THE UNIVERSITY OF IOWA

THE NATIONAL ADVANCED DRIVING SIMULATOR

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University of Iowa Technology Demonstration Study

TECHNICAL REPORT

TRANSPORTATION AND VEHICLE SAFETY RESEARCH PROGRAM

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Please contact the research team to request access to the Technology Demonstration Study Final Report Appendix.

Key Findings

This report contains the results of the University of Iowa's Technology Demonstration Study. The study evaluated drivers' attitudes toward and knowledge about five advanced driver assistance technologies prior to and after learning about the technologies by completing one of four learning protocols. The learning protocols included reading an owner's manual and/or observing a driver use the technologies during a ride-along demonstration drive. The Technology Demonstration Study focused on the functions performed by adaptive cruise control, blind spot monitor, lane keeping assist, parallel parking assist, and rear cross traffic alert.

- Participant knowledge of the five technologies significantly increased at the end of the study. On average, knowledge scores increased about 170%.

- Participant ratings of usefulness of a vehicle equipped with the function descriptions of adaptive cruise control and parallel parking assist significantly increased at the end of the study. Ratings for the usefulness of the other technologies in the study were relatively high to begin with and did not change significantly at the conclusion of the study.

- Participant ratings of trust for the function descriptions of adaptive cruise control, lane keeping assist, parallel parking assist, and rear cross traffic alert all significantly increased at the end of the study.

- Ratings of apprehension of using a vehicle equipped with each technology function significantly decreased at the end of the study for all five technologies.

- Participants reported that the owner's manual and the ride-along demonstration drive both individually contributed to their learning about the purpose and how to use each ADAS technology. However, participants assigned to the two learning protocols that included both reading the owner's manual and completion of the demonstration drive reported that the drive contributed more to their learning than the owner's manual.

- After completing the study, participants had significantly greater interest in purchasing a vehicle that performed adaptive cruise control and parallel parking functions.

- Before completing the study, participants said they would prefer to learn about advanced driver technologies through a method that included a demonstration more than 80% of the time. At the end of the study, participants opted for a learning method that included a demonstration drive more than 90% of the time.

Executive Summary

Advanced driver assistance systems (ADAS) are making striking and rapid market penetration in the consumer vehicle market. However, many consumers have little to no experience with these technologies prior to finding themselves behind the wheel. Results from the National Consumer Survey of Driving Safety Technologies conducted by the University of Iowa (UI) found driver uncertainty about technologies that are not only new and emerging, but also with ADAS technologies that have been standard for several years. As ADAS technologies quickly evolve and integrate with other in-vehicle features, this may leave consumers without the education and information needed on how to most effectively use these technologies.

The MyCarDoesWhat national education campaign, led by the UI and the National Safety Council, seeks to educate the American driving public on how to most effectively use ADAS technologies when behind the wheel of a vehicle equipped with these features.

Designed to support the broader MyCarDoesWhat campaign effort, the Technology Demonstration Study (TDS) was conducted to provide insights and understanding into driver attitudes toward and knowledge about several of the emerging ADAS technologies. Focusing on drivers who did not have prior experience or exposure to several of the ADAS technologies included in the study, a total of 120 participants, evenly split by gender, were exposed to four different learning protocols for five different ADAS technologies: adaptive cruise control, blind spot monitor, lane keeping assist, parallel parking assist, and rear cross traffic alert.

In the TDS, each participant experienced one of four different learning protocols during a site visit:

- Reading the owner's manual
- Experiencing a ride-along demonstration drive
- Experiencing a ride-along demonstration drive followed by reading the owner's manual
- Reading the owner's manual followed by a ride-along demonstration drive

All participants completed a Site Visit and Pre- and Post-Visit Surveys that measured their knowledge about and attitudes toward using the technologies.

This report details the overall study objectives; methodologies for recruiting the participant sample, survey instruments, and learning protocols; and preliminary results.

The TDS is the first study of its kind to comprehensively measure driver attitudes toward and knowledge about the five ADAS technologies included the study. The TDS greatly adds to the scientific knowledge base of driver understanding and human factors issues to be considered for future evaluation as these technologies continue to increase in market penetration. The TDS will serve as a model base to continue to measure and evaluate drivers' attitudes toward and knowledge about current and future vehicle technologies.

Introduction

Advanced driver assistance systems (ADAS) are making striking market penetration on American roadways. Most ADAS technologies promise increasing safety by providing drivers with warnings or alerts of potential hazards or even varying levels of vehicle control. However, little is known about how a driver's trust is affected when an ADAS technology does not perform as expected or anticipated.

Purpose and Research Objectives

The purpose of the TDS was to evaluate whether driver attitudes and knowledge about ADAS technologies are affected by the ways in which they learn about the technologies. The TDS included five ADAS technologies: adaptive cruise control (highway and in-town scenarios), blind spot monitor, lane keeping assist, parallel parking assist, and rear cross traffic alert.

The primary research questions of the TDS were:

1. Do drivers who are unfamiliar with ADAS technologies experience a change in their knowledge about and attitudes towards (including trust, usefulness, apprehension, and interest in purchasing) those technologies after they have learned about them by:
    a. Reading about the technologies in an owner's manual;
    b. Observing those technologies in use during a ride-along demonstration drive; or
    c. Both reading about and observing the technologies?
2. How do drivers prefer to learn about different ADAS and do their preferences change after the study? How did each learning protocol contribute to their learning?

The TDS was created to provide additional insight and scientific data for the UI's MyCarDoesWhat campaign that seeks to educate drivers on ADAS technologies that are in their vehicles today, as well as those available in the overall American fleet. Findings from the TDS will assist the campaign and research team in identifying critical gaps in driver knowledge that the MyCarDoesWhat team can address in their publically available materials and overall campaign messaging.

Methodology

The TDS was designed to measure driver knowledge about and attitudes toward five ADAS technologies. These technologies included: adaptive cruise control, blind spot monitor, lane keeping assist, parallel parking assist, and rear cross traffic alert. These systems were specifically selected for their recent increase in market penetration and relatively low level of knowledge amongst consumers. It is worth noting that, throughout the TDS, the technologies were referred to by their generic or most common name in the industry. In some instances, the technology name referred to in the TDS differed from the name used by the original equipment manufacturer (OEM), as many OEMs uniquely market and brand their individual in-vehicle safety systems to distinguish their products from competitors. In order to prevent any bias or confusion, the research team used the most straightforward, common, and generic name of the technology.

The final study sample included 60 male and 60 female drivers who were unfamiliar with ADAS technologies. All participants completed Pre- and Post-Visit Surveys that measured their knowledge about and attitudes toward using the technologies. All study procedures were approved by the UI Institutional Review Board (IRB).

Identification of Learning Outcomes

To ensure knowledge of ADAS technologies was measured similarly for all participants, regardless of which learning protocol they experienced, the research team identified a series of learning outcomes. The learning outcomes addressed the purpose, function (how the system works), and limitations of each system in most vehicles on the market (i.e., how the ADAS technologies work in general, not just in the TDS research vehicle). For each of the five ADAS technologies in the TDS, the research team obtained the owner's manuals for makes and models that had all five ADAS technologies and drafted the learning outcomes to be applicable across vehicles.

The research team ensured that both the owner's manual and the ride-along demonstration drive learning protocols included all the information directly relevant to the learning outcomes. The research team drafted 22 multiple choice knowledge questions based on the learning outcomes to assess participant knowledge of ADAS technologies before and after completing the learning protocol.

The following tables below display the learning outcomes developed by the research team for each ADAS technology included in the TDS.

