1	2	3	4	5	6	7
Always	**Often avoid it**	**Rarely avoid it**				**Never avoid it**

43) At night

44) Alone

45) On interstates or freeways

46) At rush hour or other peak traffic times for safety reasons

47) On busy roads for safety reasons

48) In the rain

50) To places you haven't been before

51) In the snow

52) In icy conditions

53) Parallel parking

Appendix H. Opinions on Autonomous Vehicle

1. Does your personal car (i.e., the car you own and normally drive) have any of the following features? Please select ***all*** that apply.

a) Adaptive cruise control
b) Obstacle detection
c) Lane departure warning
d) Lane keep assist
e) Automatic braking
f) Automatic parking
g) Other
h) None of the above
i) Not sure

2. Which of the following semi-autonomous features do you think would be helpful to you or enhance safety? Please select ***all*** that apply

a) Adaptive cruise control
b) Obstacle detection
c) Lane departure warning
d) Lane keep assist
e) Automatic braking
f) Automatic parking
g) Other
h) None of the above
i) Not sure

Lane control Features

1) I can rely on the lane control features to function properly while I am doing something else.

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

2) The lane control features provide alerts when needed.

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

3) The lane control features give too many false alerts.

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

4) The lane control features are dependable.

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

5) I am familiar with the lane control features.

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

6) I feel safe using the lane control features.

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

7) I trust the lane control features.

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

Acceleration and braking Features

8) I can rely on the acceleration and braking features to function properly while I am doing something else.

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

9) The acceleration and braking features provide alerts when needed.

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

10) The acceleration and braking features give false alerts.

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

11) The acceleration and braking features are dependable.

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

12) I am familiar with the acceleration and braking features

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

13) I feel safe using the acceleration and braking features.

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

14) I trust the acceleration and braking features.

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

15) Considering both lateral as well as acceleration and braking features, please indicate your feelings about the following statement.

I have a high degree of trust in the automated vehicle technologies in my study vehicle.

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

16) Considering both lateral as well as acceleration and braking features, please indicate your feelings about the following statement.

I have a high degree of satisfaction with the automated vehicle technologies in my study vehicle.

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

17. Do you have any of the following concerns regarding automated vehicle technologies (AVT)? Choose all that apply:

a) The system's ability to maintain awareness of surrounding vehicles or roadway infrastructure
b) The system's ability to maintain vehicular control under typical roadway conditions (e.g., steering, braking, acceleration)
c) System malfunction or stops working mid-drive

d) System could be ‘hacked’ by others, leading to a crash
e) Additional vehicle costs
f) Other: _____

3. Cost considerations aside, I would prefer for the next vehicle I purchase to have some level of AVT.

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

4. Including cost considerations, I would prefer for the next vehicle I purchase to have some level of AVT.

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

Appendix I. Instructions for the Clock Drawing Test

Step 1: Give patient a sheet of paper with a large (relative to the size of handwritten numbers) pre-drawn circle on it. Indicate the top of the page.

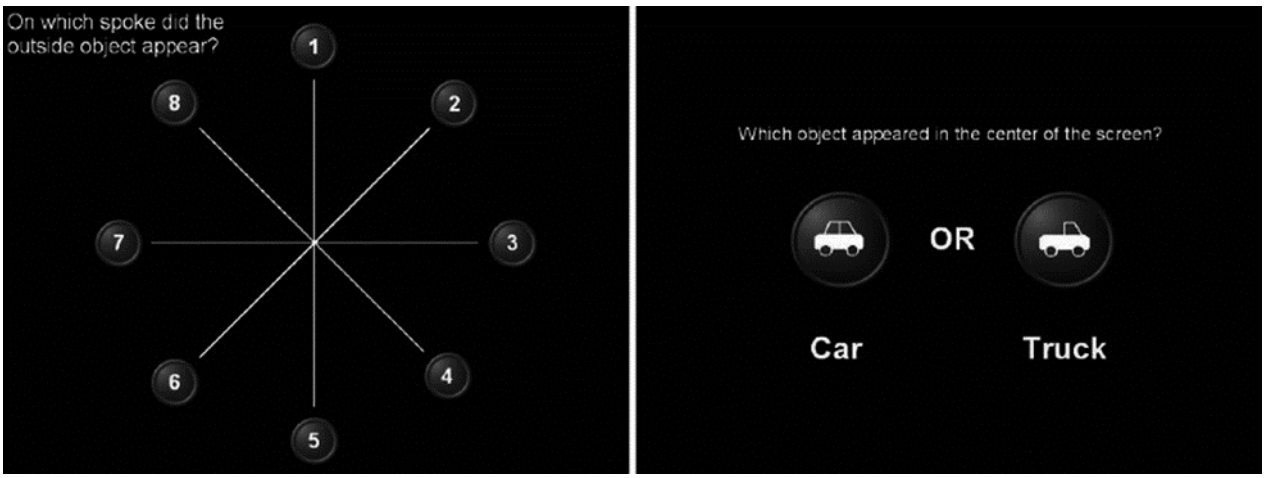
Step 2: Instruct patient to draw numbers in the circle to make the circle look like the face of a clock and then draw the hands of the clock to read "10 after 11."

