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Evaluating the Effectiveness of Drivers' Education Modules on Safety

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16. Abstract

This research examined the effectiveness of driver education and training, with particular attention to improving understanding and safe use of Advanced Driver Assistance Systems (ADAS). Four tasks were conducted: (1) interviews and surveys with Massachusetts driver education stakeholders to identify current practices and needs; (2) development of a targeted driver education module on Adaptive Cruise Control (ACC); (3) a longitudinal, between-subjects experiment comparing in-person and online driver education formats, with and without ACC content; and (4) analysis of crash and citation records one year post-training. Stakeholder insights highlighted the importance of instructional quality, parental involvement, and structured ADAS education. Experimental results did not identify consistent or statistically significant differences in the measured outcomes attributable to instructional format or ACC training, within the constraints of the study design and sample sizes. A small number of crashes or citations were reported within the first year, though event counts were too low for meaningful group-level inference. . A small number of crashes or citations were reported within the first year. Findings underscore the need for periodic review and evaluation of driver education, incorporation of ADAS training into curricula, and dissemination of best practices to enhance novice driver safety and technology competence.

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Evaluating the Effectiveness of Drivers' Education Modules on Safety

Final Report

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Disclaimer

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Massachusetts Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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Executive Summary

This study of Evaluating the Effectiveness of Drivers' Education Modules on Safety was undertaken as part of the Massachusetts Department of Transportation (MassDOT) Research Program. This program is funded with Federal Highway Administration (FHWA) State Planning and Research (SPR) funds. Through this program, applied research is conducted on topics of importance to the Commonwealth of Massachusetts transportation agencies.

Scope and Objectives

The goal of this research was to better understand the effectiveness of driver education and training as well as how such education and training can improve the use and understanding of Advanced Driving Assistance Systems (ADAS). We accomplished this goal through completion of four tasks.

In Task 1, we examined stakeholder insight using interviews and surveys to develop an informed understanding on current driver education and training programs in Massachusetts. In Task 2, the information obtained from the stakeholder surveys and interviews in Task 1 were leveraged to inform the design of the content and delivery of a driver education training module for Adaptive Cruise Control (ACC), a driver-assistance feature that automatically adjusts speed to maintain a set following distance behind a lead vehicle. In Task 3, we assessed the effectiveness of driver education format *and* the effectiveness of the ACC training module via a longitudinal, between-subjects research experiment. In the experiment, there were three groups: teens who received in-person driver education instruction that did not include ACC information, teens who received in-person driver education instruction that did include ACC information, and teens who received online driver education instruction that did not include ACC information. The comparison between in-person (Group 1) and online (Group 2) instruction reflects a naturalistic observation of two existing school environments and not a randomized controlled trial, therefore instructional format may be confounded with school and region as a result of this design choice. In Task 4, the crash and citation records for the same teen drivers from Task 3 were extracted subjectively and from the Massachusetts Vehicle Census one year after undergoing the research experiment in Task 3 to assess the long-term effects of driver education instruction that included ACC information.

Research Issue

There is mixed evidence as to the effectiveness of driver education courses, especially as it relates to the delivery and format of driver education. Some research suggests that driver education programs do not directly impact traffic crashes or citations, but rather manifest

themselves in terms of improved driver behaviors. Relatedly, there has yet to be a comprehensive examination of driver education class instruction programs to determine which, if any, modules of these programs positively influence behaviors of novice/newly licensed teen drivers.

It is also unknown whether driver education can be used to train drivers on how to interact with ADAS. Training and education are critical since not having an appropriate understanding of the capabilities and limitations associated with ADAS can be detrimental. Previous research funded by MassDOT has shown that drivers do not have a safe and structured way of understanding ADAS. However, research has also shown that it may be possible to accelerate understanding and knowledge of ADAS through targeted driver education and training.

Significance

Traffic crashes are the number one cause of death for teens and the crash rate for teen drivers is disproportionately higher than the share of licensed teen drivers. Teen driver education and training has long been suggested as a means to reduce the crash rate. It has also been shown that when it comes to methods to reduce teen driver crash risk, vehicle driver safety technology such as ADAS, is promising.

The project yielded data detailing the effectiveness of driver education programs on improving driver safety and reducing driver citations and provided insight regarding education components, delivery methods, etc. that lead to optimal effectiveness in positively influencing safe ADAS use and teen driver behavior. These outcomes will assist MassDOT in developing regulations, policies and practices throughout its driver education program curriculum and licensing processes.

Main Findings

In Task 1, four main themes emerged from the interviews and surveys: Driver education pedagogy, Parents' role, ADAS, and Safety. The theme of *Driver education pedagogy* encompasses stakeholders' insights as it relates to the method and practice of teaching teens how to drive as well as the importance of driver education instructors. The theme of *Parents'/Guardians' role* refers to the importance of parents/guardians in the driving education process, including teaching teens about how to use ADAS. The larger theme *ADAS* consists of three sub-themes: ADAS pros and cons, ADAS usage, and acquiring knowledge about ADAS. The last theme of *Safety* was focused on Junior Operator License (JOL) violations and teens receiving warnings or citations.

In Task 2, a training program was developed such that it could be delivered as a single in-person classroom lecture (approximately 30 minutes) using a PowerPoint presentation. The program comprised four sections: (1) introduction to various vehicle technologies; (2)

introduction to common ADAS technologies; (3) overview and details of ACC; (4) drivers' responsibility when using ACC. Driving education instructors were trained on how to deliver the training program to teen drivers and given general information about ADAS and ACC.

In Task 3, analysis of the subjective survey data did not reveal statistically significant differences in the teen drivers' assessment of their readiness to drive across the three groups . However, the teen drivers consistently rated themselves as more ready to drive than their parents, indicating that these teen drivers felt they are more prepared for driving than their parents believed. Most of the teen drivers felt that their driving education courses were effective and no statistically significant differences were detected between the three teen driver groups . No statistically significant differences in driving performance (e.g., hazard anticipation) were detected between the groups . When it comes to one's knowledge about ACC as well as their eye movements while driving with ACC, ACC mental model scores were similar between Group 1A and Group 1B despite Group 1B receiving targeted ACC training. This may be due to the brief duration of the training module, prior incidental exposure, retention effects, or limitations in assessment sensitivity, but it is important to note that this data does not distinguish among these plausible explanations. Group 2A showed descriptively lower ACC knowledge scores than Group 1A, though this was not statistically tested. Eye tracking behavior while using ACC was similar across groups. .

In Task 4, follow-up survey responses were obtained from 57 of 90 participants (66% response rate), yielding 5 self-reported warnings, 1 parking citation, and 7 self-reported crashes. The Massachusetts Vehicle Census identified 1 citation and 9 police-reported crashes across the full sample. The discrepancy between sources reflects differences in coverage (police-reported vs. self-reported) and survey non-response. Event counts were too small for meaningful group-level statistical inference regarding differences in warnings, citations, or crashes by driver education group..

Conclusions and Recommendations

Based on findings, we have the following recommendations:

1) There should be periodic reviews of state of driver education and driver education programs to maintain an accurate understanding of what teen drivers are being taught.
2) There should be periodic evaluations to determine the effectiveness of driver education programs. Evaluations should be multi-modal in nature and they should be conducted by multiple evaluators.
3) There should be periodic working group meetings comprised of a wide variety of stakeholders (e.g., MassDOT, driver education instructors, and transportation safety professionals) to discuss best practices for driver education.
4) Given the proliferation of ADAS in vehicles, both new and used, training teen drivers on their usage will continue to be a growing need.

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List of Acronyms

Acronym	Expansion
ACC	Adaptive Cruise Control
ADAS	Advanced Driving Assistance Systems
GDL	Graduated Drivers Licensing

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1.0 Introduction

This study *Evaluating the Effectiveness of Drivers' Education Modules on Safety* was undertaken as part of the Massachusetts Department of Transportation (MassDOT) Research Program. This program is funded with Federal Highway Administration (FHWA) State Planning and Research (SPR) funds. Through this program, applied research is conducted on topics of importance to the Commonwealth of Massachusetts transportation agencies.

1.1 Background

Motor vehicle crashes are one of the most significant causes of injuries and fatalities nationally, especially when it comes to teen drivers. Accordingly, a primary strategy for reducing teen driver crashes has been to provide formal programs to educate and train teen drivers.

1.1.1 Teen Driver Education

Driver Education is designed to prepare drivers for pre-license testing and licensing (1,2). Across the US, contemporary driver education programs include state-approved school-based, private, or parent-taught programs (3). Traditionally, driver education consists of classroom and in-vehicle driving components, with a high level of interaction and engagement (2,4,5). These programs are designed to help teen drivers safely gain some experience while also gaining the knowledge and skills needed to reduce risky driving behavior. In Massachusetts, there are approximately 100 driver education schools, which are either private, professional driver education schools or high-school based driver education schools. Driver education schools are required to have 30 hours of classroom instruction, which can be in-person, virtual, or hybrid, that teach students about Massachusetts motor vehicle laws as well as the safe operation of a motor vehicle. Students must also have 12 hours of behind-the-wheel instruction and 6 hours of observation of another student undergoing behind-the-wheel instruction. In addition, at least one parent/guardian of the student must attend a 2-hour class conducted by the driver education program (6,7).

Graduate drivers licensing (GDL) programs have been implemented in recent years and have been proven to lower fatal crash involvement rates for drivers under 18 years of age (8). GDL programs do not typically include education or training on the skills needed for the driving process. In Massachusetts, GDL programs have multiple stages. At age 16, teens can obtain their learner's permit after taking a written exam. The learner's permit has restrictions in terms of when and with whom teens can drive. Between the ages of 16.5 and 18 years old, teens may obtain their junior operator license (JOL) if they have held their learner's permit for 6 months, have taken a driver education course, completed 40 hours of supervised driving with their parent/guardian, and have passed a road test. The JOL has restrictions concerning

when teens can drive, who they can drive with, and their use of mobile devices. At age 18, teens can obtain their full driver's license with no restrictions (6,9,10).