Table 1: General driver assistance systems learning outcomes

Purpose	Function	Limitations
Are intended to support the driver by providing information, alerts, or minimal levels of control	Use radar, sensors, and/or cameras to detect the environment around the vehicle	The radar, sensors, and cameras have limitations that can affect system performance
	Require the driver to still pay full attention to the driving environment	
	Can vary a great deal between different vehicle makes and models in terms of capability and operation	
	Can each be turned off by the driver	

Table 2: Adaptive cruise control learning outcomes

Purpose	Function	Limitations
An advanced version of cruise control that not only maintains a set speed, but a set distance from the vehicle ahead as well	Provides some limited amount of braking that varies between manufacturers	Will only respond to vehicles that the system has recognized
	Requires the driver to set his/her speed and time interval distance. The time interval distance (following distance) varies in seconds, but most vehicles generally have a short, medium, and long distance they maintain from the vehicle ahead.	May "lose track" of vehicles around corners, sharp curves, and if the roadway elevation changes
	When activated, ACC takes over speed control from the driver	

Table 3: Blind spot monitor learning outcomes

Purpose	Function	Limitations
Alerts the driver with a warning when a vehicle may be located in his/her blind spot (warning varies by manufacturer - may be an illuminated symbol, sound, or vibration)	Only alerts the driver, does not take control of the vehicle in any way	Many systems are not designed to detect vehicles passing through the blind spot at extremely fast speeds
Some systems provide an escalated warning if a vehicle is located in the blind spot and the driver's turn signal is on		May not detect motorcycles, bicycles, or pedestrians in a driver's blind spot

Table 4: Lane keeping assist learning outcomes

Purpose	Function	Limitations
Designed to prevent crashes caused when a vehicle unintentionally drifts out of the lane	Detects when the vehicle may be drifting out of the lane and will gently steer the vehicle back to the lane	Not designed to work with markings that are faded, covered, in disrepair, or are overly complicated
Designed to be used at highway speeds	If the vehicle's tires leave the lane, the system will alert the driver with a warning (tone, icon, or vibration)	
Temporarily takes control of steering to try to keep the vehicle in the original lane	Relies on painted lane markings to operate effectively	
	Will not activate if a turn signal is on and the driver is drifting in the same direction as the signal	
	The driver's hands must be on the steering wheel in order for the lane keeping assist to function	

Table 5: Rear cross traffic alert learning outcomes

Purpose	Function	Limitations
Alerts the driver if one or more vehicles are about to enter the vehicle's backing path	If the system is turned on, it will activate when the vehicle is shifted into reverse	Has reduced functionality in angled parking situations
	Most useful when backing out of a perpendicular parking space where the driver cannot see other vehicles that may be coming from the right or left	
	Warning tone, flashing light on the mirrors or dashboard alert the driver there is a detected	
	Only alerts the driver, does not take control of the vehicle in any way	

Table 6: Parallel parking assist learning outcomes

Purpose	Function	Limitations
Temporarily takes control of steering the vehicle during the parallel parking maneuver	Searches for a suitable parallel parking spot, notifies the driver to brake to a stop and shift the vehicle into reverse	The parallel parking system will be cancelled if the backing speed is too fast or if a tire begins to spin or lose traction
	The driver must maintain control of the brake and the speed of the vehicle during the maneuver and shift the vehicle when the system directs him/her to do so	
	The sensors on the vehicle will alert the driver as it is getting closer to vehicles or objects around the vehicle	
	Uses a camera to show the environment around the vehicle	
	If the driver wants to stop the maneuver, he/she can turn the steering wheel or press a button (usually on the center display or steering wheel) to cancel	

Study Recruitment

Study Eligibility

The basic study eligibility requirements were defined by participant age and exposure to selected ADAS technologies. The following inclusion criteria were defined:

- 30-55 years old
- Must possess a current, valid US driver's license and must have been a licensed driver for at least three years (validated upon site visit)
- Must drive at least 90 minutes per week
- Vehicles in the potential participant's household unequipped with any of the five ADAS technologies included in the TDS

TDS Recruitment

The research team conducted a multi-faceted recruitment plan to advertise the study to potential participants. Recruitment tactics included an e-mail to UI faculty and staff, an e-mail to the National Advanced Driving Simulator (NADS) participant registry, a Craigslist posting, and word of mouth.

Recruitment began on June 1, 2016, and extended through September 11, 2016.

Potential participants accessed the TDS Eligibility Survey through the website link included in all recruitment e-mails and postings (reference Appendix A for the IRB-approved recruitment e-mail and online study announcement). After removing outlier response times, the Eligibility Survey took an average of four minutes to complete. Immediately after completing the Eligibility Survey, respondents were informed of their eligibility for the TDS.

Participants were excluded from the study if they did not meet all the inclusion criteria, if they'd had exposure to adaptive cruise control, blind spot monitor, or lane keeping assist as a driver or passenger in any vehicle, or if they had previously participated in research studies investigating new in-vehicle technologies in the past.

Respondents who completed the Eligibility Survey but did not qualify for the TDS were asked if they would be interested in adding their name to a registry of potential participants for future studies concerning ADAS technologies. A total of 112 respondents that were originally ineligible for the study noted they would like their name added to the registry. Additionally, participants who completed the full study protocol were also asked if they would like to be added to the registry. Of those that completed the entire study protocol, 119 responded they would like their contact information added to the registry.

Table 7 provides the total study enrollment and completion numbers from the time potential participants accessed the Eligibility Survey through the completion of the TDS. Please note, the "Ineligible numbers, Invited to the Pre-Visit Survey, Completed Entire Study Protocol, Final Study Sample" are reflective of the "Eligibility Survey Total" (426 respondents). The number below "Eligibility Survey Total" reflects respondents that clicked on the link, but did not complete the survey.

Table 7: Total study enrollment and completion numbers

Eligibility Survey Total *Accessed the Eligibility link but did not complete the survey*	**426** *108*
Ineligible	178
Invited to the Pre-Visit Survey	147
Completed the Pre-Visit Survey	125
Completed Entire Study Protocol	122
Final Study Sample	120

Study Methods

Pre-Visit Survey

Once potential participants were determined eligible, they received an e-mail invitation to complete the Pre-Visit Survey within 30 days.

The Pre-Visit Survey (Appendix B) included questions assessing the participant's knowledge about the ADAS technology purposes, functions, and limitations, as well as questions relating to participant's attitudes towards ADAS technologies, including usefulness, trust, apprehension. Questions were also asked to address participants' interest in purchasing vehicles with these technologies and how they would prefer to learn how to use them.

Previous research by the UI found many drivers did not know what a specific ADAS technologies were when referred to by name. To address this, some items in the Pre- and Post-Visit Surveys provided a description of the ADAS technology function rather than the name of the system. Table 8: provides the seven ADAS technology descriptions used in the TDS Pre- and Post-Visit Surveys to describe the five ADAS technologies included in the study (three described the functions of adaptive cruise control).

Table 8: Descriptions of ADAS technology functions used in the Pre- and Post-Visit Survey

ADAS Technology	ADAS Technology Function Description
Parallel parking assist	Steers my vehicle into a parallel parking space
Lane keeping assist	Keeps my vehicle in my lane if I begin to drift out of it
Blind spot monitor	Warns me of vehicles in my blind spot
Adaptive cruise control	Adjusts my speed while I'm following a vehicle
Adaptive cruise control	Brakes my vehicle to a complete stop while I'm following a vehicle
Adaptive cruise control	Accelerates my vehicle from a stop while I'm following another vehicle
Rear cross traffic alert	Alerts me when cross traffic approaches while I'm backing out of a parking space

Upon completion of the Pre-Visit Survey, participants were contacted for the study site visit. A participant's site visit was scheduled no earlier than least seven days after the completion of the Pre-Visit Survey.

Site Visit

The site visit took place at the NADS facility. All site visits were scheduled during daylight hours and lower expected travel densities. Site visits were canceled and rescheduled due to high winds or heavy precipitation.

Intake Survey

Upon arrival, participants reviewed and signed administrative documents and completed the Intake Survey, which had been uploaded onto an iPad. The Intake Survey (Appendix C) included a total of 68 questions on the following subtopics: exposure to information about the ADAS technologies covered in the study since completing the Pre-Visit Survey, Technology Readiness Index 2.0© (Parasuraman and Colby, 2015; used with permission of the authors), locus of control, driving history, and personal demographics.

Upon completion of the Intake Survey, the participant's assigned learning protocol was initiated.

Learning Protocols

Each participant was randomly assigned to experience one of four learning protocols during their site visit. Two base learning methods were designed to evaluate how drivers' knowledge and perceptions of ADAS technologies are affected by the ways in which they learn about these technologies. One base method represented a typical method of learning about in-vehicle technologies—an owner's manual—while the other consisted of observing an experienced driver using the technologies during an on-road demonstration in conditions that the technologies were intended for. These two base methods were combined to create the four between-participants learning protocols:

- Reading about the technologies in an owner's manual
- Observing an experienced driver use the technologies during a ride-along demonstration drive
- Reading the owner's manual followed by the ride-along demonstration drive
- The ride-along demonstration drive followed by reading the owner's manual

Owner's Manual Learning Method

The research vehicle used in the TDS was a 2016 full-size SUV equipped with several ADAS technologies currently available on the market. No after-market systems were installed and no modifications were made to any vehicle systems.

Information for all of the research vehicle's ADAS technologies was contained in one chapter of the OEM manual. The beginning of this chapter described the camera and radar systems that supported several different ADAS technologies, with the rest of the chapter describing each of the different ADAS technologies in detail.

Using this chapter, the research team developed an owner's manual for the TDS, specific to the five technologies included in the study. References to the manufacturer were removed, as was information pertaining to systems not included in the TDS.

The TDS owner's manual (Appendix D) consisted of six sections, with introductory material for each section written by the research team. The research team also reviewed ADAS technology content from other OEM owner's manuals in order to write this introductory material. The first section addressed driver assistance technologies in general, with a one-page introduction explaining the purpose and limitations, followed by OEM content describing the camera and radar system. After this introduction, one section for each of the five ADAS technologies included in the TDS followed.

