

## **DRIVER UNDERSTANDING OF ADAS AND EVOLVING CONSUMER EDUCATION**

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### **ABSTRACT**

Advanced driver assistance technologies are making striking market penetration into the American passenger vehicle fleet. However, little is known about driver understanding and knowledge of these technologies. These advanced driver assistance systems (ADAS) not only have the ability to alert the driver of hazards and lapses of attention but, in some instances, can intervene to prevent or lessen the severity of a crash. If drivers do not accurately understand a technology's purpose, function, and limitations, the full safety benefit may not be realized and translated to our roadways. This study was part of a broader data-driven national education campaign to help fill consumer knowledge gaps regarding ADAS technologies. Previous research from a nationally representative sample found that most consumers were uncertain about new and emerging vehicle safety technologies, as well as technologies that have been standard for years (McDonald et al., 2015). The Technology Demonstration Study was developed to understand how the way in which consumers learn about ADAS technologies for the first time affects their knowledge of and attitudes about the technologies. This study reports how drivers' knowledge of a technology is influenced by their initial exposure method to the technology. Two base learning methods were utilized for the study, both of which are traditional forms of learning for the average driver: reading the owner's manual and riding in a vehicle. From these base learning methods, four learning protocols were developed, two of which combined the methods. Evaluation of Pre- and Post-Visit Surveys showed that drivers' knowledge of the technologies increased at the end of the study. This paper reports the effects of driver knowledge by each of the four learning protocols and discusses the implications that should be considered when educating consumers on new and emerging ADAS technologies.

## INTRODUCTION

Advanced driver assistance systems (ADAS) have made significant prevalence into the American vehicle passenger fleet over the last few years. ADAS technologies show tremendous promise for improved safety on our roadways [1]. These technologies range from providing warning alerts to drivers of potential hazards to taking on various levels of control of the vehicle to avoid a crash or collision. However, little is known about consumer knowledge of these technologies, including how to interact with them effectively. One survey [2] found that the majority of consumers had heard about several different ADAS technologies, but had significant uncertainty about their operation. This was true for new technologies as well as some that had been standard equipment for years (e.g., ABS).

Prior to 2014, there was little to no historical data or studies that measured drivers' knowledge of a comprehensive number of these technologies [2]. Some of this is due to some of the ADAS technologies' recent emergence into the American fleet. Previous studies were limited in scope, in that they were either focused exclusively on only a few technologies [3, 4, 5] or targeted very specific segments of the driving population [6, 7, 8, 9] or owners of specific vehicle makes [9, 10].

Additionally, compounding the relatively small amount of data is the constant evolution of ADAS technologies. Some ADAS technologies, such as adaptive cruise control (ACC), have been available in passenger vehicles for over a number of years, although their market penetration has been most commonly found in luxury brand and higher-end trim levels [11]. Studies dating back to the 1990s and early 2000s have sought to measure driver understanding and acceptance of ACC [12, 13, 14]. These early studies of ACC measured a much different version of ACC than is available and found in vehicles today.

ADAS technologies are rapidly evolving as technological advances are made and better, more reactive technology is created. The technology is advancing so quickly that, in many instances, drivers are finding themselves behind the wheel with little to no prior experience or exposure to the technology [2]. This is exacerbated by quick market penetration over the last two years. Such ADAS technologies are now available on many entry level vehicles.

Further compounding the evolving nature and

rapid introduction into the market of these technologies is the lack of standardization of the ADAS technology interfaces and naming. Naming convention for the technologies vary considerably from one make to the next. Additionally, the manufacturer ultimately decides how to design the human-machine interface (HMI), as well as the alert timing. For example, a blind spot monitor technology in one make may only provide a visible alert on the mirrors, whereas the same technology in another make may provide a visible alert along with a haptic or auditory alert. This wide variability between manufacturers, makes, models, and even within trim levels could add confusion or misunderstanding to the operation and purpose of the technology.