Driver education programs have continued to evolve, with changes in content and delivery, along with the advent of COVID-19 marking a shift from in-person to online classes. At the same time, there has been a change in the types and availability of in-vehicle driver assist technologies, i.e., advanced driver assistance systems (ADAS), that provide support and assistance towards the driving task. A recent study by the Highway Loss Data Institute found that by 2027, the presence of ADAS is expected to increase by 20 to 27% (11). ADAS including crash prevention systems, lane centering and adaptive cruise control systems are expected to increase by 50% and 8-15% respectively. These systems can help with the task of safe driving and can potentially mitigate unwanted consequences from limitations of teenage drivers. However, to use these systems effectively, drivers need to be trained and educated on their operation and limitations.

1.1.2 Vehicle Technology and ADAS

ADAS are automotive features that can provide driver support in terms of lateral and longitudinal position and provide crash warnings and alerts (12). However, a driver's efficient use of ADAS depends on factors such as knowledge, trust, and perceptions of these systems. Extensive research has been conducted on the correlation between improving the knowledge of drivers and the safe use of ADAS (13–16). Research has also been conducted for younger and older drivers, although not specifically for teen drivers (17–20). For example, Pradhan et al (19) reported that while training did improve users' mental models about technology, it also mattered what platforms or paradigms were used in training. Hoyos et al. (18) found a difference in how younger and older drivers prefer to learn about vehicle automation. Younger drivers (18-39 years old) generally tend to prefer trial and error, whereas older drivers (40 years and older) prefer consulting the dealership or using the owner's manual. Abraham et al. (17) also found that as drivers get older, they tend to learn from the dealership and spend more time receiving instructions as compared to younger drivers. Sportillo et al. (20), compared the effectiveness of driver training mediums (video, augmented reality (AR), or virtual reality) for younger and older drivers, and found that with respect to age, older drivers given video training reacted slower than younger drivers. In addition, AR-based older drivers reacted quicker than AR-based younger drivers. While ADAS may have the potential to help mitigate the crash risk faced by new teen drivers (21–23), training teen drivers on the use of these systems remains an open concern.

1.2 Objective

The objective of this research was to better understand the effectiveness of driver education and training as well as how such education and training can improve the driver's understanding and use of ADAS. The research examined the role of the driver education framework for teen driver training and helped to identify opportunities to improve driver education programs to positively influence new driver behavior and the importance of ADAS-centric training for newly licensed drivers.

1.3 Tasks

1.3.1 Task 1: Stakeholder Engagement Regarding Teen Driver Education and Training

In Task 1, we examined stakeholder insight using interviews and surveys to develop an informed perspective on current driver education and training in Massachusetts. One objective was to gather more information about how driver education is currently delivered in Massachusetts to develop a catalog of driver education approaches. Another objective was to understand Massachusetts stakeholder perspectives on aspects of advanced technology in vehicles and how current and future technologies can be incorporated into the current driver education curriculum and program delivery framework.

To note, much of the work conducted under this task has been published in (24). The relevant text from that published article is repeated here.

1.3.2 Task 2: Development and Dissemination of ADAS Specific Training Program

In Task 2, the insights gained from the stakeholder surveys and interviews (in Task 1) were leveraged to inform the design of the content and delivery of a driver education training module for ACC. To align with current curriculum, the ACC module was standalone, but delivered in the same format and using the same delivery method as the current curriculum. In this task, we also "trained the trainers" and taught driver education instructors how to deliver the new ACC module.

1.3.3 Task 3: Survey and Driving Simulator Experiment to Assess Behavior

In Task 3, the training program developed in Task 2 was delivered to a sample of teen drivers. We then assessed the effectiveness of driver education format *and* the effectiveness of the ACC training module via a longitudinal, between-subjects research experiment. Each participant completed a series of surveys and a driving simulator experiment.

1.3.4 Task 4: Longitudinal Data Collection of Crashes and Citations

In Task 4, to assess the long term effects of teen driver education format *and* the effectiveness of the ACC training module, the crash and citation records for the same teen drivers from Task 3 were extracted from the Massachusetts Vehicle Census one year after undergoing the research experiment in Task 3.

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2.0 Research Methodology

2.1 Task 1

A convergent mixed-methods approach was employed using interviews and surveys with a diverse group of stakeholders in the transportation field that included driver education instructors, Massachusetts Department of Transportation (DOT) employees, law enforcement officers, vehicle dealership representatives, and transportation safety scholars (i.e., experts on the training and education of drivers) The study was approved and determined to be exempt by the University of Massachusetts Amherst IRB under protocol #4658.

2.1.1 Participants

For the interviews, purposive sampling, we recruited participants from three groups: law enforcement officers, driver education instructors, and Massachusetts State DOT employees with roles overseeing and/or ensuring compliance of driver education programs within the state. We conducted 11 interview sessions to reach saturation (25). Among the 11 interviews, there were 4 law enforcement officers, 4 driver education instructors, and 3 State DOT employees. Participants were recruited using various methods including flyers, email, emails, mailing lists, and with help from collaborators at the Massachusetts Department of Transportation.

For the surveys, twenty transportation safety scholars completed a survey that was designed to elicit perspectives about the topic without necessarily having to involve this cohort in interviews. As all questions were optional, the number of responses varies per question. Six automobile dealership employees completed a separate survey to gather their perspectives on teen's education and ADAS training. The transportation safety scholar professionals were recruited from a research conference, and the vehicle dealership employees were recruited from vehicle dealerships in Western Massachusetts.

2.1.2 Procedure

For the interview, potential participants were contacted via email or phone to ascertain their interest in participating in the interview study. They were informed about the purpose of the interview study, its length, as well as compensation ($100 in cash). If participants expressed interest, they were asked to complete an informed consent document and specify whether they preferred an in-person or virtual interview.

Interviews were conducted with each participant by two members of the research team, a lead interviewer who asked most questions and a secondary interviewer who took notes and asked probing/follow-up questions. The interview began with the interviewers introducing themselves and the study, followed by the participant introducing themself. Next, participants were asked a series of open-ended questions in two sections. These open-ended questions were designed a priori to elicit the interviewees' insights into topics related to driver

education and teen driver training in the first section and related to ADAS education in the second section. The questions were tailored based on the stakeholder group. If necessary, probing or follow-up questions were asked to gather additional information. The interview session lasted an average of 48 minutes (SD = 16 minutes) and was conducted, recorded, and transcribed using Zoom software. After the interviews were conducted, participants completed a payment voucher and received compensation.

Interview questions were developed based on past research (e.g., (26,27)) as well as in consultation with collaborators and colleagues in transportation safety. The interview was pilot tested to ensure interpretability, flow, and comprehensiveness. All interview questions are listed in Appendix A.

For the transportation safety scholar survey, six open ended questions asked about teen driver education and training. Fifteen multi-select (i.e., participants could select one or more response) questions were asked about ADAS training, including topics such as ADAS training delivery methods, training in relation to driver education programs, parental aspects of training, and metrics to assess ADAS training.

During a large conference focused on transportation safety, potential participants were approached by members of the research team asking them to complete a brief survey. The survey took between 5-15 minutes to complete, depending on how much time each participant spent answering the open-ended questions and whether they completed the survey in one session. Given the nature of the questions and the expertise level of the participants, the research was not deemed to be human subjects research by the institutional IRB. As such, participants did not need to provide consent, and they were not compensated.

For the automobile dealership survey, there were twenty-five questions and all of them were either multi-select or multiple-choice questions. Members of the research team visited automobile dealerships and asked to speak with staff who were knowledgeable about the vehicle training process. After providing a brief overview of the study, participants were asked if they wanted to participate. After giving consent, participants completed the survey, which took an average of 8.5 minutes (SD = 1.9 minutes) to complete. Upon completion, participants were compensated $40.

2.1.3 Data Analysis

The primary analysis of the interviews employed a qualitative thematic analysis, following a systematic multi-step approach, as set forth by Braun & Clarke (28). Initially, two researchers independently reviewed a single and randomly selected interview transcript to identify “codes”, i.e., key opinions, ideas, and pieces of information. To identify recurring themes within the interview data, the codes were collated and synthesized across stakeholder groups into a mind map. This began by grouping the codes across all interviews in the stakeholder group based on thematic similarity. Each group of codes was assigned a thematic label that encapsulated the underlying concepts. Connections between themes were identified, especially when specific ideas overlapped or influenced multiple themes. The final phase of the analysis involved synthesizing the themes across different stakeholder groups,

which involved identifying and removing duplicate themes as well as identifying (more) connections between themes as well as subthemes.

For the surveys, multiple choice responses from both surveys were quantitatively analyzed using descriptive statistics to identify common trends and preferences. For the remaining open-ended survey questions, survey responses were aggregated and summarized.

2.2 Task 2

We developed an ADAS specific training module to teach drivers about adaptive cruise control (ACC). The ADAS module incorporated the findings from three sources: (1) brief literature review of training programs; (2) current implementations of ACC in production vehicles; and (3) insights from Task 1 (Stakeholder Engagement). We selected Adaptive Cruise Control (ACC) as the focal ADAS technology because it is increasingly common in the U.S. vehicle fleet and is a representative, partially automated feature that can materially affect driver workload, attention allocation, and following behavior. ACC also has well-documented limitations and potential misuse scenarios, making it a strong candidate for structured education for novice drivers.