In total, the TDS owner's manual presented to the participants contained 38 pages based on the original content of the manual and six pages written by the research team introducing each section. Participants were given as much time as was necessary to read the manual. The median amount of time participants spent reviewing the owner's manual was 40 minutes.

Ride-Along Demonstration Drive Learning Method

For the TDS ride-along demonstration drive learning method, the participant sat in the front passenger seat of the research vehicle and observed an experienced driver (referred to as the demonstration driver) using the five different ADAS technologies on a predetermined route utilized for all participants. Prior to entering the vehicle, participants were briefly introduced to the vehicle, including the camera and sensors that support many of the ADAS technologies.

At specific points throughout the drive, the demonstration driver instructed the participant to use an iPad to play audio files (Appendix E). The first part of each audio file presented information about the next ADAS technology that would be demonstrated, explaining the general purpose of the system, how it functioned, and its limitations in any vehicle model. The second part explained the specific function and limitations of the technology in the research vehicle. Audio files ranged in length from about 30 seconds to four minutes. In addition to the audio files, participants were provided a reference sheet that displayed various icons, steering wheel settings, and buttons related to the ADAS technologies as was determined necessary by the research team.

Throughout the demonstration drive, the driver provided brief explanations on how the vehicle's systems were responding as they were demonstrated during the drive. Throughout the demonstration drive, the participant was allowed to ask the demonstration driver questions or make comments about the ADAS technologies. The demonstration driver responded to participant questions when it was safe to do so. To capture these participant questions and comments, as well as to record the execution of the demonstration drive, three GoPro Hero 4 cameras were installed in the research vehicle. One camera faced into the cabin and captured the participant and driver, a second captured the view over the participant's shoulder, including the steering wheel and the in-vehicle display, and a third captured the forward roadway. A microphone was clipped to the sun visor on the passenger side to record audio.

In addition to the demonstration driver, a driver in a second vehicle assisted with the demonstration drive (referred to as the assist driver). A hand-free (Bluetooth) cell phone connection was established between the research and assist vehicles so that the assist driver could hear the demonstration driver and participant throughout the drive. Both demonstration and assist drivers were blinded to the learning protocol assigned to each participant.

The first three ADAS technology demonstrations were parallel parking assist, blind spot monitor, and lane keeping assist. Then the adaptive cruise control demonstration occurred in two parts: adaptive cruise control during highway driving and adaptive cruise control in stop-and-go traffic situations. Rear cross traffic alert was demonstrated in the NADS parking lot at the end of the drive.

The demonstration drive took approximately 40 minutes. The route started in the NADS parking lot and continued to a residential area, suburban arterial streets, an interstate, and a US highway before returning to the NADS facility by reversing the route (see Figure 1).

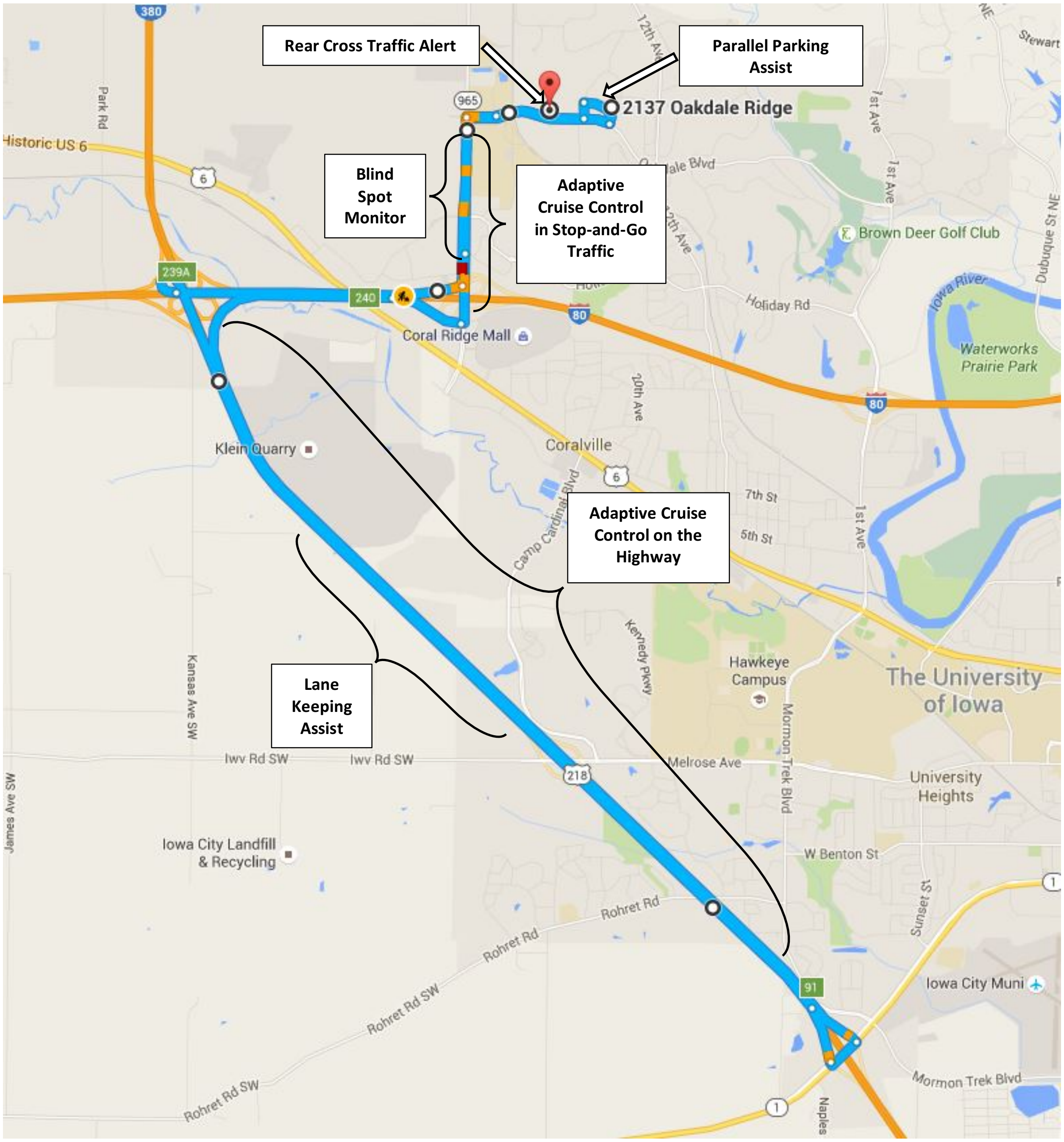

Figure 1: TDS route from to start to finish (Iowa City, IA)

Parallel Parking Assist Demonstration

Prior to the demonstration drive, a parallel parking scenario was staged with the assist vehicle and another research vehicle on a residential street near the NADS facility to create a parking space approximately 22 feet long. The vehicle in front of the parking space and the assist vehicle were parked about one foot from the curb (Figure 2).

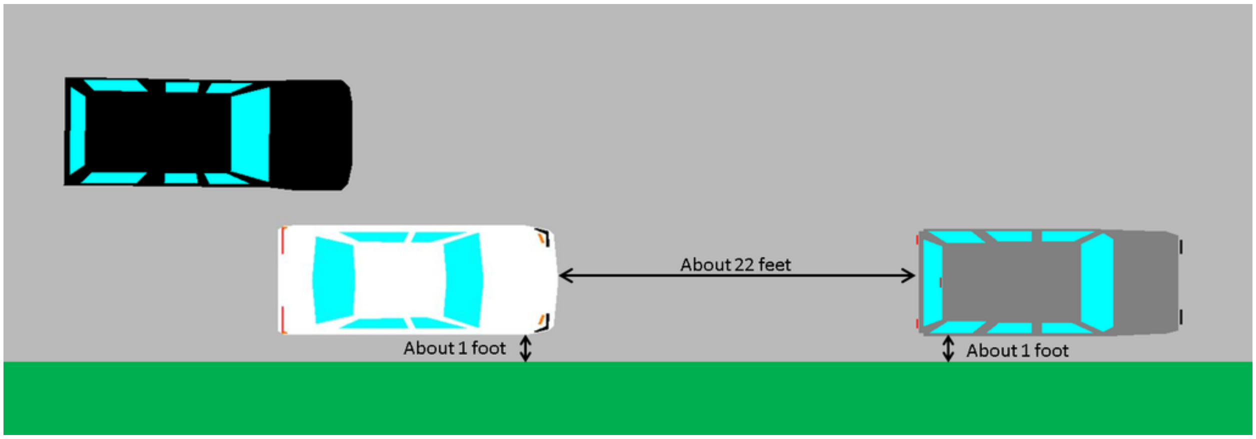

Figure 2: Parallel parking assist demonstration staging. Black vehicle is the research vehicle and white vehicle is the assist vehicle.