As these technologies continue to gain market penetration and make their way into the average American passenger vehicle, it is imperative to consider how drivers are understanding, interacting with, and perceiving these technologies, as well as the ways in which drivers learn about how ADAS may impact their overall attitude toward them.

As part of a data-driven national education campaign dedicated to informing the public about ADAS technologies, the Technology Demonstration Study (TDS) was developed. The goal of this study was to provide insight on how learning about ADAS technologies from an owner's manual or through a ride-along demonstration drive impacts a driver's knowledge and understanding of the technology.

## METHODS

The TDS methodology was developed to measure driver knowledge and attitudes towards five ADAS technologies: ACC, blind spot monitor, lane keeping assist, parallel parking assist, and rear cross traffic alert. The final sample included 60 female and 60 male drivers who were unfamiliar with the ADAS technologies included in the study. Study procedures included a Pre-Visit Survey, site visit (included an Intake Survey), completion of a randomly assigned learning protocol (either reading an owner's manual, participating in a ride-along demonstration drive, or a combination of the two), and a Post-Visit Survey.

This paper focuses measuring driver understanding and knowledge of the ADAS technologies, which were administered in the Pre- and Post-Visit Surveys. The following subsections detail the ADAS technology learning outcomes, sample methodology, and finally, the data collection

procedures.

### Identification of Learning Outcomes

As detailed in the Introduction, it was identified early-on in the study development that there is immense variability between the actual deployment of these technologies from one manufacturer to the next. To address this issue, the research team identified a series of “learning outcomes” for all ADAS technologies in the study. The learning outcomes included the purpose, function (how the system works), and limitations of each technology. It was expected that a participant would learn these outcomes from their participation in the study.

The research team identified the outcomes with the technology’s general application in mind, regardless of a specific manufacturer brand, make, or model. To achieve this, various owner’s manuals for popular makes and models equipped with one or more of the five ADAS technologies included in the TDS were obtained and learning outcomes were drafted to be applicable across all types of vehicles. For example, many ACC technologies’ time intervals vary from one model to the next. With this example in mind, the learning outcomes focused on the general application of the technology (in the ACC scenario, a time interval) and that most manufacturers offered a short, medium, and long time interval. This practice was carried throughout all of the ADAS technologies’ learning outcomes to identify the purpose, function, and limitations of each system.

All information included in the study’s learning protocols (the owner’s manual and the ride-along demonstration drive) adequately covered each learning outcome for each technology. Finally, the Pre- and Post-Visit Surveys included 22 multiple choice questions that assessed a participant’s knowledge of each ADAS technology and were directly based on the learning outcomes.

The following tables 1-5 display the learning outcomes developed for each ADAS technology included in the study.

**Table 1.**  
**General ADAS learning outcomes**

|                    |   |
|--------------------|---|
| <b>Purpose</b>     | Are intended to support the driver by providing information, alerts, or minimal levels of control     |
| <b>Function</b>    | Use radar, sensors, and/or cameras to detect the environment around the vehicle                       |
|                    | 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  |
| <b>Limitations</b> | The radar, sensors, and cameras have limitations that can affect system performance                   |

**Table 2.**  
**ACC learning outcomes**

|                    |   |
|--------------------|---|
| <b>Purpose</b>     | An advanced version of cruise control that not only maintains a set speed, but a set distance from the vehicle ahead as well  |
| <b>Function</b>    | Provides some limited amount of braking that varies between manufacturers   |
|                    | 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. |
|                    | When activated, ACC takes over speed control from the driver  |
| <b>Limitations</b> | Will only respond to vehicles that the system has recognized  |
|                    | May "lose track" of vehicles around corners, sharp curves, and if the roadway elevation changes   |