2.2.1 Literature Review

Through a brief literature review of articles designed to assess the effectiveness of ADAS training on driver performance, a few key insights emerged that guided the design of ACC training. First, there are differences in terms of how the mode of presentation affects performance. For example, training delivered through instructional videos is more effective in terms of glance behavior, mental workload, and overall driving performance in comparison to a demonstration approach, wherein the driver is taught by an instructor followed by an in-vehicle demonstration (16). Taking it one step further, interactive and hands-on experience (e.g., in a simulator, augmented reality, or virtual reality environment) where drivers can practice using the technology is more effective than watching videos or reading an owner's manual in terms of driving performance, situation awareness, and trust (20,29–31). Third, many articles have identified key components to be contained in any ADAS training program, such as the driver's responsibility when using ADAS (32,33), how to activate and deactivate ADAS (33), as well as abilities and limitations of ADAS (32,33). Taken together, insights from the literature review suggest that ACC training should be interactive, should include video demonstrations, and should contain information about ACC functions as well as the driver's role when operating a vehicle with ACC.

2.2.2 Current Implementations of ACC in Production Vehicles

Through numerous sources (Car and Driver Magazine, Kelly Blue Book, US News World and Report, CNBC, Edmunds, and the Massachusetts Vehicle Census), we identified the top five vehicle manufacturers and models: (1) Ford F-150; (2) Chevy Silverado; (3) Toyota Rav4; (4) Honda Accord; and (5) Toyota Camry. Next, we identified their implementation of ACC through user manuals, online videos, and photos. In doing so, we discovered that:

1. Manufacturers use different names for ACC.
2. Most implementations of ACC are similar, but there are differences in terms of their limitations (e.g., when ACC can be activated or under what conditions ACC will not operate).
3. All vehicles require the driver to activate ACC, set the speed, and set the following distance using buttons on the steering wheel. The layout of the buttons, the text on the buttons, the images on the button, as well as the placement of the buttons (left or right side of steering wheel) varied between manufacturers.
4. All vehicles display the settings for ACC (once engaged) in the instrument cluster. However, the images, font size, content, etc. varies significantly between vehicles.
5. If a vehicle is equipped with a higher level of automation (e.g., Level 2 automation that combines ACC with a lane centering system), turning off the Level 2 automation to only use ACC may be a non-intuitive process.

Given the vast differences that existed even within these top five vehicle makes and models, we decided that the focus of training should be on ACC in a general sense with very little mention of specific operationalizations of ACC.

2.2.3 Insights from Task 1

Based on insights from Task 1, we identified desired traits of ACC training with respect to: (1) timing; (2) presentation format; and (3) generalizability.

Based on the information gleaned from the interviews as well as the current structure of Massachusetts Driver Education curriculum, it was determined that the ideal time to present information about ACC was within an already existing training module.

More specifically, driver education curriculum is 30 hours of classroom instruction plus 6 hours of behind-the-wheel instruction. Lengthening the curriculum by adding an additional module was not feasible, especially since some teen drivers take their driver education course in a compressed time span (i.e., one week). As such, we identified module 3 ("Understanding the vehicle and its controls") as the best module to integrate ACC training. Module 3 is to cover topics such as devices that aid visibility, e.g., back up cameras and blind spot monitoring, as well as vehicle safety, thereby providing a natural fit for material focused on ACC. Relatedly, since the ACC training must be incorporated within an existing module that is approximately 2 hours, it was decided that ACC training should be no more than 30 minutes. The benefit of incorporating ACC training into an existing module is that by the time novice drivers are introduced to this content, they will have already gone over other vehicle handling and vehicle control basics, which are also presented in module 3. Introducing more advanced material on ACC after this foundational content provides a natural progression.

Task 1 interviewees described the common presentation formats used for the classroom component of driver education programs including lectures with the assistance of presentations and videos. This format provides for a more engaging and thought-provoking experience for novice drivers. It will also appeal to a variety of learning styles. Though some

interviewees commented on the need for behind-the-wheel training for technology such as ACC, many expressed concern for the technology's potential distraction to the drivers. This is especially the case for new teenage drivers who may not yet have perfected their fundamental driving skills. Additionally, interviewees commented on the old age (5-10 years old) of vehicles used for driver education instruction. Data on actual vehicle ownership highlight how teenage drivers often drive vehicles that are 6-10 years old (34,35). Taken together, it is highly unlikely that teens would be taught on or drive a vehicle that has ACC. As such, the format for ADAS training would also be in the form of classroom instruction, consisting of a lecture with a PowerPoint presentation and videos, with no behind-the-wheel instruction. Doing so not only allows for consistency across sites but also allows for a train-the-trainer approach. As most driver education instructors are not well versed in ADAS or ACC, we taught the instructors about ADAS and ACC and taught them how to deliver the ACC training. In this way, not only are the novice drivers benefiting from learning about ACC, but so are the instructors.

Task 1 interviewees frequently said they do not read owner's manuals, but rather search online for information about their specific version of ADAS and ACC. Combined with differences observed between actual implementations of ACC, the ACC training will focus on ACC more broadly, e.g., how it functions, its abilities, and its limitations, versus a specific implementation of ACC. This will allow for generalizability across vehicles that the novice drivers may experience both in their personal life and in terms of the vehicles they drive for driver education courses.

2.3 Task 3

We conducted a longitudinal survey study and a simulator study to assess: (1) the effectiveness of driver education; and (2) the effectiveness of a new training module on adaptive cruise control (ACC). The survey and simulator study were approved by the University of Massachusetts Amherst IRB under protocol #5370. We received an NIH Certificate of Confidentiality to ensure participants' data as it relates to crashes is protected.

2.3.1 Driving Schools and Experimental Design

The two driving schools were located on opposites sides of MA; one was in Western MA and the other was in Eastern MA. These two schools were chosen because they provide different methods of driving instruction: the driving school referred to as 'Group 1' teaches classroom instruction in person in a physical classroom whereas the driving school referred to as 'Group 2' teaches classroom instruction online. To note, we were focused on the *natural observation* of differences between delivery methods versus intentionally manipulating the delivery method through this project. In Group 1B, they teach a revised version of Module 3 that includes ACC training, which was developed in Task 2 for this project. As such, the full experimental design for this study is shown in Figure 2.1.

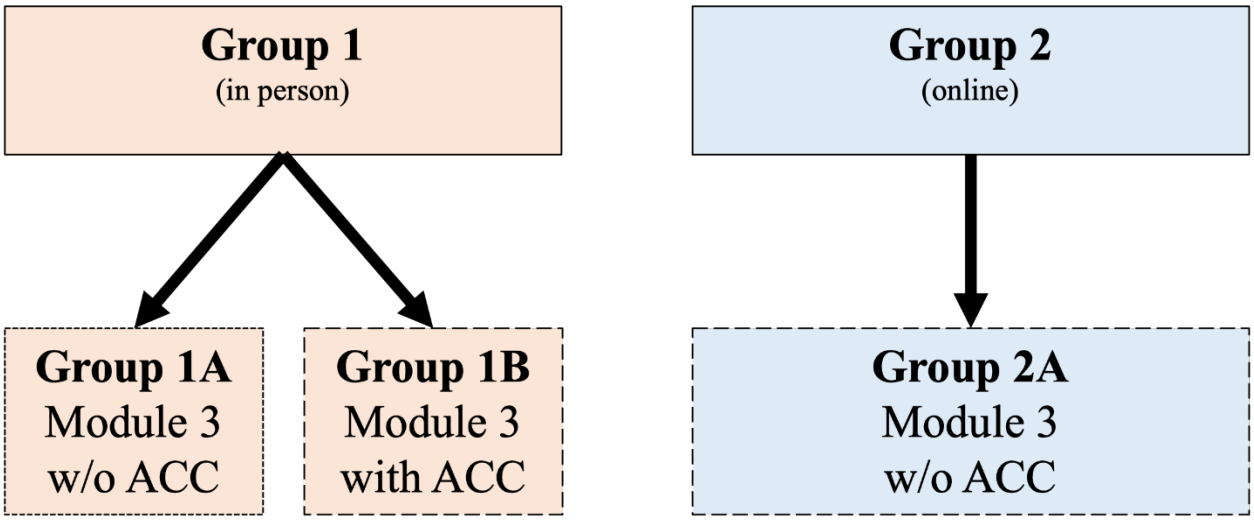

Figure 2.1: Experimental Design

We recruited 90 student driver participants in total (Group 1A, Group 1B, and Group 2A). Group 1A and Group 2A were compared to assess the effectiveness of different instruction formats, i.e., in person versus online. Group 1A and Group 1B were compared to assess the effectiveness of the ACC training.

An important design consideration is that the comparison between Group 1A and Group 2A represents a naturalistic observation of two existing instructional environments. Because the two groups attended different driving schools in different geographic regions of Massachusetts (Western MA vs. Eastern MA), instructional format may be confounded with school, instructor, and regional factors. Observed differences (or lack thereof) between these groups cannot be attributed solely to instructional delivery method. The aim of this design choice was to preserve ecological validity by observing actual delivery conditions rather than artificially imposing formats on schools.

Regarding Group 1A and Group 1B, the assignment was based on enrollment timing. Students who enrolled at the Western MA school after the ACC module was integrated into the curriculum comprised Group 1B, and those who enrolled prior comprised Group 1A. This was not randomized, and potential cohort effects should be considered when interpreting differences between these groups.

2.3.2 Equipment

To allow for a controlled environment to observe teen driver behavior, we used the medium fidelity simulators housed in our portable trailer (Figure 2.2). These driving simulators have been installed as a teaching and evaluation tool for teen drivers and have been designed to be transportable in the trailer to various locations. Thus, they were the ideal mechanism to assess student driver behavior in two different locations: Western MA and Eastern MA.

Figure 2.2: UMass Human Performance Lab Driving Simulator Trailer on the left and one of the driving simulators inside the trailer on the right

The driving simulator was upgraded to allow for the simulation of ACC; the human-machine interface for ACC is shown in Figure 2.3. The student driver participant controls ACC, including the speed and distance settings using a series of buttons below the steering wheel.