At the parallel parking assist demonstration site, the demonstration driver followed the instructions provided by the research vehicle to parallel park, verbalizing these instructions for the participant as the vehicle maneuvered into the parking space.

Blind Spot Monitor Demonstration

After completing the parallel parking assist demonstration, the research vehicle, followed by the assist vehicle, traveled to a four-lane suburban arterial street with a dividing median where the demonstration driver moved into the right lane while the assist driver remained in the left lane. The demonstration driver asked the participant to look at the driver's side mirror as the assist vehicle began to overtake the research vehicle. After a few seconds, the turn signal was activated so the participant could observe how the blind spot warning indicator changed from static illumination to flashing illumination. The flashing illumination continued until the assist vehicle cleared out of the research vehicle's blind spot.

After a signalized intersection, the roadway widened to three lanes. The assist vehicle moved to the right lane and reduced speed so it could be passed by the research vehicle. The demonstration driver instructed the participant to look at the passenger side mirror and then activated the right turn signal so the indicator would flash. The blind spot monitor demonstration ended when the assist vehicle was no longer in the blind spot.

Lane Keeping Assist Demonstration

After entering onto the four-lane divided US highway and permitting traffic approaching from the rear to pass, the demonstration driver gently steered the vehicle towards the right lane boundary while the participant observed the steering wheel or the road to see how the system attempted to correct lane position. This lane keeping assist demonstration to the right was executed a second time. Then the driver demonstrated the lane keeping assist towards the left lane boundary twice.

Adaptive Cruise Control on the Highway Demonstration

The adaptive cruise control on the highway demonstration took place over five miles on a four-lane divided US highway. After entering the highway, the driver set the adaptive cruise control speed to 60 mph and showed the participant how the system was set to the longest time interval setting (about three seconds). After passing the research vehicle, the assist vehicle then entered the lane in front of the research vehicle and maintained a constant speed of 57 mph, causing the research vehicle to reduce speed. While the set speed was then increased, the demonstration driver showed the participant that this did not result in a change to the research vehicle's actual speed as it was still following the slower-moving assist vehicle. Then the time interval was changed to the shortest setting (about one second) and the vehicle accelerated to close the gap. Finally, the middle time interval setting of about two seconds was demonstrated, with the demonstration driver noting that the adaptive cruise control was again reducing the speed to increase the gap between the vehicles.

During the adaptive cruise control on the highway demonstration, the assist vehicle accelerated out of the range determined by the time interval setting while the adaptive cruise control maintained the vehicle's set speed of 65 mph.

To prepare to exit the highway, the assist driver reduced speed and, as the gap between the two vehicles closed, the adaptive cruise control decelerated the research vehicle according to the time interval setting. While on the off-ramp, the demonstration driver put the adaptive cruise control system into standby mode, concluding the adaptive cruise control on the highway demonstration.

Adaptive Cruise Control in Town Demonstration

While still following the assist vehicle, the research vehicle exited the interstate. After turning off the exit-ramp onto a multi-lane suburban arterial street, the demonstration driver set the adaptive cruise control to the speed limit of 40 mph and the longest time interval setting. This road had three signalized intersections that could be used for the demonstration. If any stoplight was amber or red, the assist vehicle braked, resulting in the adaptive cruise control slowing the research vehicle. Each participant was given the opportunity to experience a successful demonstration in stop-and-go traffic at least once and no participant experienced it more than twice. The braking demonstration was considered successful if the research vehicle decelerated to a speed of 5 mph or less.

If the first two traffic lights did not provide for a successful demonstration, an alternate route was used to encounter another traffic light. If that was unsuccessful, the route continued onto a low-volume street without stoplights. The adaptive cruise control was set to 25 mph and the longest time interval. Then the assist vehicle signaled for a left turn into a parking lot and braked to a complete stop before making the turn.

Rear Cross Traffic Alert Demonstration

After completing the adaptive cruise control in stop-and-go traffic demonstration, the returned to the NADS parking lot, pulling into a reserved perpendicular parking space with a mini-van parked in the adjoining space on the passenger side (see Figure 3). In the parking aisle, the assist driver waited out of view of the participant.

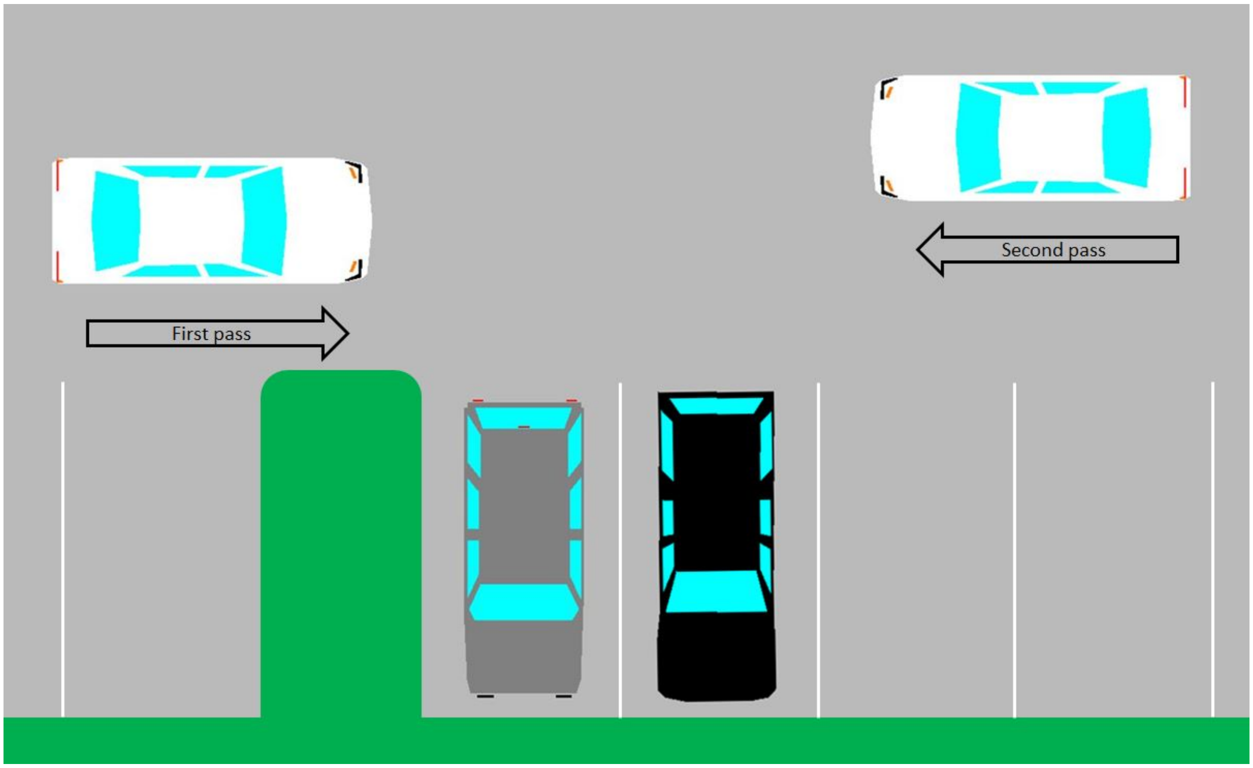

Figure 3: Rear cross traffic alert demonstration staging. Black vehicle is the research vehicle, white vehicle is the assist vehicle, and gray vehicle is the parked mini-van.

After the assist driver was in position, the demonstration driver announced to the participant that the rear cross traffic alert system would be activated when the vehicle was backing. The demonstration driver then shifted into reverse and paused briefly before letting their foot slowly off the brake to begin backing. As the research vehicle backed out of the spot, the assist driver drove forward down the parking aisle at a speed between 10-15 mph. As the assist vehicle approached, the rear cross traffic alert sounded through the research vehicle's front and rear passenger side speakers and provided a visual warning on the console display and on the side of the vehicle where the assist vehicle was coming from. After the assist vehicle passed behind the research vehicle, the demonstration driver pulled back into the parking space and the demonstration was repeated with the assist vehicle approaching from the driver's side.

Post-Visit Survey

Once participants had completed the entire learning protocol to which they were assigned, they were shown to an office (if they had just finished the demonstration drive) and presented with an iPad preloaded with the Post-Visit Survey (Appendix F).

The Post-Visit Survey included 69 questions. The survey included questions assessing participants' knowledge of ADAS technology purposes, functions, and limitations, as well as their perceptions of ADAS technologies were repeated from the Pre-Visit Survey to allow for comparison analysis. The survey also asked participants about their learning preferences of the ADAS technologies based on the learning protocol they experienced in the study.

The average Post-Visit Survey response time was approximately 30 minutes.