Appendix J. Useful Field of View Manual

Visual Information Processing Speed (UFOV®) Test

Participants will briefly be presented one of two very similar target stimuli (truck or car icon that differ only slightly) in the center of the display. In addition to this, a second simultaneously presented target icon that is the same as the central target is presented in one of eight possible peripheral locations at varying eccentricities in a 35-degree region around the central visual field.

Participants are asked to identify both what the central target is as well as the location of the peripheral target. The presentation duration of the stimulus display is dynamically varied up or down until the participant reaches a 75% correct response accuracy. Presentation time is recorded.



Administer the Visual Information Processing Speed (UFOV®) Test

The monitor needs to be roughly 18 inches away from the participant. Note that the UFOV® part of the program advances on its own through the instruction pages. Experimenters need to be ready to read the instructions as soon as it has been opened. If participant asks questions or is distracted and the experimenter needs to start again, press both mouse buttons to get to the navigation page and restart the test.

Open Useful Field of View (UFOV) and read instructions to participant exactly as printed on screen- though clarify that the sound will not be on.

Begin practice session.

If more practice is suggested by the program, a screen will appear after practice suggesting a repeating of the instructions

If participant chooses to repeat the instructions/practice, click “Repeat Instructions”

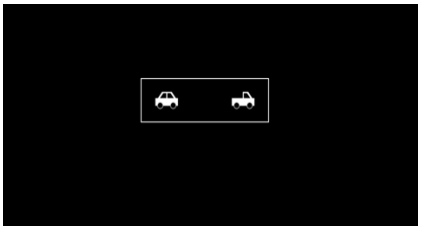
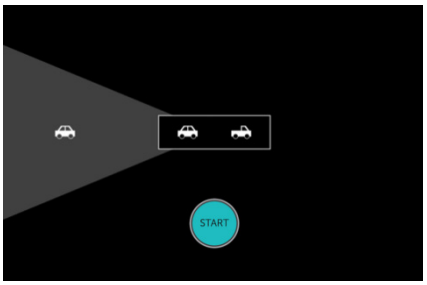
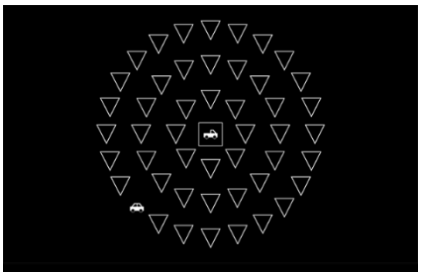
If participant chooses to continue in spite of the suggested repeated instructions/practice, click "continue".

Participant may go through the practice session up to 3 times as desired by the participant.

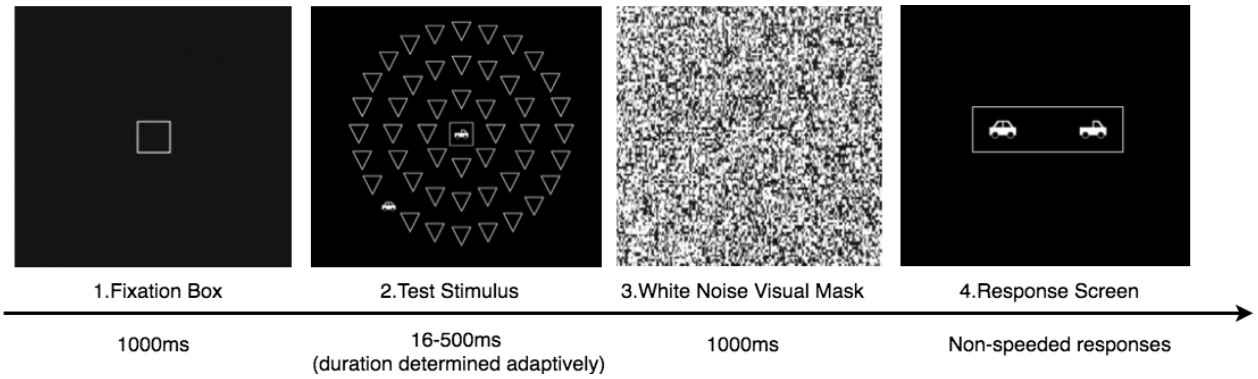
Click "continue" to begin the test.