Figure 2.3: ACC Human-machine interface

In addition to the driving simulator, this study also employed the head mounted eye tracker shown in Figure 2.4. The eye tracker was used to track participant's eye movements while driving in the simulator.

Figure 2.4: Eye tracking glasses (Tobii Pro 3)

Finally, a GoPro camera was installed behind the driver's seat in the simulator to record the driving simulator experiment. The video camera was placed above the participant's shoulder and was able to record the computer screens, steering wheel movement, pedal movement, etc.

2.3.3 Participant Recruitment and Selection

Through purposive sampling, we focused on recruiting student driver participants from the two different driving schools. For Group 1, on a bi-weekly basis, the driving school provided contact information for recent students who had obtained a learner's permit (with appropriate permissions/agreements). We then contacted potential student driver participants via email to assess their interest in participating in the study. They were informed about the purpose of the study, its length (60-90 minutes), as well as compensation ($100). Interested participants completed a screening form to ensure they were eligible (see Appendix C for the screening survey). To be eligible, participants must have: (1) their driving permit; (2) be under the age of 18; (3) attend one of the two driving schools. If they were deemed eligible, we scheduled them for the study.

In addition to recruiting student driver participants via email, we also moved the portable trailer to the Group 1 driving school on three subsequent days for easier data collection (i.e., by removing the barrier of transportation to our laboratory). Under those circumstances, potential participants were directly identified by the driving school and scheduled for the study.

Similarly, for the Group 2 driving school, we moved the portable trailer to a location near the driving school to remove the transportation barrier. Student driver participants were notified of the study from the driving school. If participants indicated interest, they completed a screening form and if they were deemed eligible, they scheduled themselves for the study.

2.3.4 Study Participants

We collected data from 60 participants from Group 1: 28 did not have ACC training (Group 1A) and 32 had ACC training (Group 1B). We collected data from 30 participants from the Group 2 School.

2.3.5 Survey Development

In addition to a demographic survey to capture information such as age and gender (see Appendix C), we developed three sets of surveys to assess:

(1) Driver education instruction (e.g., time spent on each module and the format of instruction),
(2) Teen driving skills and knowledge, and
(3) ACC specific knowledge (e.g., their mental model of how ADAS functions).

The student driver participants' parent/guardian also completed a survey to assess their driving skills and knowledge and ADAS specific behaviors, identical to surveys (1) and (3) above.

Surveys were developed based on past literature, insights from the research team, and suggestions from the project champions. More specifically, to assess driver education instruction, we developed a survey to: (1) assess teen's knowledge of Massachusetts specific driving regulations (e.g., related to the Junior Operators License); (2) gather detail on the format, length, type, etc. of their classroom and behind-the-wheel instruction; (3) gather subjective information on the teen's perception of the instructor's effectiveness in teaching; (4) gain information concerning their parent/guardian's involvement in behind-the-wheel driver training. The survey contained a total of 39 questions. (See Appendix C for the survey.)

To assess teen driving skills and knowledge, we relied on the Readiness to Drive Scale developed by the University of North Carolina Center for the Study of Young Drivers[1] and refined by the Insurance Institute for Highway Safety. The Readiness to Drive Scale assesses the teen's readiness or ability to perform a wide list of driving maneuvers (e.g., stay in their lane or drive in light rain). Teens rated their own ability to perform these maneuvers while parents/guardians rated their teens' ability to perform these maneuvers without the parent/guardian in the vehicle. The survey contains a total of 32 questions. (See Appendix C for the survey.)

To assess ACC specific knowledge, we re-used the mental model survey used in past research. The ACC mental model survey assesses one's understanding of ACC functions and limitations with true/false questions. The study participants also rated their confidence in each answer. The study participants completed the ACC mental model survey to assess their own understanding of the technology. Similarly, parents/guardians completed the ACC mental model to assess their own understanding of the technology. The survey contained a total of 20 questions. (See Appendix C for the survey).

Teen's crash, citation, and warning record was inspected to ascertain the effectiveness of driver education instruction on real-world driving behavior (i.e., Task 4). However, because not all crashes are reported to the police, we administered a survey to teens' approximately 12 months after their participation in the experiment (see Appendix C for the follow-up survey).

2.3.6 Simulator Experiment Development

The simulator experiment was developed to assess the student driver participants' ability to: (1) identify hazards (e.g., look at appropriate areas of the roadway); (2) mitigate hazards (e.g., maintain a safe speed); (3) maintain attention to the roadway (e.g., minimize glances to distracting devices), and (4) effectively use ADAS (e.g., know when to turn off ADAS due to system limitations). We designed three driving scenarios to assess these skills.

In the first scenario, we assessed the participant's ability to identify and mitigate hazards, or in other words, their hazard anticipation and hazard mitigation abilities. Through the scenario, participants are presented with various situations that test their skills. For example, while driving down a road with two lanes in either direction, the participant approaches a mid-block crosswalk. The participant is traveling in the right while a line of cars is stopped in the left turn lane. In this situation, the correct behavior is for the participant to slow down and look to the left to ensure that a pedestrian is not in the crosswalk (Figure 2.5).

Figure 2.5: Driving scenario wherein the participant is slowing down and looking to the left (red circle) for a pedestrian

The second scenario assessed participant's ability to maintain attention on the roadway while completing a distracting task. More specifically, participants are asked to follow closely behind a lead vehicle that frequently changes its speed. While following behind the vehicle, the participant also must complete a secondary task: participants must press a button on the left or right side of the steering wheel depending on which shapes appear on the screen (Figure 2.6).

Figure 2.6: Driving scenario wherein the participant follows behind a lead vehicle while also completing a distracting task – respond to shapes (e.g., two red diamonds) that appear in lower portion of center screen. The red circle indicates the participant's gaze (i.e., on the lead vehicle and not on the secondary task).

The third scenario assessed participant's understanding and usage of ACC. While driving on a highway and navigating a moderate amount of traffic density (including bicyclists on the side of the road), the participant must turn on and successfully use ACC (Figure 2.7).

Figure 2.7: Driving scenario wherein the participant must successfully use ACC. The red circle indicates the participants gaze, which is on the ACC human-machine interface.

We pilot tested the simulator drives with 10 people (e.g., faculty and undergraduate students) and made modifications to ensure the directions were understandable, the drivers were of an appropriate length, etc.

2.3.7 Procedure

We began by obtaining informed consent (for parents/guardians) and assent (for teens). The student driver participants and their parent/guardians completed the surveys in the following order: Demographics (Teen and Parent/Guardian), Driver Education Instruction (Teen), Readiness to Drive (Teen and Parent/Guardian), and ACC Mental Model (Teen and Parent/Guardian). Following survey completion, the participant put on the eye tracking glasses and the glasses were calibrated. Then, the participant moved to the driving simulator portion of the experiment. Once the participant was seated, they experienced a practice drive

to familiarize themselves with the simulator controls, understand how to operate ACC, and to reduce the effects of simulator sickness. Participants experienced the three simulator scenarios in a counterbalanced order. Participants were given an extra set of instructions before the divided attention drive to ensure they understood the secondary task. Throughout all drives, the participant's behavior was recorded from: the simulator itself (e.g., speed), the eye tracker, and the video camera. Once the drives were completed, participants (both the teen and their parent/guardian) were compensated. Each experiment (first set of surveys and driving simulator experiment) lasted approximately 60-90 minutes.

Approximately 12 months after the student driver participants completed the driving simulator portion of the experiment, they were asked to complete a follow-up survey to gather information concerning their crash, citation, and warning history.

2.4 Task 4

The goal of this task was to inspect the student driver participants' crash, citation, and warning records to ascertain the effect of driver education instruction on real-world driving behavior. This task involved tracking the teen drivers' crash, citation, and warning data for 12 months after they had completed the simulator experiment in Task 3.

2.4.1 Massachusetts Vehicle Census Data Collection Process

Queries were designed to identify appropriate crash, citation, and warning records based on the student driver participants' identifying information (e.g., license number). Data was retrieved from the Massachusetts DOT data warehouse (housed within UMassSafe) at a regular frequency. The census included detailed information about each citation, including the type of citation (civil infraction, criminal application, warning, or arrest) as well as the location and time of day. The census included comprehensive information about each crash including ambient lighting, roadway type (e.g., intersection), location, crash severity, number of vehicles involved, posted speed limit, and weather conditions. To note, the census only contained information from police reported crashes and citations.

2.4.2 Survey Data Collection Process

A 12-month follow up survey was sent to the student driver participants 12 months after they completed the data collection procedures of Task 3. The survey (see Appendix C) focused on gathering information about two items: (1) crashes that are not in the Massachusetts crash and citation census (e.g., those that are not reported to the authorities); and (2) details concerning crashes and citations that are not in the Massachusetts crash and citation census (e.g., what type of ADAS was in use during the time of the crash). Participants were compensated $10 for completing the 12 month follow up survey.

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3.0 Results

3.1 Task 1

3.1.1 Thematic Analysis from Interviews

The results of the thematic analysis of the interview transcripts were seven themes:

1. Safety,
2. Driving education instructors,
3. Driving education curriculum,
4. Parents/Guardians role,
5. ADAS pros and cons,
6. Acquiring ADAS knowledge, and
7. ADAS usage.

These seven themes categorized the range of responses that were obtained from the interviews. From these seven themes, four main overarching themes emerged that encompassed the seven themes, which were: Driver education pedagogy, Parents' role, ADAS, and Safety. These four overarching themes encompass the original seven themes, hereafter referred to as sub-themes. More specifically, the overarching theme of Driver education pedagogy encompasses the Driver education instructors and Driving education curriculum subthemes whereas the overarching theme of ADAS includes ADAS pros and cons, Acquiring ADAS knowledge, and ADAS usage sub-themes. Figure 3.1 shows a mind map of the four overarching themes as connected with each other and the corresponding sub-themes.