Participant Compensation

Participants were compensated $10 for completing the Pre-Visit Survey and $65 for the site visit portion of the study.

Data Management and Security

Data Storage

Throughout data collection, survey data was downloaded for quality control measures. All datasets for this study were stored in access-control folders that only TDS project staff are permitted to access. The research team merged all survey data into one large dataset to allow for comprehensive analysis and cleaned the final dataset to include the 120 participants. The research team conducted statistical analyses for research questions 1 and 2, with results noted in the following sections. Bolded font in the charts indicates statistically significant findings.

All demonstration drive video was downloaded to an access-controlled folder and transcribed for further analysis.

Electronic Data

The Eligibility Survey was publicly available to anyone who accessed the survey link. The Eligibility Survey link was housed within Qualtrics and the data was only accessible to the TDS administrative team at the UI who were responsible for the recruitment and management of participant enrollment. The Pre-Visit Survey utilized the Qualtrics panel mailer function to send an individual survey link to eligible individuals. All final data datasets include de-identified data that only note a unique identifier matching the Pre-Visit Survey, Intake Survey, and Post-Visit Survey data for each participant.

Results

As mentioned, seven ADAS technology function descriptions were used in the Pre- and Post-Visit Surveys to describe the five ADAS technologies included in the study (please reference Table 8). These descriptions were used to evaluate driver attitudes of trust, usefulness, apprehension, and interest in purchasing each ADAS technology. Additionally, in the Post-Visit Survey, each technology was specifically referred by its name referenced in the study to measure driver attitudes (including trust, usefulness, apprehension, and interest in purchasing). All knowledge questions were referred to specifically by the name used throughout the study.

The image below recalls the main subtopics in each survey.

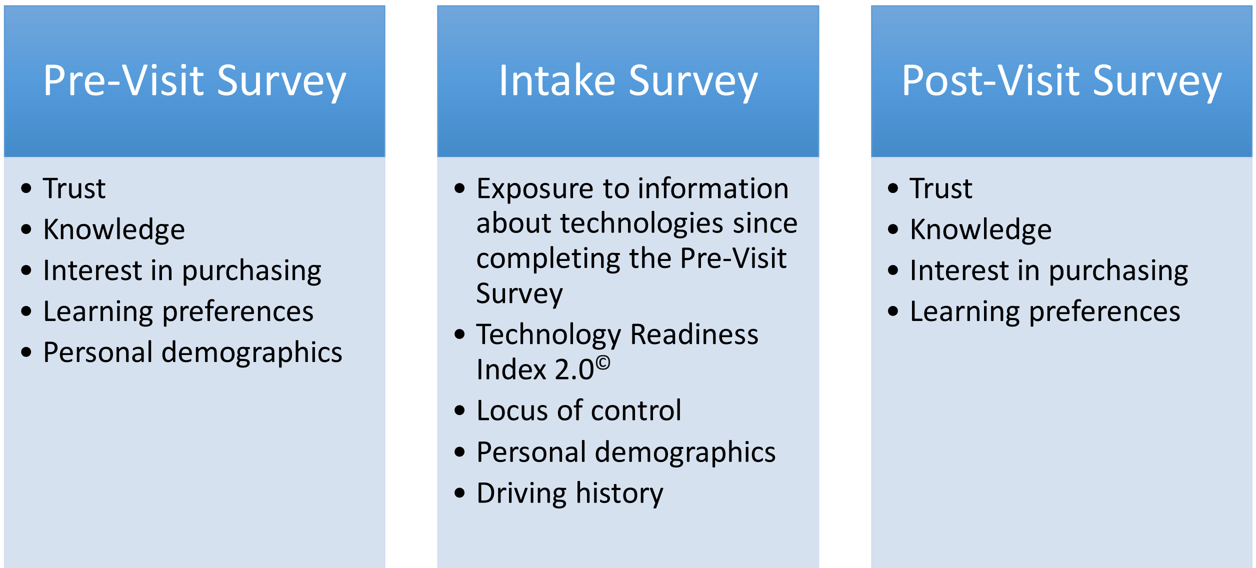

Figure 4: Main subtopics in each TDS survey

ADAS Technology Knowledge

Participant knowledge about the ADAS technologies was measured by comparing participants' answers to 22 knowledge questions on the Pre- and Post-Visit Surveys. Responses to each knowledge question were converted to scores by assigning a value of 1 when participants selected the correct answer and 0 otherwise. Scores were summed across the 22 items to create a composite knowledge score. Composite knowledge scores possible ranged from 0 to 22. On average, participants got six knowledge questions correct on the Pre-Visit Survey (Table 9). After completing the site visits, the knowledge scores increased on average by 10 points to an average score of 16.45 correct on the Post-Visit Survey.

Table 9: Number of correct answers on ADAS technology knowledge questions and results of two-way paired samples t-tests

	Pre-Visit		Post-Visit		Paired Samples Test	
Variable	**Mean**	**SD**	**Mean**	**SD**	**t statistic**	**p value**
Composite Knowledge Score	**5.99**	**2.970**	**16.45**	**2.688**	**31.053**	**<0.001**

ADAS Technology Perception Ratings

A number of subjective ratings were examined in the study. Those were rating related to usefulness, trust, apprehension, and interest in purchasing.

Ratings of Usefulness

Ratings of usefulness were measured by comparing participants' answers to 7 questions on the Pre- and Post-Visit Surveys. Based on function descriptions, each participant rated how much they agreed that the seven ADAS technology functions would be useful in their own driving. The ratings ranged from 1 (“strongly disagree”) to 7 (“strongly agree”).

Table 10 shows the ratings for each of the seven ADAS technology functions. For the Pre-Visit Survey ratings, the adaptive cruise control functions of accelerating from and braking to a stop while following another vehicle received the lowest ratings; on average, participants “slightly disagreed” and were neutral when considering the usefulness of these systems, respectively. They “slightly agreed” that the adaptive cruise control function of adjusting speed while following a vehicle and the parallel parking assist function would be useful.

After completing their assigned learning protocol, participants agreed more strongly that all the functions performed by the adaptive cruise control and the function of the parallel parking assist would be useful in their driving (all p values < 0.001). Ratings for lane keeping assist, blind spot monitor, and rear cross traffic alert functions indicated that, on average, participants “agreed” to “strongly agreed” that these functions would be useful before they completed their assigned learning method protocols, and the ratings did not change significantly between the Pre- and Post-Visit Surveys.

Table 10: Ratings of agreement with statements about the usefulness of systems that perform ADAS technology functions and results of two-way paired samples t-tests

Statement	Pre-Visit		Post-Visit		Paired Samples Test	
I would find a system that does the following useful in my driving:	**Mean**	**SD**	**Mean**	**SD**	**t statistic**	**p value**
Steers my vehicle into a parallel parking space	**5.17**	**1.703**	**5.83**	**1.322**	**4.193**	**<0.001**
Keeps my vehicle in my lane if I begin to drift out of it	5.79	1.424	5.97	1.414	1.366	0.175
Warns me of vehicles in my blind spot	6.62	0.751	6.46	0.933	-1.700	0.092
Adjusts my speed while I’m following a vehicle	**4.65**	**1.734**	**5.56**	**1.642**	**4.987**	**<0.001**
Brakes my vehicle to a complete stop while I’m following a vehicle	**3.94**	**1.962**	**5.17**	**1.620**	**7.189**	**<0.001**
Accelerates my vehicle from a stop while I’m following another vehicle	**3.26**	**1.734**	**4.71**	**1.727**	**7.658**	**<0.001**
Alerts me when cross traffic approaches while I am backing out of a parking space	6.49	0.925	6.62	0.797	1.285	0.201

Ratings of Trust

Ratings of trust were measured by comparing participants' answers to 7 questions on the Pre- and Post-Visit Surveys. Participants gave ratings of how much they agreed with trusting the function descriptions of each ADAS technology on both the Pre- and Post-Visit Surveys. Before learning about the ADAS technologies participants, on average, were neutral in their ratings for the three adaptive cruise control functions, "slightly agreed" with trusting systems performing parallel parking assist and lane keeping assist functions, and "agreed" that they trusted systems performing blind spot monitor and rear cross traffic alert functions. After completing their assigned learning protocol, with the exception of blind spot monitor systems, participants' ratings of trust in the systems all increased significantly (all p values ≤ 0.002). The blind spot monitor function had an initially high rating of trust in the Pre-Visit Survey and the slight increase in the ratings for the Post-Visit Survey was close to being statistically significant (p = 0.052).