**Table 3.**  
**Blind spot monitor learning outcomes**

|                    |   |
|--------------------|---|
| <b>Purpose</b>     | 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) |
|                    | Some systems provide an escalated warning if a vehicle is located in the blind spot and the driver's turn signal is on  |
| <b>Function</b>    | Only alerts the driver, does not take control of the vehicle in any way   |
| <b>Limitations</b> | Many systems are not designed to detect vehicles passing through the blind spot at extremely fast speeds  |
|                    | May not detect motorcycles, bicycles, or pedestrians in a driver's blind spot   |

**Table 4.**  
**Lane keeping assist learning outcomes**

|                    |   |
|--------------------|---|
| <b>Purpose</b>     | Designed to prevent crashes caused when a vehicle unintentionally drifts out of the lane                          |
|                    | Designed to be used at highway speeds   |
| <b>Function</b>    | Temporarily takes control of steering to try to keep the vehicle in the original lane                             |
|                    | Detects when the vehicle may be drifting out of the lane and will gently steer the vehicle back to the lane       |
|                    | If the vehicle's tires leave the lane, the system will alert the driver with a warning (tone, icon, or vibration) |
|                    | 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                 |
| <b>Limitations</b> | Not designed to work with markings that are faded, covered, in disrepair, or are overly complicated               |

**Table 5.**  
**Rear cross traffic alert learning outcomes**

|                    |  |
|--------------------|--|
| <b>Purpose</b>     | Alerts the driver if one or more vehicles are about to enter the vehicle's backing path  |
| <b>Function</b>    | If the system is turned on, it will activate when the vehicle is shifted into reverse  |
|                    | 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 vehicle  |
|                    | Only alerts the driver, does not take control of the vehicle in any way  |
| <b>Limitations</b> | Has reduced functionality in angled parking situations   |

**Table 6.**  
**Parallel parking assist learning outcomes**

|                    |   |
|--------------------|---|
| <b>Purpose</b>     | Temporarily takes control of steering the vehicle during the parallel parking maneuver  |
| <b>Function</b>    | Searches for a suitable parallel parking spot, notifies the driver to brake to a stop and shift the vehicle into reverse                                      |
|                    | 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    |
| <b>Limitations</b> | The parallel parking system will be cancelled if the backing speed is too fast or if a tire begins to spin or lose traction                                   |

**Sample Methodology**

The basic study eligibility criteria were defined by age, gender, and exposure to the ADAS technologies in the study. 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 study

The majority of participants were recruited to the study from an email sent to eligible individuals identified within the UI National Advanced Driving Simulator (NADS) Participant Registry and from a mass email sent to UI faculty, staff, and students. Other recruitment efforts included Craigslist and word of mouth. All recruitment efforts included a link to an eligibility survey.

Participants were excluded after the eligibility survey if they did not meet all the inclusion criteria, if they'd had exposure to ACC, 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. Individuals were recruited and enrolled into the study until the final desired sample of 120 participants between

the ages of 30 and 55, balanced by gender, was obtained.

### **Study Procedures**

Once determined to be eligible, participants were invited to complete the online Pre-Visit Survey which included questions about their current knowledge of each ADAS technology, as well as their attitudes towards the ADAS technologies including trust, usefulness, and apprehension. Upon survey completion, study staff randomly assigned each participant to one of four learning protocols and scheduled a site visit to the NADS facility. This visit was scheduled at least one week after the completion of the Pre-Visit Survey. The learning protocol assignment was not known to the participant at the time of the site visit scheduling.

At the beginning of the site visit, each participant completed the consent and video release forms and then began the study procedures. Site visit study procedures included the Intake Survey, the learning protocol, and Post-Visit Survey.

The Intake Survey included participant demographic questions, perceptions of technology, and questions related to any exposure to the ADAS technologies included in the study since completing the Pre-Visit Survey.

After completing the Intake survey, participants began the activities for the assigned learning protocol. Upon completion of the learning protocol, the Post-Visit Survey was administered to assess participants' knowledge of each ADAS technology, as well as attitudes toward the systems including trust, usefulness, and apprehension. Participants were paid \$75 for completing all study procedures. If only the Pre-Visit Survey was completed, the participant was paid \$10.