Three Subtests in UFOV Test

Examples of icons used in UFOV test: Car :  Truck:  Distractor: 

Subtest No.	Measure	Task Description	Test stimulus display
1	Processing speed	Task requires participant identified the target, which is a car or a truck displayed at the center of the screen.	
2	Divided attention	Task requires participants to identify the center target and the location of peripheral target displayed simultaneously	
3	Selective attention	Task requires participants to identify the center target and the location of peripheral target displayed simultaneously, but includes visual distractors displayed around targets.	

For each trial, four display screens (Figure) were displayed sequentially. The assessment software automatically adjusted the length of the test stimulus displayed according to participant responses.



Four screens displayed in UFOV test trial (take Subset 3 as an example).

Appendix K. Intake Session Protocol

Older Driver's Impressions of Level 2 Autonomous Vehicle Technologies

- **Packet Contents**
  - **2 copies of informed consent**
  - **W-9 form**
  - **Clincard**
  - **Ipad for clincard payment**
  - **Clock drawing test**
  - **Paper copies of surveys as backup**

1. Escort participant to confidential prep room for a final eligibility check and review and signing of the informed consent form. Offer the participant a bathroom break before beginning the procedures.

2. Direct participant to sit in non-rolling chair.

3. *The overall scope of this project is to better understand drivers' opinions and feelings towards advanced convenience features. We would like to place you into one of our vehicles with these advanced convenience features. The duration of the project will be for 4 weeks, but you can choose to discontinue at any point. We are interested in your opinions of the various systems and your feelings about using them. You will be able to use the vehicle as you normally would your own. When we get to that point, I will spend time with you showing you the vehicle and showing you how to use not only the basic features such as windshield wipers and the radio, but also the advanced convenience features.*

4. As a final eligibility screening, the participant will be asked to present his or her valid U.S. Driver's License and proof of liability insurance. The researcher will verify that the license is valid (by checking the date and other state-specific factors, as available) and confirm that the participant has current liability coverage and return all documentation to the participant
   a. Current Insurance – look for expiration date and name to match
   b. Current license – look for expiration date and name to match

5. Once it has been determined that the participant is eligible, the consent process will begin. Review the consent form with the prospective participant, answering all questions. Should the prospective participant wish to enroll in the study following this review, the researcher will ask him or her to sign two copies of the informed consent form, one of which will be given to the participant and the other stored in a locked cabinet at the research facility.
   a. Make sure both consent forms are signed and dated by both parties

6. Next information necessary for participant compensation will be collected. This includes Social Security Number and address, necessary to ensure proper compensation via ClinCards (debit cards used by research institutions to accomplish compensation of subjects). The participant will be asked to sign a W-9 tax form (Appendix D).
    a. Fill out W-9 form – highlighted portions
    b. Fill out clincard information on ipad

7. Take a picture of the participant for driver identification purposes.

8. Complete clock drawing assessment
    a. Instruct participant: *"Draw numbers in the circle to make the circle look like the face of a clock, and then draw the hands of the clock to read "10 after 11""*
    b. Do not repeat instructions more than twice total, if participant requires more repetition, tell them to do their best (unless it is simply a hearing issue).

9. Complete the Intake Questionnaire - note that the participant may leave any questions blank except for participant number.
    a. Verify participant ID at beginning of questionnaire

10. Complete the Pre-Study AVT Exposure Questionnaire – note that the participant may leave any questions blank except for participant number.
    a. Verify participant ID at beginning of questionnaire

11. Complete the Useful Field of View test
    a. Log into Prep Computer using:
        i. ".\PrepUser"
        ii. "Vttiproom1580.."
    b. The monitor needs to be roughly 18 inches away from the participant
    c. Use Firefox to pull up a browser, several bookmarks should be present at the top of the browser
    d. Navigate to UFOV bookmark at top of screen
    e. Click "sign in" on upper right
        i. Email from excel sheet
        ii. smxstudy
    f. Note that due to the system using a touchscreen, the LAST image clicked on will appear grayed out
    g. Note that the UFOV® part of the program advances on its own through the instruction pages. Experimenters need to be ready to read the instructions as soon as it has been opened. If participant asks questions or is distracted and the experimenter needs to start again, press both mouse buttons to get to the navigation page and restart the test.

h. Open Useful Field of View and read instructions to participant exactly as printed on screen- though clarify that the sound will not be on.
i. Begin practice session.
j. If more practice is suggested by the program, a screen will appear after practice suggesting a repeating of the instructions
    i. If participant chooses to repeat the instructions/practice, click “Repeat Instructions”
k. If participant chooses to continue in spite of the suggested repeated instructions/practice, click “continue”
l. Participant may go through the practice session up to 3 times as desired by the participant.
m. Click “continue” to begin the test

12. Pay participant on Ipad using ClinCard system

Escort participant outside to briefly see the vehicle they will use in the study – ensure the participant notes they are comfortable driving that style of vehicle.