Table 11: Ratings of agreement with statements about trusting systems that perform ADAS technology functions and results of two-way paired samples t-tests

Statement	Pre-Visit		Post-Visit		Paired Samples Test	
I would trust a system to:	**Mean**	**SD**	**Mean**	**SD**	**t statistic**	**p value**
Steer my vehicle into a parallel parking space	**4.82**	**1.638**	**5.62**	**1.413**	**5.152**	**<0.001**
Keep my vehicle in my lane if I begin to drift out of it	**5.18**	**1.387**	**5.63**	**1.489**	**3.904**	**0.002**
Warn me of vehicles in my blind spot	5.72	1.305	6.01	1.156	1.967	0.052
Adjust my speed while I'm following a vehicle	**4.23**	**1.704**	**5.51**	**1.552**	**7.434**	**<0.001**
Brake my vehicle to a complete stop while I'm following a vehicle	**3.62**	**1.716**	**4.74**	**1.657**	**6.027**	**<0.001**
Accelerate my vehicle from a stop while I'm following another vehicle	**3.70**	**1.768**	**5.23**	**1.642**	**8.211**	**<0.001**
Alert me when cross traffic approaches while I am backing out of a parking space	**5.58**	**1.321**	**6.09**	**1.030**	**3.341**	**0.001**

Ratings of Apprehension

Participants rated their agreement with statements regarding feeling apprehensive about using systems that perform each of the ADAS technology function descriptions in the Pre-Visit Survey. Participants "slightly disagreed" that the two functions that only give the driver warnings (i.e., blind spot monitor and rear cross traffic alert) made them feel apprehensive. They "slightly agreed" that the adaptive cruise control functions of accelerating from and braking to a stop while following another vehicle made them feel apprehensive. After learning about the ADAS technologies in the study, ratings about apprehension for all seven ADAS technology functions decreased significantly (all p values ≤ 0.002, except for blind spot monitor which had a p value of 0.035).

Table 12: Ratings of agreement with statements about feeling apprehensive about using systems performing ADAS technology functions and results of two-way paired samples t-tests

Statement	Pre-Visit		Post-Visit		Paired Samples Test	
I feel apprehensive about using a system that:	Mean	SD	Mean	SD	t statistic	p value
Steers my vehicle into a parallel parking space	3.61	1.795	3.01	1.808	-3.129	0.002
Keeps my vehicle in my lane if I begin to drift out of it	3.45	1.637	2.68	1.721	-4.233	<0.001
Warns me of vehicles in my blind spot	2.53	1.573	2.14	1.358	-2.131	0.035
Adjusts my speed while I'm following a vehicle	4.44	1.709	3.09	1.824	-6.656	<0.001
Brakes my vehicle to a complete stop while I'm following a vehicle	5.03	1.776	3.84	1.916	-5.123	<0.001
Accelerates my vehicle from a stop while I'm following another vehicle	5.09	1.664	3.26	1.908	-8.192	<0.001
Alerts me when cross traffic approaches while I am backing out of a parking space	2.77	1.663	2.03	1.249	-3.928	<0.001

Ratings of Interest in Purchasing a Vehicle with ADAS Technologies

In both the Pre- and Post-Visit Surveys, participants were asked to think about their next vehicle purchase and rate their interest in systems that perform each of the function descriptions. Before learning about the ADAS technologies included in the TDS, on average, participants "slightly disagreed" or were neutral in their interest in systems that performed parallel parking assist or adaptive cruise control functions. After completing their assigned learning protocol, interest in purchasing these systems significantly increased (all p values ≤ 0.01). Before their study visit, participants agreed they were interested in lane keeping assist ("slightly agree"), blind spot monitor ("agree"), and rear cross traffic alert ("agree") functions when considering a vehicle purchase in the future and these ratings did not change significantly after learning about the ADAS technologies.

Table 13: Ratings of interest in purchasing a vehicle with systems performing ADAS technology functions and results of two-way paired samples t-tests

Statement	Pre-Visit		Post-Visit		Paired Samples Test	
Thinking about your next vehicle purchase, how interested are you in systems that do the following:	**Mean**	**SD**	**Mean**	**SD**	**t statistic**	**p value**
Steers my vehicle into a parallel parking space	**4.31**	**1.944**	**4.86**	**1.876**	**3.201**	**0.002**
Keeps my vehicle in my lane if I begin to drift out of it	5.28	1.577	5.38	1.811	0.703	0.484
Warns me of vehicles in my blind spot	6.08	1.182	6.14	1.266	0.524	0.602
Adjusts my speed while I'm following a vehicle	**4.28**	**1.963**	**4.90**	**1.880**	**3.033**	**0.003**
Brakes my vehicle to a complete stop while I'm following a vehicle	**3.83**	**1.969**	**4.29**	**1.959**	**2.606**	**0.010**
Accelerates my vehicle from a stop while I'm following another vehicle	**3.32**	**1.749**	**3.91**	**1.896**	**3.307**	**0.001**
Alerts me when cross traffic approaches while I am backing out of a parking space	5.95	1.413	6.23	1.228	1.863	0.065

Learning Preferences

Participants were asked before and after how they would prefer to learn about each ADAS technology. At the end of the study they were asked to assess how much each learning method they experienced (manual, demo, or both) contributed to their learning.

Preferred Methods for Learning to Use ADAS Technologies

In both the Pre- and Post-Visit Surveys, participants were asked which learning protocol they would prefer if they needed to learn how to use the different ADAS technologies. The results are shown in Table 14. Comparing the Post-Visit Survey responses to the Pre-Visit Survey responses across all participants, the number who said they preferred to learn only by reading the owner's manual or by reading first and then receiving a demonstration decreased while those who said they would prefer to learn about a new ADAS technology by only receiving a ride-along demonstration drive or by receiving a ride-along demonstration drive before reading the owner's manual increased. This was true for all five ADAS technologies included in the TDS. Collectively across all five ADAS technologies, participants more often preferred to learn through a protocol that included a demonstration drive. Before completing the site visit, only

17% of the time did participants prefer to only read the owner's manual compared with just 8.5% at the end of the study.

Table 14: Participants' Pre- and Post-Visit Survey responses about how they would prefer to learn about different ADAS technologies

If I needed to learn how to use ____, I would:	**Read the owner's manual**		**Receive a demonstration from another driver**		**Read the owner's manual and then receive a demonstration**		**Receive a demonstration and then read the owner's manual**		**Other**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Adaptive Cruise Control	15	7	25	40	38	29	32	44	10	0
Blind Spot Monitor	20	14	28	49	38	25	27	31	7	1
Lane Keeping Assist	21	10	27	50	36	24	29	36	7	0
Parallel Parking Assist	16	6	27	45	39	23	32	46	6	0
Rear Cross Traffic Alert	24	14	27	52	33	20	29	34	7	0

Each participant's Post-Visit Survey learning preferences were compared to their Pre-Visit Survey learning preferences to see if they had changed. Table 15 shows the percent of participants who selected a different learning preference at the end of the study than they did initially. After completing the study, about 70% of participants who initially said they would like to learn about different ADAS technologies by reading the owner's manual selected a different learning preference. Approximately 60% of those who initially said they would like to learn by first reading the owner's manual and then receiving a ride-along demonstration drive selected a different learning preference on the Post-Visit Survey.

The participants in this study were very interested in learning about ADAS technologies through demonstrations. Prior to their site visits, participants indicated that they would prefer to learn about the five ADAS technologies through a method that included a demonstration 83% of the time. This increased to more than 91% at the end of the study. A few cautions must be made when interpreting these results. The first is that if all four learning methods were equally preferable, a method including demonstration would be selected about 75% of the time. Additional analyses are needed to determine if participant preference for a method including demonstration is sufficiently outside the realm of random chance. A second caution is the effect of self-selection bias, that is, that the people who expressed interest in the TDS and then decided to complete a site visit may have done so because they were very interested in the possibility of seeing ADAS technologies in action. As a result, we cannot at this time generalize the learning preferences observed in this participant sample to consumers as a whole.

Table 15: Percent of participants by ADAS technology who preferred a different way of learning after completing the study

	Learning Preference Report on Pre-Visit Survey							
If I needed to learn how to use _____, I would:	**Read the owner's manual**		**Receive a demonstration from another driver**		**Read the owner's manual and then receive a demonstration**		**Receive a demonstration and then read the owner's manual**	
ADAS Technology	**N**	**Percent**	**N**	**Percent**	**N**	**Percent**	**N**	**Percent**
Adaptive Cruise Control	12	80.00	9	36.00	21	55.26	15	46.88
Blind Spot Monitor	14	70.00	10	35.71	24	63.16	14	51.85
Lane Keeping Assist	16	76.19	9	33.33	23	63.89	13	44.83
Parallel Park Assist	11	68.75	9	33.33	22	56.41	15	46.88
Rear Cross Traffic Alert	17	70.83	7	25.93	20	60.61	15	51.72
Total	70	72.92	44	32.84	110	59.78	72	48.32

Across all five ADAS technologies, at least 60% of participants assigned to the ride-along demonstration drive only protocol or to the demonstration drive/owner's manual protocol changed their learning preferences. In contrast, 57% of participants assigned to the owner's manual only protocol did not change their learning preferences. The differences in the proportions of participants in the different learning protocols who changed their learning preferences were significantly different for adaptive cruise control, $X^2(3) = 8.48$, $p = 0.037$, and parallel parking assist, $X^2(3) = 8.12$, $p = 0.047$.