### **Learning Protocols**

The study utilized two base learning methods to serve as the evaluation on participants' knowledge and perceptions of the systems. The first method, reading the owner's manual, was chosen as it is a traditional way that drivers learn information regarding their vehicle. The second method was a ride-along demonstration drive where the participant observed an experienced driver using each of the five ADAS technologies in the study. The two base methods were combined to create four between-participant learning protocols:

- Reading about the systems in an owner's manual

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

Fifteen females and 15 males were randomly assigned to each of the four learning protocols.

### **Owner's Manual**

Throughout the entirety of the TDS, one research vehicle equipped with the five ADAS technologies was utilized for all participants. The original owner's manual for the research vehicle was modified to create the owner's manual for the TDS, retaining only the information pertinent to the five ADAS technologies. In addition, all references to the manufacturer were removed and the manufacturer's specific technology names were replaced with generic ones.

The TDS owner's manual consisted of six sections. The first section of the manual provided information on ADAS technologies in general, with a one-page introduction explaining the purpose and limitations, followed by the research vehicle's owner's manual content describing the camera and radar system. After this initial introduction, one section for each of the five ADAS technologies in the TDS followed, each with a generic introduction written by the research team.

### **Ride-Along Demonstration Drive**

For the ride-along demonstration drive, prior to entering the research vehicle in the NADS parking lot, participants were briefly introduced to the vehicle, including the location of the camera and sensors that supported many of the ADAS technologies. The participant then sat in the front passenger seat of the research vehicle and an experienced driver on the research team (referred to as the demonstration driver) drove a predetermined route, demonstrating the five different ADAS technologies.

The demonstration drive began in the NADS parking lot and continued to a residential area, suburban arterial roads, an interstate, and a US highway before reversing the route back to the NADS. The drive took approximately 40 minutes to complete and included demonstration of all five ADAS technologies in nearly identical fashion for all participants. At specific points during the drive, prior to the demonstration of each technology, the participant was instructed to play an audio file on

an iPad. The audio file provided a general description of that ADAS technology in most vehicles (purpose, functionality, and limitations). The audio file also described the functionality of the ADAS technology unique to the research vehicle. A visual aid that illustrated the steering wheel controls and icons for the ACC and lane keeping assist, which were difficult to see from the passenger position, was also provided. Participants were allowed to make comments and ask questions about the ADAS technologies; however, other communication was kept to a minimum. Questions were answered when the driver deemed it safe to do so. All audio and communication exchanged between the participant and driver were captured from cameras placed inside the vehicle.

As part of the drive, an additional driver assisted the demonstration driver in another (assist) vehicle to assure the demonstrations were consistent and safe. Communication through a hands-free (Bluetooth) cell phone connection was used between the drivers. To maintain the highest possible consistency between participants, a total of two demonstration drivers and four assist drivers worked in groups to become familiar with the detailed route protocols. All drivers were blind to the learning protocol randomly assigned to the participants.

A brief description of each ADAS technology's demonstration is described below. The technologies are presented in the same order they were demonstrated during the drive to all participants.

**Parallel Parking Assist** A staged parallel parking space was pre-arranged by the demonstration and assist drivers in a residential area. As the demonstration driver approached the parking demonstration area, the driver activated the parallel parking assist and followed the directions provided by the system while the participant observed. The driver controlled the speed of the vehicle and shifted (when prompted) while the system steered the vehicle into the space.

**Blind Spot Monitor** The blind spot monitor was demonstrated on a four-lane suburban arterial street with a median divider. The participant observed the indicator warning icons for both the standard warning (occurred when a vehicle was in the blind spot) and the escalated warning (occurred when a vehicle was in the blind spot and the turn signal was activated) on both the driver and passenger sides of the vehicle.