Appendix L. Vehicle Training Checklist

Start time: _____ End time: _____

	Vehicle Equipment
	Participant shown all DAS components
	Participant advised not to disconnect OBD-II cable
	Participant advised not to hang items from the head unit or block the cameras
	Participant given opportunity to ask questions about the data collection equipment
	Basic Vehicle Features
	Key Fob and Vehicle start procedures
	Windshield Wipers
	Headlights and High beams
	HVAC controls- manual and on vehicle display
	Sunroof and interior lights (sunroof and vent, dome lights, reading lights)
	Pairing cellphone with Bluetooth system
	Gauges (speed, fuel level, engine temperature)
	Vehicle Information Display (include use of steering wheel buttons to change display)
	Gear shift selector
	Use of Start/Stop button to turn off the vehicle
	Basic Vehicle Features review (point out vehicle manual location and answer participant questions)
	Advanced Vehicle Features
	Instruction on Advanced Features
	Driver Assistance System
	Adaptive Cruise Control
	Active lane control with lane departure warning
	Blind spot warning

	Review of basic safety precautions
	Test Drive with Researcher Driving
	Test Drive with Participant Driving

I certify that I have provided instruction according to the checklist above.

_____ _____ _____

Researcher Signature Researcher Name (Print) Date

I certify that I have received instruction according to the checklist above.

_____ _____ _____

Participant Signature Participant Name (Print) Date

Appendix M. Vehicle Condition Checklist

Year:_____Make:_____ Model:_____ Date:_____

VEHICLE CONDITION CHECKLIST

□ Prior to installation □ After installation □ Prior to de-installation □ After de-installation

	EXTERIOR			Description
BODY	**Panels**			
	Bumpers			
	Doors			
	Hood			
	Trunk			
	Tailgate			
	Grill			
	Trim			
	Roof Rack			
	License Plate			
	Paint			
GLASS	**Glass**			
	Mirrors			
	Wipers			
LIGHTS	**Headlights**			
	Taillights			
	Brake lights			
	Parking lights			
	Hazard lights			
	Reverse lights			
	Turn signal			
	License plate lights			
	Fog lights			
INTERIOR				
ELEC	**Seats**			
	Seatbelts			
	Carpet/Floor Mats			
	Door trim/panels			
	Headliner			
	Visors			
	Handles:Ceiling/Do			
	Dashboard			
	HVAC			
	Stereo			

I, _____ have read the above description of my vehicle's condition and agree that it accurately reflects the current condition of my vehicle. This inspection was conducted:

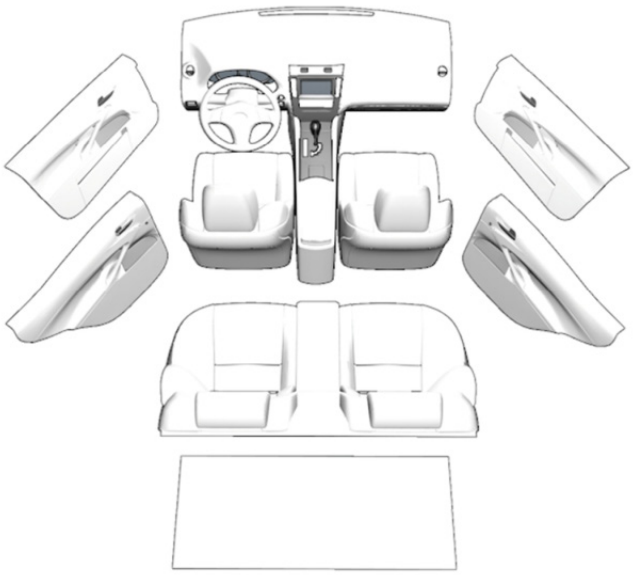
□ Prior to installation □ After installation □ Prior to de-installation □ After de-installation

_____

_____

Signature ***Date*** _____ ***AM / PM***

Time



Appendix N. Weekly Interview Script

Date: _____

Participant Number: _____

Vehicle YMM: _____

Week of Study: _____

Inform the participant: I have some questions for you about your experience with the vehicle you have been driving. These will help us better evaluate your comfort with automated vehicle technologies.

Probe Questions:

Did you drive the study vehicle this week? Y or N

a. If participant says no, ask him/her the reason.
b. If the participant says yes, ask how many days this week did you drive the study vehicle?

0	1	2	3	4	5
None	1 day	2 days	3-4 days	4-5 days	Almost Everyday

Did you use or experience any of the automated vehicle technologies this week? Y or N

If Y, which ones? _____

How often did you use or experience any of these automated features?