Participants' learning responses before and after their site visits were examined for each ADAS technology included in the TDS. The results below detail the findings for each ADAS technology.

Adaptive Cruise Control

Of the 15 participants who initially said they preferred to learn about adaptive cruise control from the owner's manual, 80% (n=12) selected a different learning preference at the end of the study. Half of these (n=6) selected demonstration drive/owner's manual, 25% (n=3) selected owner's manual/demonstration drive, and the other 25% selected demonstration drive only. Of the 25 participants who initially preferred to learn about adaptive cruise control from the demonstration drive, only 36% (n= 9) of participants changed their answer at the end of the study. Six of these (67%) selected demonstration drive/owner's manual. Of the 38 participants who initially said they would prefer owner's manual/ demonstration drive, 55% (n=21) selected a different learning preference at the end of the study; two thirds (n=14) decided they would prefer demonstration drive/owner's manual and 24% (n=9) changed to demonstration drive only. Fifteen of the 32 who initially preferred to learn about adaptive cruise control by demonstration drive/owner's manual selected a different option in the Post-Visit Survey; 60% (n=9) decided the demonstration drive only would suffice and one third (n=5) opted for owner's manual/demonstration drive.

Blind Spot Monitor

Twenty participants initially said they preferred to learn about blind spot monitor from the owner's manual; 70% (n=14) selected a different learning preference at the end of the study with about equal preference between demonstration drive only (n=5), owner's manual /demonstration drive (n=5), and demonstration drive/owner's manual (n=4). Of the 28 participants who initially preferred to learn about blind spot monitor from the demonstration drive, only 36% (n=10) of participants changed their answer at the end of the study. Five of these (50%) selected demonstration drive/owner's manual. Of the 38 participants who initially said they would prefer owner's manual/demonstration drive, 63% (n=24) selected a different learning preference at the end of the study; 46% (n=11) decided they would prefer the demonstration drive only, and 38% (n=9) changed to demonstration drive/owner's manual. Just over half (n=14) of the 27 who initially preferred to learn about blind spot monitor by demonstration drive/owner's manual selected a different option in the Post-Visit Survey; 71% (n=10) decided the demonstration drive only would be preferable and about one fifth (n=3) opted for owner's manual/demonstration drive.

Lane Keeping Assist

Twenty-one participants initially said they preferred to learn about lane keeping assist from the owner's manual; 76% (n=16) selected a different learning preference at the end of the study: demonstration drive only (n=6), owner's manual/demonstration drive (n=7), and demonstration drive/owner's manual (n=3). Of the 27 participants who initially preferred to learn about lane keeping assist from the demonstration drive, only one third (n=9) of participants changed their answer at the end of the study. Five of these (56%) selected demonstration drive/owner's manual. Of the 36 participants who initially said they would prefer owner's manual/demonstration drive, 64% (n=23) selected a different learning preference at the end of the study; 48% (n=11) decided they would prefer demonstration drive/owner's manual and 43% (n=10) changed to demonstration drive only. Of the 29 participants who initially preferred to learn about lane keeping assist by demonstration drive/owner's manual, 45% (n=13) selected a different learning preference of lane keeping assist in the Post-Visit Survey; 85% (n=11) opted for the demonstration drive only learning method.

Parallel Parking Assist

Sixteen participants initially said they preferred to learn about parallel parking assist from the owner's manual; 69% (n=11) selected a different learning preference at the end of the study: 55% (n=6) changed to demonstration drive only and 45% (n=5) opted for demonstration drive/owner's manual. Of the 27 participants who initially preferred to learn about parallel parking assist from a demonstration drive, only one third (n=9) of participants changed their answer at the end of the study. Eight of these (89%) selected demonstration drive/owner's manual. Of the 39 participants who initially said they would prefer owner's manual/demonstration drive, 56% (n=22) selected a different learning preference at the end of the study; 68% (n=15) decided they would prefer demonstration drive/owner's manual and 27% (n=6) changed to demonstration drive only. Of the 32 participants who initially preferred to learn about parallel parking assist by demonstration drive/owner's manual, 47% (n=15) selected a different learning preference in the Post-Visit Survey; 80% (n=12) opted for the demonstration drive only learning method and 20% (n=3) preferred owner's manual/demonstration drive.

Rear Cross Traffic Alert

In the Pre-Visit Survey, 24 participants indicated they would prefer to learn about rear cross traffic alert by reading about it in the owner's manual. More than 70% (n=17) selected a different learning preference on the Post-Visit Survey. Almost 60% (n=10) of those who changed their answer opted for the demonstration drive only, 24% (n=4) selected owner's manual/demonstration drive, and 18% (n=3) chose demonstration drive/owner's manual. Of the 27 participants who initially preferred to learn about rear cross traffic alert with a demonstration drive, only 26% (n=7) said they preferred a different learning method after the study; six of those (86%) decided to select demonstration drive/owner's manual. Thirty-three participants opted for owner's manual/demonstration drive on the Pre-Visit Survey; just over 60% (n=20) had a different preference at the end of the study. More than half (55%, n=11) opted for demonstration drive/owner's manual and 30% (n=6) selected demonstration drive only. Of the 29 participants who initially preferred to learn about rear cross traffic alert by demonstration drive/owner's manual, just over half (n=15) selected a different learning preference; 73% (n=11) selected the demonstration drive only learning method.

Effects of Assigned Learning Protocol on Learning Preferences

Cross tabs of assigned learning protocol by Post-Visit Survey learning preference were created for each of the five ADAS technologies and Chi-square tests for independence were conducted. For blind spot monitor, lane keeping assist, and rear cross traffic alert, the null hypothesis of independence between assigned learning protocol and preferred learning method was not rejected.

For adaptive cruise control, the null hypothesis of independence between assigned learning protocol and preferred learning method was rejected, $X^2(9) = 20.92$, $p = 0.013$. Examination of the observed and expected frequencies showed that participants assigned to the demonstration drive only learning protocol more often preferred to learn about adaptive cruise control with the demonstration drive/owner's manual option (63%, n=19), as eight more people than expected selected that option, while only one person preferred the owner's manual/demonstration drive learning method, six fewer participants than expected. Those participants assigned to the owner's manual/demonstration drive learning protocol preferred that learning method over demonstration drive/owner's manual, with about six more than expected selecting the former option and six fewer than expected selected the latter.

Table 16: Cross-tab of learning protocol assigned during the study and preferred method of learning adaptive cruise control reported on Post-Visit Survey.

	Read the owner's manual	Receive a demonstration from another driver	Read the owner's manual and then receive a demonstration	Receive a demonstration and then read the owner's manual
Demonstrative drive	2	8	1	19
Demonstration drive/Owner's Manual	2	12	7	9
Owner's Manual	2	9	8	11
Owner's Manual/Demonstration drive	1	11	13	5

For parallel parking assist, the null hypothesis of independence between assigned learning protocol and preferred learning method was also rejected, $X^2(9) = 19.12$, $p = 0.0242$. One person assigned to the demonstration drive only learning protocol opted for the owner's manual/demonstration drive learning method, five fewer than expected. Half those participants (n=15) preferred the demonstration drive/owner's manual method of learning about parallel parking assist and 47% (n=14) preferred to learn with the demonstration drive only. Of the participants assigned to the owner's manual/demonstration drive learning protocol, 37% (n=11), about five more than expected, preferred the owner's manual/demonstration drive learning method and only 20% (n=6) preferred the demonstration drive/owner's manual learning method, about six fewer than expected.

Table 17: Cross-tab of learning protocol assigned during the study and preferred method of learning parallel parking assist reported on Post-Visit Survey

	Read the owner's manual	Receive a demonstration from another driver	Read the owner's manual and then receive a demonstration	Receive a demonstration and then read the owner's manual
Demonstrative drive	0	14	1	15
Demonstration drive/Owner's Manual	2	9	4	15
Owner's Manual	3	10	7	10
Owner's Manual/Demonstration drive	1	12	11	6

Ratings of How the Learning Protocols Contributed to Participant Learning

On the Post-Visit Survey, all participants were asked to rate how much the learning protocol they experienced contributed to their learning of the purpose and function of each ADAS technology. For example, everyone assigned to a learning protocol that included the owner's manual was asked to rate their agreement on a scale from 1 ("strongly disagree") to 7 (“strongly agree”) with the statements, “Reading the owner's manual contributed to my understanding of the purpose of Adaptive Cruise Control on the highway,” and “Reading the owner's manual contributed to my understanding of the function of Adaptive Cruise Control on the highway.” Similarly, everyone assigned to a learning protocol that included the demonstration drive was asked to rate their agreement with the statements, “The demonstration drive contributed to my understanding of the purpose of Adaptive Cruise Control on the highway,” and “The demonstration drive contributed to my understanding of the function of Adaptive Cruise Control on the highway.”