**Lane Keeping Assist** The lane keeping assist demonstration was completed on a high-speed four-lane divided US highway. The participant observed the research vehicle drift toward the lane boundary and then observed the system steering to keep the vehicle in the lane. The demonstration was completed twice to the right and twice to the left. The assist vehicle drove in the adjacent lane to prevent overtaking traffic from interrupting the demonstration.

**ACC** To demonstrate the full functionality of the research vehicle's ACC, the demonstration occurred in two roadways: on the same US highway and a suburban arterial with stop light-controlled intersections. During the highway demonstration, the participant observed three of the ACC system's five time interval settings (short, middle, and long). On the suburban arterial, the participant observed the functionality of the ACC system in stop and go traffic situations, including how the ACC system can brake to a complete stop and re-accelerate while following the assist vehicle. All participants observed at least one stop or near-stop (5 mph or less).

**Rear Cross Traffic Alert** The demonstration drive concluded with the rear cross traffic alert demonstration in the NADS parking lot. After pulling into a perpendicular parking space, the demonstration driver slowly backed out of the parking space while the assist vehicle traveled towards the rear passenger side of the research vehicle, activating the rear cross traffic alert on the right side. The participant then observed the rear cross traffic alert from the driver's side, as the assist driver made another pass from the left.

## **RESULTS**

The final dataset included a total of 120 participants from the Iowa City regional area between the ages of 30 and 55 ( $M = 41.4$ ,  $SD = 8.2$ ), balanced equally by gender. All participants had at least 12 years of driving experience ( $M = 24.6$ ,  $SD = 8.5$ ). The majority of participants were employed outside the home (92%) and the mode household income range was \$50,000 - \$99,999.

### **ADAS Technology Knowledge**

Analyses in this paper focus on the 22 driver knowledge questions included in the Pre- and Post-Visit Surveys. These questions were identical in content in both surveys. All knowledge questions were randomized in appearance within the surveys between participants. While the five ADAS

technologies did not have an identical number of knowledge score questions, each technology did have knowledge questions that measured the purpose, function (how the technology works), and limitations. To ensure the purpose, function, and limitations were equally measured for each technology, the technologies had varying numbers of knowledge questions.

Participant knowledge about the ADAS technologies was measured by comparing participants' answers to the 22 knowledge questions on the Pre- and Post-Visit Surveys. All driver knowledge questions only had one correct answer choice. Responses to each knowledge question were converted to scores by assigning a value of 1 when participants selected the correct answer and received 0 when they selected anything other than the correct answer. Scores were calculated for each participant into a continuous variable by adding together the correct responses to the 22 driver knowledge questions. This resulted in a total possible score range of zero through 22.

Knowledge scores were calculated for all participants. On average, participants got six knowledge questions correct on the Pre-Visit Survey (Table 1). After completing the site visit, the knowledge scores increased on average by 10 points to an average score of 16.45 correct on the Post-Visit Survey.

Analysis of the knowledge score means were calculated for each of the four learning protocol groups as reflected by Table 7. The Pre- and Post-Visit Survey knowledge scores and the standard deviation with each learning protocol are noted.

**Table 7.**  
**Knowledge score by learning condition**

|                                      | <b>Pre-Visit Knowledge Score (SD)</b> | <b>Post-Visit Knowledge Score (SD)</b> |
|--------------------------------------|---------------------------------------|--|
| All participants                     | 5.99<br>(2.97)                        | 16.45<br>(2.69)                        |
| Demonstration drive                  | 5.87<br>(2.94)                        | 15.73<br>(2.43)                        |
| Owner's manual                       | 5.63<br>(2.44)                        | 15.43<br>(2.94)                        |
| Demonstration drive + owner's manual | 6.7<br>(3.26)                         | 17.77<br>(2.51)                        |
| Owner's manual + demonstration drive | 5.77<br>(3.19)                        | 16.87<br>(2.27)                        |

The following table (Table 8) represents the difference within each group of the total knowledge score from the Pre- to Post-Visit Surveys. The paired

samples test in Table 8 illustrates that the difference from the Pre- to Post-Visit Surveys was statistically significant within each condition group.