	1	2	3	4	5
Adaptive Cruise Control	On some rare occasions	Less than half the time I use the car	About half the time I use the car	More than half time I use the car	Almost every time I use the car
Blind Spot Alert	On some rare occasions	Less than half the time I use the car	About half the time I use the car	More than half time I use the car	Almost every time I use the car
Lane Alert	On some rare occasions	Less than half the time I use the car	About half the time I use the car	More than half time I use the car	Almost every time I use the car

Lane Keeping	On some rare occasions	Less than half the time I use the car	About half the time I use the car	More than half time I use the car	Almost every time I use the car

Did weather impact your experience with the automated vehicle technologies? Y or N

If Y, please elaborate

Did traffic impact your experience with the automated vehicle technologies? Y or N

If Y, please elaborate

Did trip distance impact your experience with the automated vehicle technologies? Y or N

If Y, please elaborate

Did the type of road you traveled impact your experience with the automated vehicle technologies? Y or N

If Y, please elaborate

Did anything else impact your experience with the automated vehicle technologies? Y or N

If Y, please elaborate

Please indicate your feelings about the following statements regarding the degree to which you trust the vehicle technologies.

I have a high degree of trust in the adaptive cruise control technology in my study vehicle.

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

I have a high degree of trust in the blind spot alert technology in my study vehicle.

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

I have a high degree of trust in the lane alert technology in my study vehicle.

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

I have a high degree of trust in the lane keeping technology in my study vehicle.

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

Please indicate your feelings about the following statements regarding your level of satisfaction with the vehicle technologies.

I have a high degree of satisfaction with the adaptive cruise control technology in my study vehicle.

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

I have a high degree of satisfaction with the blind spot alert technology in my study vehicle.

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

I have a high degree of satisfaction with the lane alert technology in my study vehicle.

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

I have a high degree of satisfaction with the lane keeping technology in my study vehicle.

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

Appendix O. Focus Group Working Guide

Greetings (2-3 minutes)

- Greet participants and check names to ensure correct participants are in focus group.
- As them come in, ask them to make a name tent.

Facilitator Introduction and Ground Rules (2-3 minutes)

Hello, our names are (NAMES). We are researchers at the Virginia Tech Transportation Institute. Thank you for taking the time to come and share your thoughts and opinions.

PURPOSE OF THE MEETING

- Purpose of this meeting is to discuss what you thought about the advanced features you used and experienced in the study vehicle that you drove.
- We are going to ask you some questions and need you to respond openly and honestly. There are no right or wrong answers—we just want your opinions.

CONFIDENTIALITY

- We are recording this discussion. Please speak loudly and clearly so we can get a good recording of your comments.
- We will summarize the discussions, but what you say will not be linked to your name.
- If you feel uncomfortable, you can refuse to answer a question or you may stop.

LOGISTICS

- This focus group will run for about 90 minutes, we are very appreciative of the time that you are spending and will honor it by not running over.
- Bathrooms are located (DIRECTIONS).
- Please silence phones and only take a call if it is important. This will help us avoid distractions and finish on time.

GROUND RULES

- Please let me know if you are uncomfortable with any of these rules. If you are ok with these rules, let's agree to follow them during this meeting.
    - Listen to each other
    - Everyone participate fully

- No side conversations
- Spelling does not count
- Don't criticize others
- Finish on time

Throughout the session I'll be summarizing your input on flip charts. Please stop me if I ever capture one of your comments incorrectly. I want to make sure I get your input recorded accurately.

Elapsed Time: About 5 minutes

Introductions and Transition (15 minutes)

INTRODUCTIONS (5)

- I'd like to start by going around the room.
  - **Please tell us your first name, the study vehicle you drove**, and **where you typically drove the vehicle**.
- *As each person speaks, make notes on flip chart.*

TRANSITION (10)

- Next I'd like to spend some time discussing the advanced features in your vehicles.
  - **What advanced features did you use or experience most while driving the study vehicle?**
- *Ask for clarification. Notes on flip chart. Check-in to be sure everyone gave an example.*
- *Potential follow-up prompts:*
  - *When did you experience these features?*
  - *What prompted you to use these features?*

Elapsed Time: 20

Key Questions: Feelings (25-30 minutes)

BRAINSTORM (5)

- Next we are going to talk about how you felt about the features you used or experienced.
  - **What one word describes how you felt about the advanced features in your vehicle when you began the study, during the first week of driving the vehicle**?
- Take sticky note and write one word that describes how you felt about the features when you began the study. Write BIG. One word. Emphasize 1st week (write 1 in corner of sticky note).
  - **What one word describes how you feel about the advanced features in your vehicle now– at the end of the study**?