Ratings of How the Owner’s Manual Contributed to Participant Learning

Ratings of how the owner’s manual contributed to participants’ learning of the purpose and function of each ADAS technology for those who only read the owner’s manual were compared to the ratings of those assigned to the two learning protocols that included both the owner’s manual and the demonstration drive. The ratings given by those who only read the manual were very similar to those who were in the protocols that included both learning methods. Between samples two-way t-tests confirmed that there were no significant differences in the ratings of how the owner’s manual contributed to participant learning. In addition, ratings between the various ADAS technology purposes and functions were similar. Overall the participants who read the owner’s manual “slightly agreed” to “agreed” that it contributed to their learning.

Ratings of How the Demonstration Drive Contributed to Participant Learning

Ratings of how the demonstration drive contributed to the participants’ learning of the purpose and function of each ADAS technology for those who experienced only the demonstration drive were compared to the ratings of those who both read the owner’s manual and experienced the demonstration drive. The ratings given by those who experienced the demonstration drive only were very similar to those who were assigned to the learning protocols that included both learning methods. Between samples two-way t-tests confirmed that there were no significant differences in ratings between the groups. In addition, ratings between the various ADAS technology purposes and functions were similar. Overall participants who experienced the demonstration drive “agreed” to “strongly agreed” that it contributed to their learning.

Comparison for the Groups Experiencing Both Learning Methods

Each participant’s ratings of how each learning method contributed to their learning were compared for the two between-participant groups that experienced both learning methods, i.e., those assigned to the protocol that read the owner’s manual before experiencing the demonstration drive and those assigned to the protocol that experienced the demonstration drive before reading the manual. For example, a participant’s rating for the statement, “Reading the owner's manual contributed to my understanding of the purpose of Adaptive Cruise Control on the highway” was compared to that same participant’s rating for the statement, “The demonstration drive contributed to my understanding of the purpose of Adaptive Cruise Control on the highway.” A paired samples two-way t-test was conducted for each of the ADAS technology functions and purpose statements. The results are shown in Table

18. For all the learning contribution statements for the purpose and function of all the ADAS technologies, the demonstration drive was given higher ratings, indicating that across the board participants who experienced both learning methods rated the demonstration drive as contributing more to their learning than the owner's manual.

Table 18: Ratings of how the owner's manual and the demonstration drive contributed to participant learning for those who experienced both learning methods and the results of the paired samples two-way t-tests

Learning Method	**Reading the Owner's Manual**		**Demonstration Drive**		**Paired Samples Test**	
	Mean	**SD**	**Mean**	**SD**	**t statistic**	**p value**
the purpose of Adaptive Cruise Control on the highway	**5.43**	**1.522**	**6.60**	**0.785**	**6.276**	**<0.001**
the function of Adaptive Cruise Control on the highway	**5.63**	**1.235**	**6.73**	**0.516**	**6.846**	**<0.001**
the purpose of Adaptive Cruise Control in town	**5.18**	**1.467**	**6.23**	**1.079**	**6.221**	**<0.001**
the function of Adaptive Cruise Control in town	**5.27**	**1.287**	**6.47**	**0.812**	**7.227**	**<0.001**
the purpose of blind spot monitor	**5.62**	**1.290**	**6.48**	**0.948**	**5.595**	**<0.001**
the function of blind spot monitor	**5.62**	**1.277**	**6.68**	**0.537**	**6.172**	**<0.001**
the purpose of lane keeping assist	**5.67**	**1.336**	**6.48**	**0.892**	**4.986**	**<0.001**
the function of lane keeping assist	**5.62**	**1.303**	**6.67**	**0.542**	**6.101**	**<0.001**
the purpose of rear cross traffic alert	**5.70**	**1.306**	**6.47**	**0.812**	**4.737**	**<0.001**
the function of rear cross traffic alert	**5.58**	**1.418**	**6.63**	**0.581**	**5.504**	**<0.001**
the purpose of parallel parking assist	**5.47**	**1.512**	**6.45**	**1.016**	**5.364**	**<0.001**
the function of parallel parking assist	**5.32**	**1.384**	**6.63**	**0.610**	**7.064**	**<0.001**

Discussion

After completing their site visits, participants in the TDS had significantly higher total knowledge scores. On average, knowledge scores increased about 170%. Future analyses will determine whether the increase in knowledge was similar across all five ADAS technologies and whether the knowledge scores varied according to the assigned learning protocol.

After learning about ADAS technologies, participants had increased trust and decreased apprehension about using ADAS technologies that performed all the specified functions. Ratings of usefulness and interest in purchasing did not significantly change for blind spot monitor, rear cross traffic alert, or lane keeping assist—systems that only provide alerts or momentary input to vehicle control. However, learning about adaptive cruise control and parallel parking assist—systems that take over speed control and steering control to perform a specific driving task—led an increase in ratings of usefulness and a greater interest in purchasing a vehicle equipped with those systems.

Across all ADAS technologies, a significant proportion of participants (60-85%) who initially said they would prefer to learn about ADAS technologies by experiencing a demonstration drive and then reading the owner's manual changed their learning preference to demonstration drive only. Relatively few participants (<36%) who initially said they would prefer the demonstration drive only preferred a different learning method after the study, but most of those who did change their preference opted for experiencing a demonstration drive followed by reading the owner's manual. Those who initially preferred to read the owner's manual before experiencing the demonstration drive were more likely to select a demonstration drive before reading the owner's manual for adaptive cruise control, parallel parking assist, and rear cross traffic alert. Additionally, those participants were equally likely to select demonstration drive only or a demonstration drive followed by reading the owner's manual for blind spot monitor and lane keeping assist. Additionally, these observations did not seem to be affected by which learning protocol the participant had been randomly assigned to.

Participants assigned to a learning protocol that included both the demonstration drive and the owner's manual indicated that the demonstration drive contributed more to their learning than the owner's manual. It is possible that these results could reflect a bias in the participants who experienced both methods. For example, perhaps the demonstration drive was a more enjoyable task compared to reading the owner's manual and, for that reason, participants who experienced both learning methods may be more likely to give the demonstration drive a higher rating. However, the participants who only read the owner's manual said it contributed to their learning about the same amount as those who experienced both learning methods. Likewise, those who experienced only the demonstration drive said it contributed to their learning about the same amount as those who both experienced the demonstration drive and read the owner's manual. The high level of consistency in these results across the different learning protocols and the different ADAS technologies lend evidence that this is solid finding.

Limitations

Driver understanding of ADAS technologies is an emerging area of focus within vehicle safety and collision avoidance research. Driver knowledge will need to continue to be investigated further to better understand driver knowledge of ADAS technology use and function, especially as the technologies evolve. Additionally, the TDS sample focused on the population that previous research has shown is the mostly likely to purchase a vehicle equipped with ADAS technologies in the near future. Future studies should expand to additional population samples. The effect of self-selection bias should also be taken into consideration when considering these results. For example, people who expressed interest in the TDS and then decided to complete a site visit may have done so because they were very interested in the possibility of seeing ADAS technologies in action. Finally, the site visit period for participants that received both the owner's manual and ride-along demonstration drive could have lasted up to two and half hours, a length of time that could have introduced participant fatigue. This study also had participants observe rather than drive and it is possible that actually driving may further enhance a driver's mental model of ADAS technologies.

Conclusion

The TDS sought to evaluate how the ways in which drivers learn about ADAS technologies affects their knowledge and perceptions of the technologies. The study focused on two base learning methods that are conventional in the real-world: reading an owner's manual and experiencing a ride-along demonstration drive.

The TDS results show increased ratings of trust and usefulness for several of the technologies included in the study. Additionally, the TDS results show decreased ratings of apprehension of all the ADAS technologies and increased interest in purchasing a vehicle equipped with several of the technologies in the study. These findings support the idea that exposure to the technologies impacts a driver's attitudes toward and knowledge of the technologies in the future. The TDS provided insight to how drivers' trust is affected by their initial exposure to the technology.

To our knowledge, the TDS protocol is the first of its kind to measure driver trust, knowledge, and learning preference of driver assistance technologies. The UI believes the protocols developed for the TDS can be expanded to include various brands and trim levels and be adapted to include new and innovative learning methods.

To better understand how to best educate and inform the driving public about these instrumentally life-saving technologies, researchers, policy makers, and the industry must understand how drivers are currently learning about the technologies and how those learning methods affect their knowledge and perceptions. Improved driver understanding will significantly better American roadways.

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