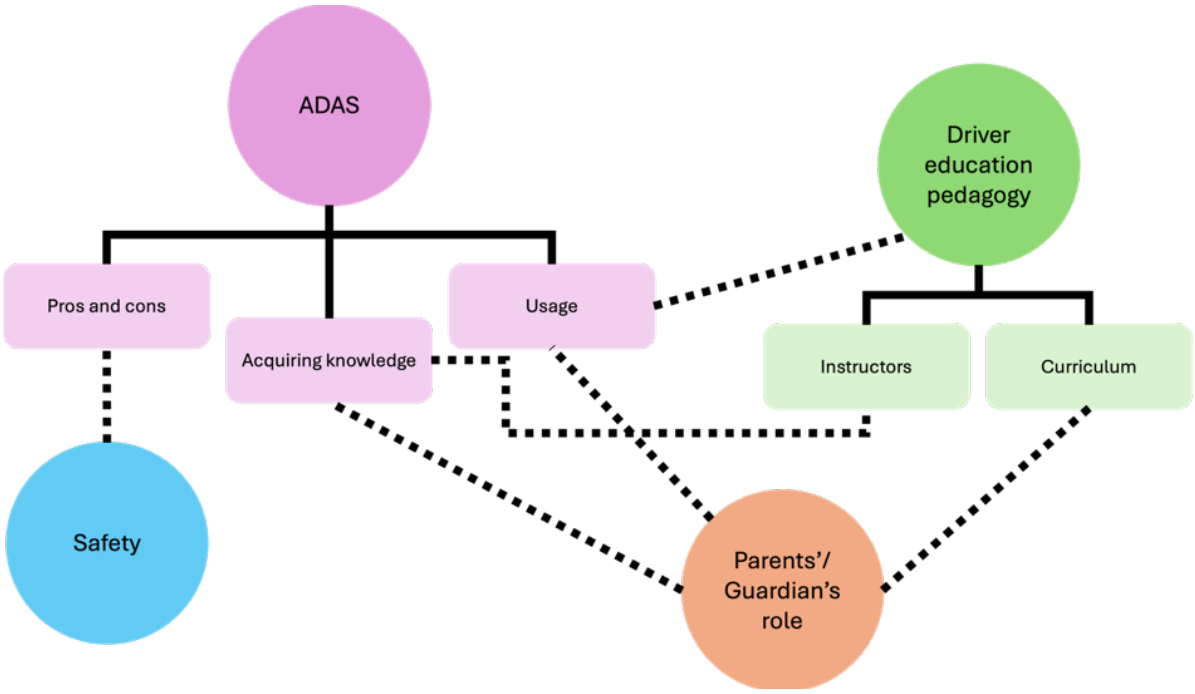

Figure 3.1: Mind Map showing the main interview themes as they relate to one another. The solid lines represent the owner-member relationship between main themes and sub-themes, while the dashed lines represent related connections identified by the study between main themes and sub-themes.

The theme of *Driver education pedagogy* encompasses the stakeholders' insights as it relates to the method and practice of teaching teen drivers how to drive; this theme includes two sub-themes: curriculum and instructors. Regarding the curriculum, the stakeholders discussed the different sections of the driver education curriculum, the best mode to teach driver education, as well as what materials should be used. For example, one stakeholder said: *"[the] most effective way to deliver drivers' [education] would be to have smaller classrooms which focuses on one-on-one interaction between instructor and student*". Another stakeholder commented on format with: "*it has been observed that there is higher attendance on zoom lectures*". There was also mention of how the current driving education curriculum does not teach teens about ADAS, yet there are opportunities for ADAS material to be added. In addition, stakeholders commented on how to properly teach teen drivers who have different learning styles, to ensure that teens are retaining the content. The driver education instructors sub-theme explains the importance of having driver education instructors that can have an impact on a teen drivers' learning. It is exemplified with the following quote: "*the experience of the drivers' instructors can have a major impact on students*."

The theme of *Parents'/Guardians' role* refers to the importance of parents/guardians in the driving education process. Stakeholders highlighted the fact that the State DOT requires parents/guardians to do behind-the-wheel training with their teen driver, but fewer parents/guardians are spending time teaching their children to drive. One stakeholder said: "*Parents tend to leave the teaching up to the driving schools and feel that they do not need to*

have any involvement." Not only are parents/guardians required to drive with their teen drivers, but those lessons can also help teens better interact with law enforcement officers and learn how to drive with ADAS. From the interviews, it was noted that "*teens tend to model their driving after watching adults [or] parents drive and drivers' [education] can teach them the rules of the road*". Allowing teens the opportunity to practice with parents/guardians can be a great benefit and develop good driving skills. For example, when teens watch their parents/guardians get pulled over by law enforcement, if they witness a calm interaction with law enforcement, that can educate teens on how to have calm interactions with law enforcement. Last, most cars that parents/guardians drive have ADAS, which parents/guardians may or may not know how to operate. If parents/guardians are allowing their teens to drive in their vehicles, parents/guardians can teach teens how to use these systems. Therefore, they can teach their children how to avoid distractions and how to not rely too heavily on ADAS.

The larger theme *ADAS* consists of three sub-themes: ADAS pros and cons, ADAS usage, and acquiring knowledge about ADAS. Regarding ADAS pros and cons, one stakeholder said: "*ADASs systems make people better drivers and help to prevent accidents*", highlighting an advantage of ADAS. On the contrary, another stakeholder indicated that: "*people rely too heavily on ADAS."* Regarding teen drivers specifically, it appears if ADAS can be useful, but if not used properly, it can be unsafe. For ADAS usage, this showed what type of personal experience stakeholders had with ADAS. One stakeholder mentioned that they "*have adaptive cruise control on my car and also lane departure alerts.*" Finally, in terms of acquiring ADAS knowledge, there are many methods to teach people about ADAS. The interviews indicated that most adults are learning about ADAS either by using online resources, such as Google or YouTube, or using their vehicle owner's manual. However, when it comes to teens, they need more specialized training, especially because teens do not have the privilege of receiving on-site training at new car dealerships: teens often receive used cars or do not purchase the cars themselves. Stakeholders emphasized this in varying ways. For example, one stakeholder said: "*as ADAS becomes more standard than optional, it should be included in driver education classes and license testing*" whereas another said: "*the best way to teach teens about ADAS is through a controlled environment where they learn the basics of ADAS*." All in all, since teen drivers can be distracted by a multitude of things, the addition of ADAS may prove to be another distraction, and as such, teen drivers need proper training on how to use the technology.

The last theme of *Safety* was focused on violations by Junior Operator License (JOL) holders and teen drivers receiving warnings or citations. Most interactions that law enforcement officers have with teen drivers is when they are stopped for a traffic violation, sometimes because they violated a JOL restriction and other times because they've broken a driving law. In terms of the JOL violations, stakeholders shed light onto how "*speeding is the biggest offense, and the 2nd biggest offense is distracted driving*." In terms of teen drivers getting pulled over, stakeholders revealed that "*when teens get pulled over they tend to be worried about getting a ticket*." Yet it can be important because "*while the fines may be harsh, [it may be] necessary to get the point across to teens and [it] can save lives*." By giving teen drivers a warning or a citation it may teach them to not make the same mistake again, thereby preventing a crash.

3.1.2 Transportation Safety Scholar Surveys

In terms of what driver education should focus on, transportation safety scholars had numerous, but somewhat similar viewpoints. They highlighted the following objectives: (1) hazard perception and overall safety; (2) knowledge and skills for safe driving; (3) awareness of driver responsibilities and the driving environment; and (4) minimizing driver distraction and inattention. When asked about how parents/guardians can be better incorporated into the teen driver education process, suggestions centered on co-learning, where both the parent/guardian and teen learn safe driving skills together to reinforce learning, along with frequent and continuous hands-on involvement from the parent/guardian.

Transportation safety scholars were asked about the most and least effective elements of driver education. Of the 15 responses concerning the most effective elements, 8 were focused on behind-the-wheel training with an experienced driver, whether that be an instructor or a parent/guardian. Other responses were quite varied, but highlighted items like crash mitigation and defensive driving. In terms of the least effective elements, many highlighted the ineffectiveness of making students memorize mundane details or obscure rules for a test. Others highlighted the limited utility of classroom learning (in comparison to behind-the-wheel training) as it is passive and can be highly dependent on instructor quality.

Transportation scholars had differing opinions regarding educating and teaching teen drivers about ADAS and ACC, transportation safety. In terms of the best methods for teaching teen drivers about ADAS, 14 of 17 respondents said behind-the-wheel practice was best and 11 of 17 respondents said video tutorials were best. There were varying viewpoints as to how ACC may affect teen driving behavior: 6 of 11 respondents said it would lead to increased trust and hence, less attentive driving behaviors and 4 of 11 respondents said it would lead to improved driving confidence and less stress. Transportation safety scholars also had suggestions for how driver education programs could leverage technology to teach teens about ADAS. Most of the transportation scholars (9 of 11) suggested employing virtual reality training. Last, in terms of how parents/guardians should be involved in the process of educating teens about ADAS, 9 out of 10 respondents said modeling the appropriate behavior was appropriate and 8 out of 10 Transportation scholars supported setting clear rules about usage.

3.1.3 Automobile Dealership Surveys

When selling vehicles to teen drivers or their parents, the most common concerns were found to be safety, reliability, and price. In addition, 66% of respondents said that the vehicles they sell usually have special features (e.g., key fob that contains a speed limiter) that are targeted toward teen drivers.