CLARIFY (10)

- *Post week 1 and let each person describe their feeling. Hold sticky note about end of study.*
    - **Please describe this feeling for me**.
- *Post end of study, let each person describe feeling. As posting end of study, explore change.*
    - **Please describe this feeling for me.**

EXPLORE CHANGE (15)

- *Line participant comments in a row (e.g., Nervous-Impressed) as they provide responses. As they give end of study note, ask them what caused feelings to change or not change. Note on new sticky and post in line. *Remind them to make sure I capture their thoughts correctly.*
    - **NAME, what caused your feelings to change from _ to _?**
    - **NAME, what caused your feelings to remain the same?**
- *Summarize some of the primary causes of change or lack of change. (e.g., "It looks like time and experience led to a change in feelings for many of you, while some feelings didn't change due to distrust in the features.") Then ask:*
    - **What would make you feel more comfortable with these features?**

Max Elapsed Time: 50 [TAKE PICTURE OF STICKY NOTES]

Key Questions: BEST/LEAST (15 min)

- I'm passing out a sheet with "BEST" & "LEAST" boxes. In a few words please fill in:
    - **What is the one thing you liked the BEST about these features?**
    - **What is the one thing you liked the LEAST about these features?**
- Let's start with what you liked BEST.
    - *Did this apply to a specific feature or was it across them all?*
- What about what you liked LEAST.
    - *Did this apply to a specific feature or was it across them all?*
- Put up on flip chart major points, check-in to see that captured thoughts accurately and from each participant. Make sure and collect sheets. Discuss as time allows.

Max Elapsed Time: 65

Key Questions: View of safety (20 min)

- **Suppose a friend is considering purchasing a car with these features and they ask you if you think if they improve driving safety or not. What would you say?**
- I'd like to get some quotes from you. In 5 words or less write what you'd tell your friend. You can use more than one sticky note if you have more than one comment. Please write BIG. One idea per sheet.

- As you finish your quotes, come and put them up on the wall under a category – Yes, improves safety, No, doesn't improve safety, or Maybe … If you'd rather not get up, just give me your quotes and tell me where you'd like them to go.
    - *After they put their comments on the board, go through each one and ask for clarification. If time is running short, facilitator post.*
- **What prompted those of you with comments in the <u>(yes, maybe, no)</u> column, to give that response to your friend?**
- **(*If time allows ask*): For those of you with comments in the "No" column, what needs to happen before you'd tell your friend "Yes, it improves safety"?**

Elapsed Time: 85 [TAKE PICTURE OF STICKY NOTES]

<u>Ending (5)</u>

- **We asked you to participate because we value your input. To that end, what did we miss? Is there anything we should've discussed that we didn't?**
- *Open discussion.*

Elapsed Time: 90 MAX [TAKE PICTURES OF FLIP CHART PAGES]

<u>Closing/Payment</u>

- *Thank all the participants for their time and contributions!*
- *Remind them of how the payment process works.*

BEST & LEAST

The one thing I liked **BEST** about the features	The one thing I liked **LEAST** about the features

Table. Focus Group Question Route

Introduction	Please tell us your first name, the study vehicle you drove and where you typically drove the vehicle.
Transition	What advanced features did you use or experience most while driving the study vehicle?
Key Topic 1: Feelings about the features and how/why those feelings changed with exposure	What one word describe how you felt about the advanced features in your vehicle when you began the study, during the first week of driving the vehicle?
	What one word describes how you feel about the advanced features in your vehicle now, at the end of the study?
	What caused you feeling to change / remain the same?
	What would make you feel more comfortable with these features?
Key Topic 2: Best and least liked features	What is the one thing you liked the BEST about these features?
	What is the one thing you like the LEAST about these features?
Key Topic 3: View of safety	Suppose a friend is considering purchasing a car with these features and they ask you if you think if they improve driving safety or not. What would you say?

Appendix P. AVTs Settings of Four Manufacturers

AVT System Activation Across Manufacturers

Manufacturer	BSA	LA	ACC	LKA
Audi	On Automatically, can adjust brightness	Have to activate (40+ mph), steering, visual, and vibration	On automatically if enable cruise control, cannot turn off, also have automatic low-speed ACC	Have to activate (40+ mph), steering, visual, vibration
Infinity	On Automatically, can adjust brightness	On automatically, chimes and visual	On automatically if tap cruise control button, normal cruise if hold	Have to activate-chime, visual and steering input-can be set to high/low intervention
Mercedes	On Automatically	On automatically (37+ mph), visual and vibration	On automatically if enable cruise control, also have automatic low-speed ACC	On automatically if cruise control is on (37+ mph) –visual, vibration and steering (and directional braking)
Volvo	On Automatically	On automatically (30+mph)	On automatically if enable cruise control- can disable	On automatically (30+mph) – visual

Appendix Q. Description of Data Acquisition System (DAS)

All study vehicles were instrumented with a Data Acquisition System (DAS) comprised of the following components:

1. NextGen Main Unit
2. Head Unit
3. Network Box
4. Radar
5. Radar Interface Box
6. Solid-state data drive

DAS components are pictured in Figure 1:

Figure 1. DAS components.