**Table 8.**  
**Knowledge score difference by learning condition**

|                                      | <b>Difference from Pre- to Post-Visit Survey (SD)</b> | <b>p-value</b> | <b>T statistic</b> | <b>df</b> |
|--------------------------------------|---|----------------|--------------------|-----------|
| All participants                     | +10.46<br>(0.28)                                      | <0.001         | 31.05              | 119       |
| Demonstration drive                  | +9.87<br>(0.51)                                       | <0.001         | 16.7               | 29        |
| Owner's manual                       | +9.8<br>(0.50)  | <0.001         | 13.58              | 29        |
| Demonstration drive + owner's manual | +11.07<br>(0.75)                                      | <0.001         | 16.97              | 29        |
| Owner's manual + demonstration drive | +11.1<br>(0.92)                                       | <0.001         | 15.49              | 29        |

When considering only the Post-Visit Survey knowledge score (not considering for the Pre-Visit Survey knowledge score or standard deviation), participants in the condition that received the ride-along demonstration drive followed by the owner's manual had the highest calculated knowledge score of 17.77, with a standard deviation of 2.51. It should be noted that this group also had the highest calculated Pre-Visit Survey knowledge score total, as well as the highest standard deviation value in the Pre-Visit Survey. The both groups both had the greatest difference of knowledge score gain from the Pre-Visit Survey the Post-Visit Survey of +11.07 and 11.1.

When only considering the difference from the Pre- to Post-Visit Survey, participants that reviewed the owner's manual followed by the demonstration drive had the greatest difference from the Pre- to Post-Visit Survey of +11.1, slightly larger than the difference calculated for participants receiving the demonstration drive followed by reviewing the owner's manual.

The conditions that only consisted of the demonstration drive or reviewing the owner's manual had knowledge score totals of 15.73 and 15.43, respectively. Additionally, the demonstration drive only protocol participants had a calculated difference of 9.87, while the owner's manual only participants had a calculated knowledge score difference of 9.8 from the Pre- to Post-Visit Surveys. The owner's manual only had the lowest calculated Pre-Visit Survey knowledge score of the four groups at 5.63,

with the second greatest standard deviation among the four protocols. The owner's manual only protocol also had the lowest calculated knowledge score in the Post-Visit Survey, with the greatest standard deviation of the four protocol groups.

To better understand the variance between the groups, a set of ANOVA analyses was conducted. The research team wanted to understand if there were any effects of each group's starting (Pre-Visit Survey) and ending (Post-Visit Survey) knowledge scores, and the difference in the knowledge score from Pre- to Post-Visit Survey by protocol. The research team found that the Pre-Visit Survey differences between the groups were not statistically significant. Additionally, the differences from the Pre- to Post-Visit Surveys were not statistically significant between the groups, either. ANOVA results found that, when comparing the "only groups" (those only receiving the demonstration drive or owner's manual protocol) to the "both groups" (those experiencing both the demonstration drive and owner's manual), while the means were greater for the "both groups," this was not statistically significant. When considering the Post-Visit Survey knowledge score only by protocol group, the scores were statistically significant ( $p = 0.018$ ).

## DISCUSSION

Prior to the site visit, participant knowledge about ADAS was relatively low and only slightly better than the score expected for guessing at random (about 5.23). After completing their site visits, on average, TDS participants (regardless of learning protocol) had significantly higher total knowledge scores. On average, knowledge scores increased approximately 170%. Additionally, within each protocol group, the knowledge score increased from the Pre- to Post-Visit Survey. These results indicate that, regardless of learning protocol, participants gained knowledge about the ADAS technologies.