All the automobile dealership employees indicated that training is always given to customers when they purchase a vehicle. (Note that this may be a social desirability bias as past research has shown a more variable experience when it comes to customer training at dealerships (36).) It was also agreed that training is required to be given to everyone

purchasing a vehicle, i.e., every customer receives the training. In addition, it was widely agreed (83%) that customers can receive more training after they leave the lot. The information included in the training concerns vehicle safety systems, entertainment systems, Bluetooth connectivity, and basic vehicle controls. However, most (66%) employees agreed that vehicle training differs based on if a customer purchases a new vehicle versus a used vehicle. The training itself can be given in a variety of different locations: in the car, in the showroom, or on the internet. In addition, training is given before and/or after vehicle purchase. Most training lasts between 30 minutes and 1 hour, although one respondent said the training was 30 minutes or less. Across the dealerships surveyed, the salesperson is the one who delivers the training, and each salesperson has between moderate to a great deal of experience in delivering the training.

Regarding training customers on ADAS, 83% of the dealership respondents said they do not receive enough information (e.g., from the car manufacturer) on teaching customers about ADAS. Despite this, when dealerships inform customers about ADAS, they tell them about the features, they show them the features, and they sometimes use brochures. Relatedly, car dealership employees tell customers about ADAS during the vehicle demonstration, during the test drive, and after they purchase the car. Exact information given to customers about ADAS varied but could include things like the value proposition of ADAS (e.g., how it may lower insurance rates) as well as demonstrating the ADAS features (e.g., how to turn it on and use cases for when the ADAS may be helpful). When it came to teaching teen drivers about ADAS, car dealership employees had multiple suggestions including video tutorials, in person/hands on demonstrations, comprehensive courses (e.g., that are 2-3 days), interacting learning sessions (e.g., where the teen driver must show they understand the system), and integration into current driver education courses.

3.2 Task 2

The training program was delivered via lecture using a PowerPoint presentation. The presentation had four sections: (1) vehicle technology background and history; (2) types of ADAS; (3) ACC description; and (4) driver's roles when using ACC. All slides for the training program are in Appendix B.

The goal of section 1 was to introduce various types of vehicle technology. It began with a brief background of technological developments in vehicles, starting with technology such as fuel injection and anti-lock brakes. With this technology, the driver is still responsible for accelerating/braking, steering, and object detection. However, newer technology can warn the driver of risks, control steering, and even brake to prevent a crash. Newer technologies like these are referred to as ADAS. ADAS can improve driver safety and convenience. It can also change the way they people drive.

Section 2 introduced the more common ADAS technology and began by discussing, in a general sense, how the technology typically works and what sensors are required for the technology to function appropriately (e.g., Figure 3.2). Next, it introduced some of the most

common ADAS technologies, including alerts and warning systems (e.g., blind spot monitoring); collision mitigation systems (e.g., automatic emergency braking); and automated driving technologies (e.g., ACC).

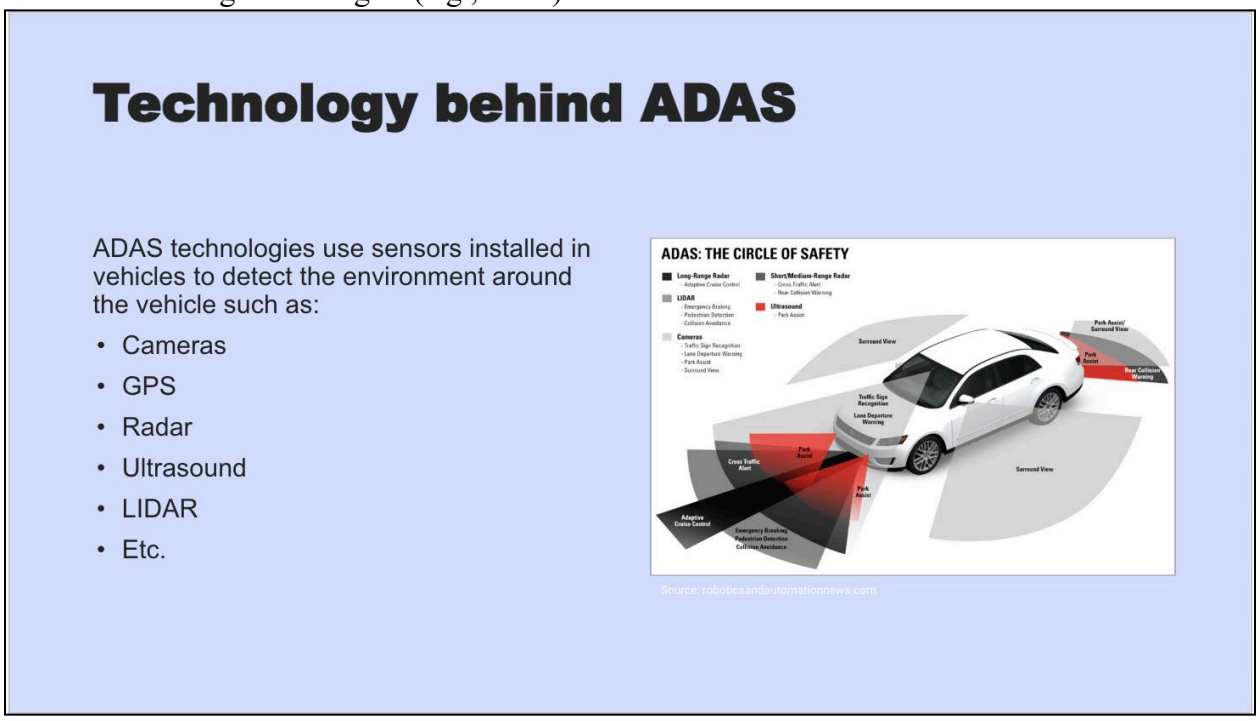

Figure 3.2: Training program slide detailing common sensors required for ADAS

Section 3 delved into ACC. An overview of ACC was given, including its definition as well as how it compares to traditional cruise control. Next, a video was provided to show how ACC dynamically changes speed depending on traffic conditions. Then, the sensors that are required for ACC were described. Details about how to use ACC, including its activation, deactivation, and settings were described with text and images. Limitations of ACC were covered in detail in both text and images (e.g., Figure 3.3).

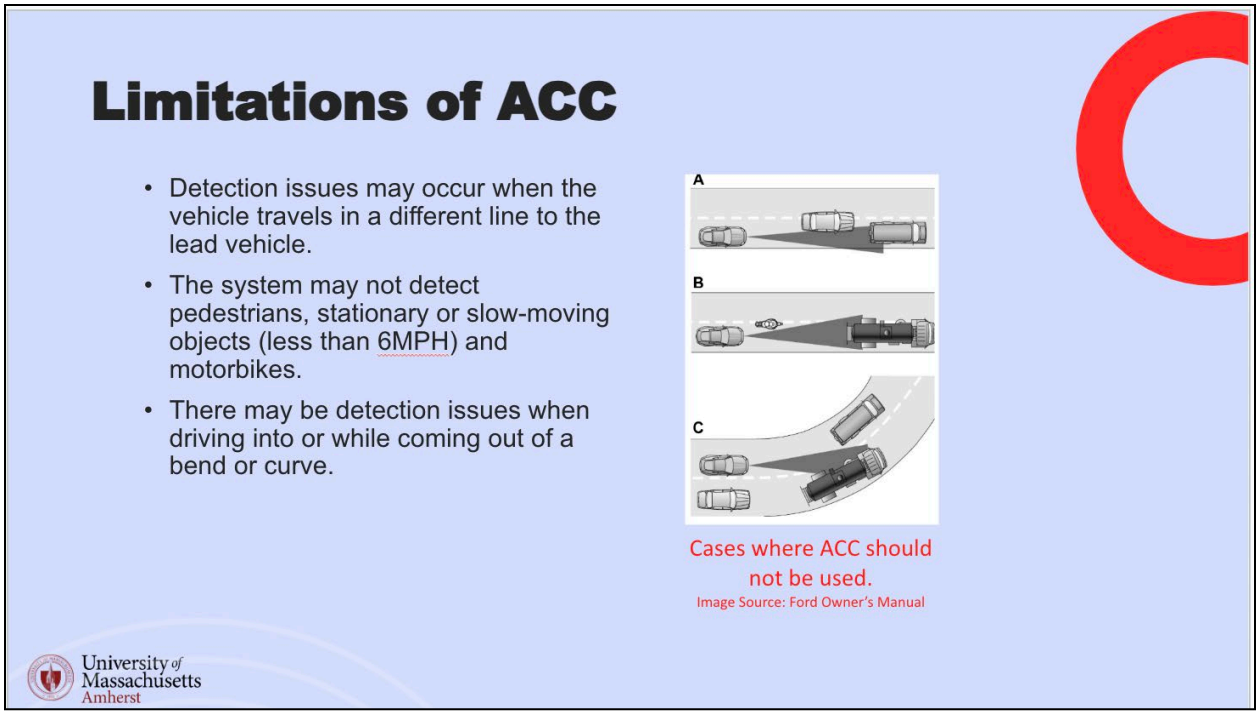

Figure 3.3: Training program slide discussing ACC limitations

Section 4 detailed the driver's responsibility when using ACC. First, the focus was on driver responsibilities before one activates and uses ACC, including being aware of road conditions and reading the owner's manual. Next, driver responsibilities while operating ACC were covered, including remaining alert of surroundings and monitoring the ACC functionality.

3.2.1 The *Train-the-Trainer* Approach and Insights

Based on insights from previous tasks, it was established that there was a critical need to ensure that the driver education instructors had up-to-date and complete knowledge and background about the ADAS domain and topic, including safety related issues, how to use ADAS, and its associated capabilities and limitations. In addition to ensuring updated knowledge, this will also result in consistent delivery of the instructional content given that the educators themselves are basing the instruction on a common set of principles and facts.