Figure 2 depicts the location of each of the DAS components in the instrumented vehicle.

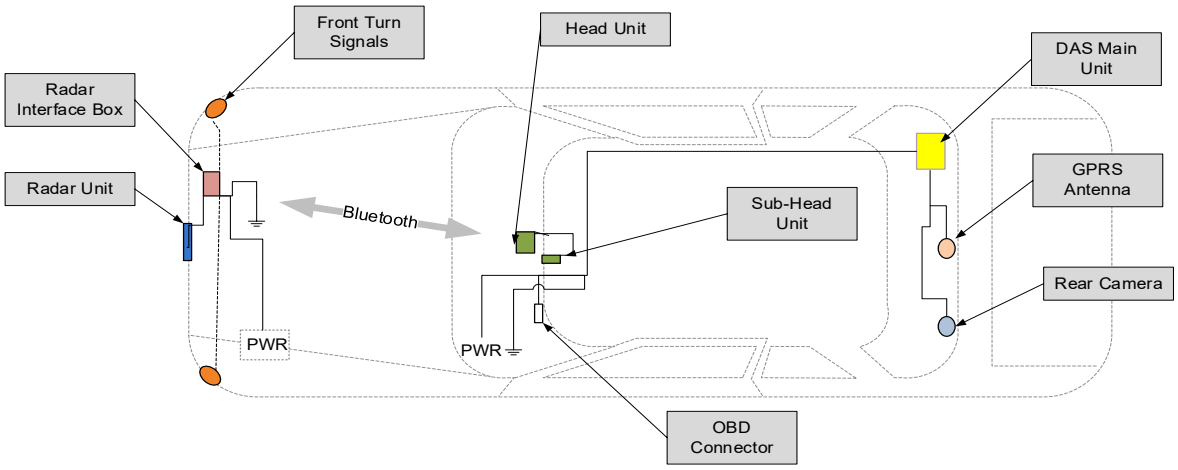


Figure 2. DAS component locations in the vehicle.

In addition, the miniature data acquisition device (miniDAS) was installed near the middle of the front windshield towards the area where the dashboard and windshield intersect (see Figure 3).

Figure 3. MiniDAS device location.

VTTI's mini-DAS allowed for un-intrusive collection of data from the vehicle network, multiple sensors and video cameras. The data include vehicle controls, such as brakes, turn signals, throttle, speed and lights, acceleration values along the X, Y, and Z axis, GPS location and time of day. In addition, the sensors collected GPS (to assess location of vehicle at a particular point in time), alcohol presence, temperature and light level. Video data collected via five cameras installed in the study vehicle (see Figure 4):

1. One view of the participant's face

2. One view of the instrument panel
3. One facing the forward roadway
4. One view facing the vehicle footwell
5. One facing the participant's hands on the steering wheel, instrumental panel, and center console of the vehicle.

Figure 4. Video views.

An experimenter introduced and showed the locations of the DAS to participants before the road drive training and asked them not to block the sensors and cameras.

Appendix R. Summary of Statistical Results

Summary of Statistical Results of Comparing Initial and Experienced Opinions on Vehicles with Automated Features

Question		*Before	*After	Mean Diff	DF	Std Error	Test Statistic	P-Value
Lane Control Features	1) I can rely on the lane control features to function properly while I am doing something else.	M=4.67 SD=0.35	M=4.94 SD=0.46	0.28	17	0.61	t=0.46	0.65
	2) The lane control features provide alerts when needed.	M=5.83 SD=0.23	M=5.94 SD=0.30	0.11	17	0.34	Z=20.00	0.55
	3) The lane control features give too many false alerts.	M=4.28 SD=0.21	M=3.06 SD=0.50	-1.22	17	0.47	t=-2.61	0.02
	4) The lane control features are dependable.	M=5.39 SD=0.26	M=5.56 SD=0.33	0.17	17	0.39	t=0.43	0.67
	5) I am familiar with the lane control features	M=3.72 SD=0.58	M=6.44 SD=0.17	2.72	17	0.64	t=4.25	<0.001
	6) I feel safe using the lane control features.	M=4.72 SD=0.37	M=5.94 SD=0.31	1.22	17	0.47	t=2.61	0.02
	7) I trust the lane control features.	M=4.72 SD=0.37	M=5.83 SD=0.27	1.11	17	0.48	t=2.29	0.03
Acceleration and Braking Features	8) I can rely on the acceleration and braking features to function properly while I am doing something else.	M=4.28 SD=0.36	M=4.94 SD=0.42	0.67	17	0.57	t=1.18	0.26
	9) The acceleration and braking features provide alerts when needed.	M=5.33 SD=0.31	M=5.11 SD=0.41	0.67	17	0.57	t=-0.39	0.70
	10) The acceleration and braking features give too many false alerts.	M=4.00 SD=0.18	M=2.77 SD=0.32	-1.35	16	0.36	t=-3.73	<0.01
	11) The acceleration and braking features are dependable.	M=5.06 SD=0.24	M=5.72 SD=0.27	0.67	17	0.35	t=1.90	0.08