The mean knowledge scores for each learning protocol varied for both the Pre- and Post-Visit Surveys. The mean knowledge scores on the Pre-Visit Survey for all four learning protocols were within 1.1 points of one another. When considering these Pre-Visit Survey scores only, no significant differences between the participants randomly assigned to the four learning protocols were found. In other words, all four between-participant groups began the study with comparable levels of knowledge of ADAS technologies, even though some variability exists between the scores.

Although at the end of the study participants in the two protocol groups that received both the demonstration drive and owner's manual did have mean knowledge scores more than a point higher than those who received only the demonstration drive or only the owner's manual group, this difference was not statistically significant. Considering that the four learning groups began the study with essentially the same knowledge level, further in-depth analyses are required to understand the true differences in these scores. For example, there may be differences between the learning protocols that resulted in better scores for the driver knowledge questions regarding limitations versus those on purpose or function. Future analyses can investigate if a learning protocol affects which components participants learn about best (purpose, function, or limitation of a system).

While there was individual variety, each learning protocol's mean knowledge score was statistically significant, indicating that learning protocol had an overall effect on participants' knowledge of the ADAS technologies. As indicated, further analyses must be conducted to better understand the uniqueness of the effect on knowledge by each participant.

## LIMITATIONS

Driver understanding of ADAS technologies in the in a broader context is an emerging area of study within human factors and automotive HMI in general. While there is robust literature in HMI issues related to alerting drivers in the crash avoidance context, little is known about how such ADAS technologies are understood when all combined. Until recently, few new technologies have been introduced to the driver. ABS and electronic stability control (ESC) were among the few technologies to be introduced. Now there is suddenly a myriad of technologies coming into vehicles all at once.

To best measure driver understanding of these changing and evolving technologies, future and continued study of driver knowledge of the purpose, function, and limitations must continue to be investigated. Due to time limitations, this study concentrated on five ADAS technologies, which only represents a small number of the overall driver assistance technologies available on the market today. Future studies should expand the number of technologies included.

The TDS focused on a specific subcomponent of the population: individuals in the age range that



are most likely to purchase a vehicle equipped with these features. Future studies should consider additional age populations to adequately measure any possible differences in comparisons.

As in all experimental studies, there is a self-selection effect. For example, individuals that expressed interest in participating in the study may have been more interested in technology, vehicles, or research and wanted the opportunity to observe ADAS technologies. Additionally, the site visit varied in length for participants from approximately one hour to more than two and half hours, depending on the learning protocol. For example, the protocol involving both the owner's manual and ride-along demonstration drive could have lasted up to two and half hours. This time commitment could have potentially deterred some individuals from participating in the study.

Finally, this study evaluated changes in driver knowledge based on reading written materials about or direct observation of the ADAS technologies. Previous research indicates that an individual's mental model is crafted and developed based on actual use and experience with the technology or interface [15]. Knowledge scores may be impacted or influenced by a driver's first use of the technology and this influence should be further investigated.

## CONCLUSION

The TDS sought to understand how drivers' first exposure to five ADAS technologies through two conventional learning methods affected their knowledge of and attitudes about the technologies.

Regardless of initial exposure method to the ADAS technologies, knowledge scores increased among all participants. Each of the four learning protocol groups did individually experience increased knowledge scores from the Pre- to Post-Visit Surveys, demonstrating that these conventional learning methods are effectively conveying information about the technologies to the consumer.

These findings illustrate that initial exposure method to the ADAS technologies influences a driver's overall knowledge of the technology. However, further studies and analyses are necessary to understand the individual effects of each learning method on various elements of driver understanding relating to the technologies (i.e., purpose, function, or limitation of the technology). It is critical that drivers completely understand these technologies to ensure their safety benefits

are translated onto our roadways. As these ADAS technologies continue to evolve, consumer education should be evaluated to ensure the driver understands how to most effectively engage, interact, and anticipate the technology's actions.

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