Given this requirement, an important sub-task was to design and implement a 'train-the-trainer' procedure to ensure that the instructional material and content were well understood by the persons who would be delivering it to the teen drivers. For the purposes of this research study, the train-the-trainer session was undertaken by one of the PIs. For larger deployments, instructors may have to be further trained or certified to administer this training.

The train-the-trainer procedure for this research was conducted in three phases: First, a formal and structured overview regarding the motivation behind the training, an introduction to the topic of ADAS and driving safety, and the overall goals of the training; next, a slide-by-slide instruction of the actual training content, wherein the PI not only explained the

material in the content, but also provided contextual and background information on the content, including the reasons that it had been included in the training material; and, finally an in-person review of a trained instructor's delivery of the material to a classroom of teen drivers, with comments and discussion if required after the classroom instruction.

The train-the-trainer procedure was undertaken at the Western MA driving school, with three instructors as the trainees. The first two phases, overview and training, were conducted in about an hour. The third phase (review) was also undertaken in the same driving school, with one of the three trained instructors providing the instruction to a new batch of teen driver ed students (~10 students). This instruction took about 20 minutes and was provided as an in-classroom instruction with both power-point slides, and whiteboard illustrations.

The review phase of the train-the-trainer procedure yielded some important general insights, a few of which are listed here. While providing prescriptive content for instruction is important, there should be leeway for the content to be delivered by the instructors according to their individual styles – if the content is not modified. Since most teens may have very little idea about the technologies in general, it may be advisable to start with a more attractive "hook" by illustrating a contemporary incident or technology (say Tesla AutoPilot) before introducing the material. This will also allow the instructor to highlight and reinforce the misperceptions that drivers may have about such technologies. An important addition to the training could contain information about how to infer if one's vehicle indeed has a technology or not, since this is not immediately evident to drivers. A final important insight was that it is critical that the instructors themselves do not have any misperceptions or incomplete information about these systems, as that may lead to a contamination or bias in the information that is provided to the students. This insight further reinforces the necessity and critical nature of this train-the-trainer process.

3.3 Task 3

When interpreting the following between-group comparisons, readers should note that Group 1A/1B and Group 2A attended different driving schools in different regions of the state. Differences (or lack thereof) between Group 1 and Group 2 may reflect school- or region-level factors in addition to instructional format.

3.3.1 Teen's Readiness to Drive

Teen drivers and their parents rating of teen driver readiness to drive is shown in Figure 3.4. (Note: the minimum score is 32, meaning the teen is not ready for driving and the maximum score is 160, meaning the teen is ready for all aspects of driving.) Among teens, scores were very similar across all three groups, indicating that no matter the driving education school, teen drivers have similar subjective rating of their readiness to drive in various situations. Similar to teen drivers' ratings, scores across all three groups are similar. What's important to highlight is the difference in scores: parents consistently give ratings that are approximately

15 points lower than the teens. This indicates that teens feel they are more prepared for driving than their parents believe.

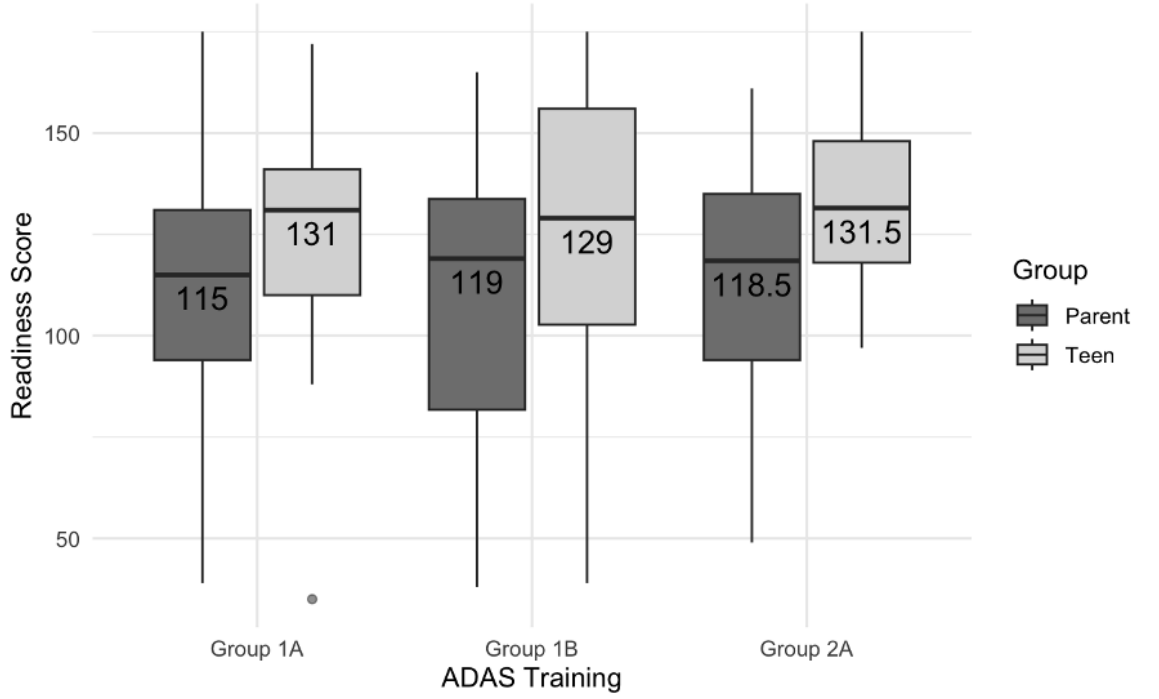

Figure 3.4: Readiness to drive scores, separated by Teen/Parent as well as Group

3.3.2 Driver Education Instruction

Student Driver participants across all groups felt as if they learned something in the driver education course and that the course was effective (Figure 3.5 and Figure 3.6). Group 1A and Group 1B participant (i.e., in person driver education) said they learned slightly more than Group 2A (i.e., online driver education). However, Group 2A students said their course was more effective than Group 1A and Group 1B.

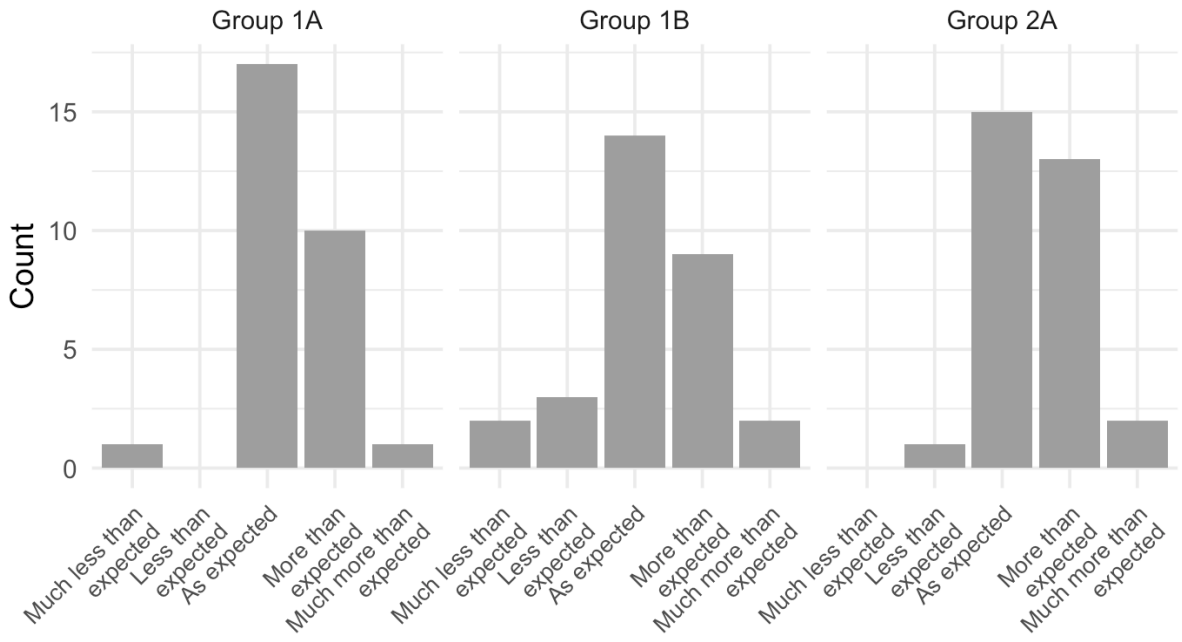

Figure 3.5: How much students felt they learned in the driving education courses, separated by group

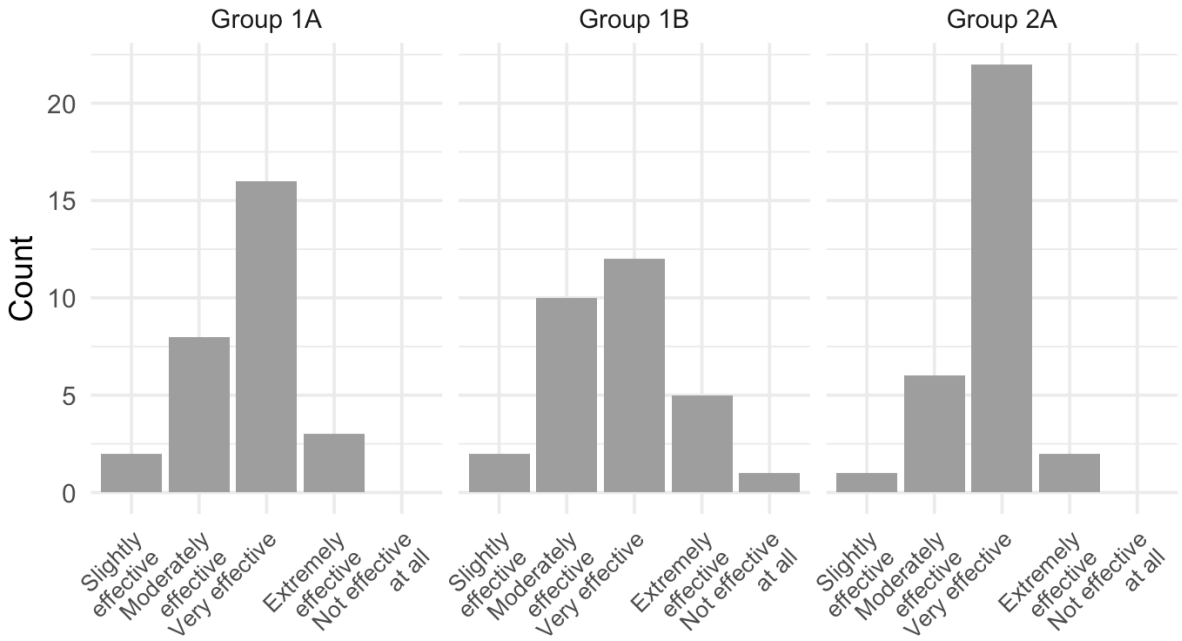

Figure 3.6: Teen Drivers' overall rating of the driving education course', separated by group

In terms of the materials used for instruction, participants across all groups watched videos and were given quizzes or tests. Student driver participants in Group 2A were issued a handbook that went along with classroom instruction.