Question		*Before	*After	Mean Diff	DF	Std Error	Test Statistic	P-Value
	12) I am familiar with the acceleration and braking features.	M=3.44 SD=0.51	M=5.83 SD=0.37	2.39	17	0.70	t=3.43	<0.01
	13) I feel safe using the acceleration and braking features.	M=4.56 SD=0.39	M=5.61 SD=0.30	1.06	17	0.50	t=2.11	0.05
	14) I trust the acceleration and braking features.	M=4.61 SD=0.40	M=5.67 SD=0.27	1.06	17	0.45	t=2.33	0.03
15) Considering both lateral as well as acceleration and braking features, please indicate your feelings about the following statement. I have a high degree of trust in the automated vehicle technologies in my study vehicle.		M=5.00 SD=0.21	M=5.50 SD=0.35	0.50	17	0.35	t=1.41	0.18
16) Considering both lateral as well as acceleration and braking features, please indicate your feelings about the following statement. I have a high degree of satisfaction in the automated vehicle technologies in my study vehicle.		M=4.83 SD=0.26	M=5.50 SD=0.38	0.67	17	0.47	Z=43.50	0.09
3. Cost considerations aside, I would prefer for the next vehicle I purchase to have some level of AVTs.		M=6.11 SD=0.24	M=6.06 SD=0.34	-0.06	17	0.37	Z=6.00	1.00
4. Including cost considerations, I would prefer for the next vehicle I purchase to have some level of AVTs.		M=5.89 SD=0.30	M=5.78 SD=0.37	-0.11	17	0.30	Z=-6.00	1.00

*M= mean; SD= standard deviation; *Higher values indicate stronger agreement according to participant ratings *1: Strongly Disagree, 2: Moderately Disagree, 3: Slightly Disagree, 4: Neither Agree Nor Disagree, 5: Slightly Agree, 6: Moderately Agree, 7: Strongly Agree

Appendix S. AVTs Weekly Trust and Satisfaction Ratings

AVTs Weekly Trust and Satisfaction Ratings

Feature	Week	Mean (SD) rated degree of trust	Mean (SD) rated degree of satisfaction
ACC	1	5.87(1.13)	6.13(1.13)
	2	5.81(1.25)	5.86(1.31)
	3	6.28(1.07)	6.22(1.06)
	4	6.11(1.13)	6.06(1.16)
	5	6.33(0.97)	6.33(0.91)
BSA	1	6.2(1.08)	6.07(1.22)
	2	6.62(0.8)	6.52(0.93)
	3	6.33(1.28)	6.5(0.86)
	4	6.56(1.04)	6.5(1.04)
	5	6.56(1.25)	6.56(1.25)
LA	1	5.8(1.08)	5.4(1.24)
	2	6.52(0.68)	5.86(1.71)
	3	6.5(1.04)	6.28(0.96)
	4	6.33(0.91)	6.28(0.96)
	5	6.44(0.86)	5.83(1.65)
LKA	1	5.87(1.13)	5.53(1.25)
	2	5.81(1.25)	5.48(1.72)
	3	6.28(1.07)	5.61(1.58)
	4	6.11(1.13)	6(1.28)
	5	6.33(0.97)	5.28(1.78)

*SD= standard deviation

*1=strongly disagree, 2= moderately disagree, 3=slightly disagree, 4=neither agree nor disagree, 5=slightly agree, 6=moderately agree, 7=strongly agree

Summary of Statistical Results of Investigating the Changes in Mean of Trust and Satisfaction over Weeks

	BSA	ACC	LA	LKA
Trust	F(4, 85) = 0.22 p = 0.93	F(4, 85) = 0.84 p = 0.51	F(4, 85) = 1.15 p = 0.34	F(4,85) = 0.71 p = 0.59
Satisfaction	F(4, 85) = 0.27 p = 0.90	F(4, 85) = 0.50 p = 0.73	F(4, 85) = 1.32 p = 0.27	F(4, 85) = 0.63 p = 0.64