There were also differences in class size across the groups, as shown in Figure 3.7. Group 1A and 1B had smaller class sizes than Group 2A.

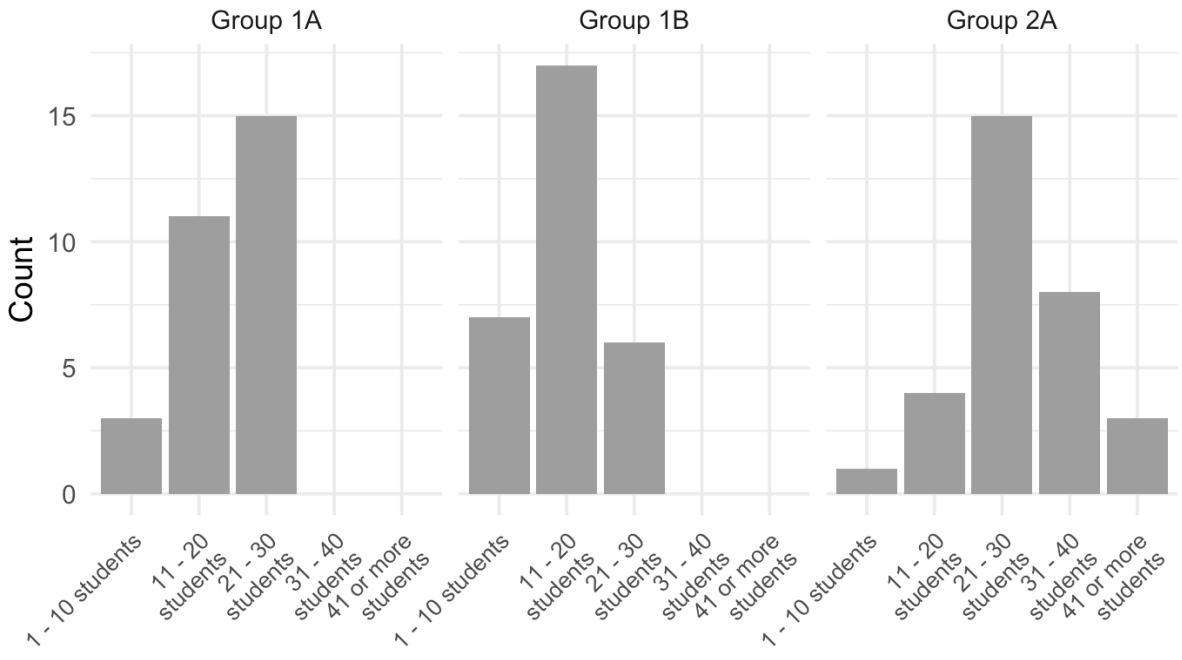

Figure 3.7: Number of students in the driver education course, separated by group

Students in Groups 1A and 1B had fewer classroom instructors than students in Group 2A (Figure 3.8).

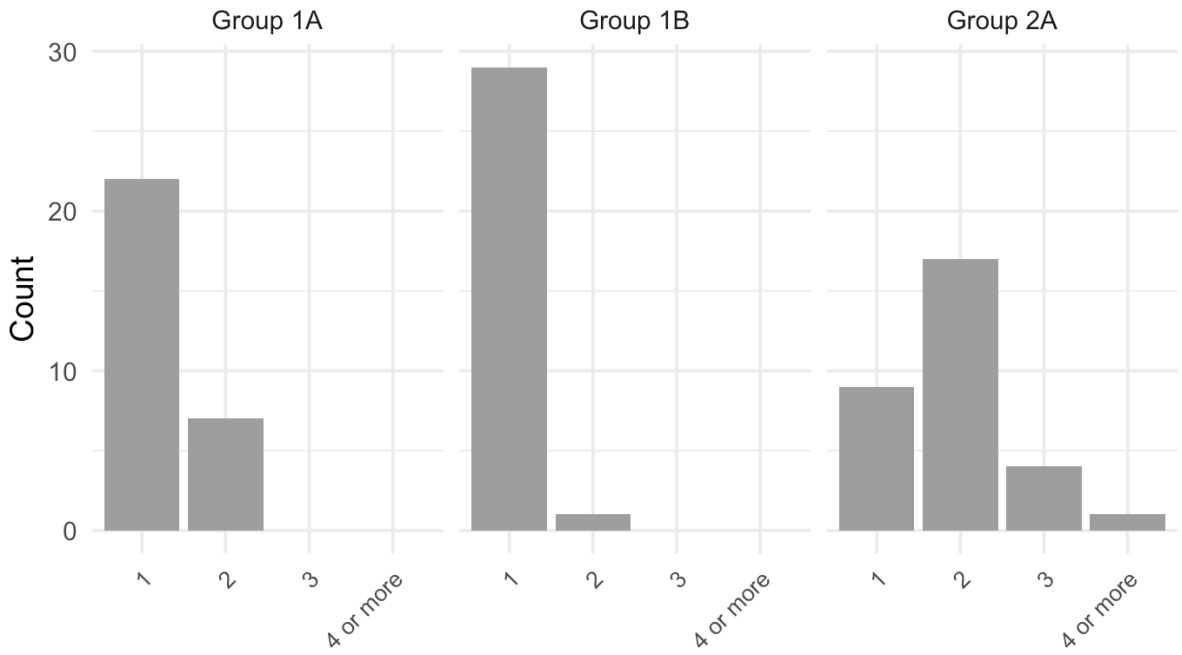

Figure 3.8: Number of classroom instructors in the driver education course, separated by group

There was also variation in terms of the length of driver education instruction (Figure 3.9). Across all groups, approximately half of the participants take a 1 week driver education course.

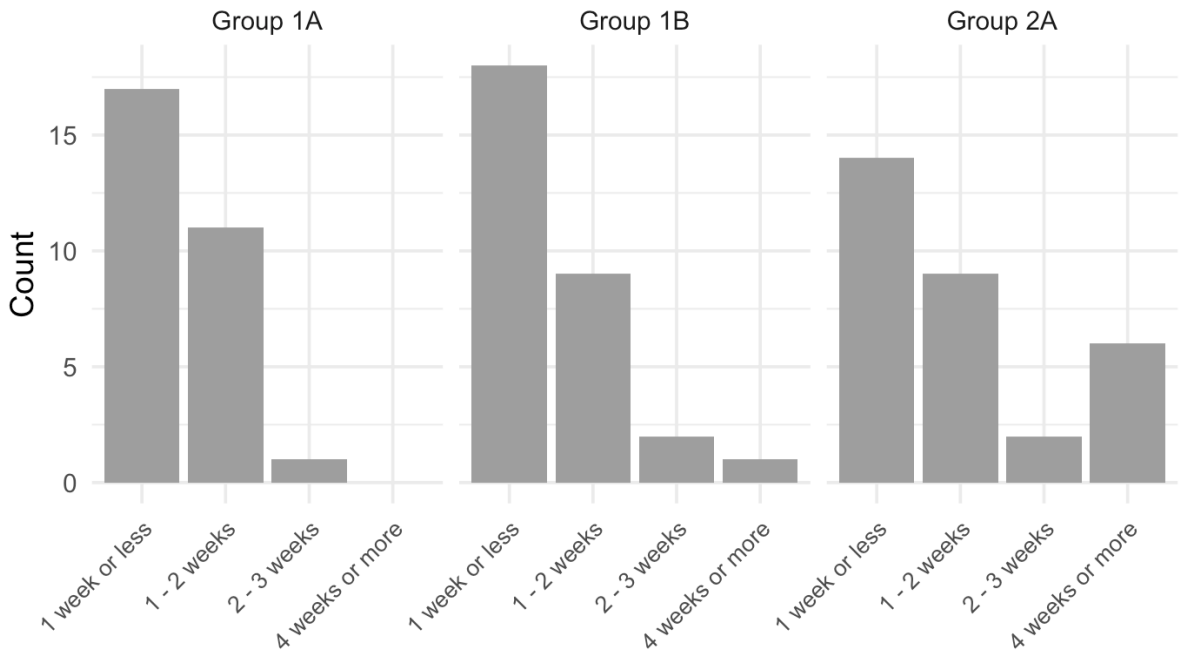

Figure 3.9: Length of the driving education course, separated by group

Students rated their classroom instructors on a variety of metrics, as shown in Figure 3.10, Figure 3.11, and Figure 3.12.

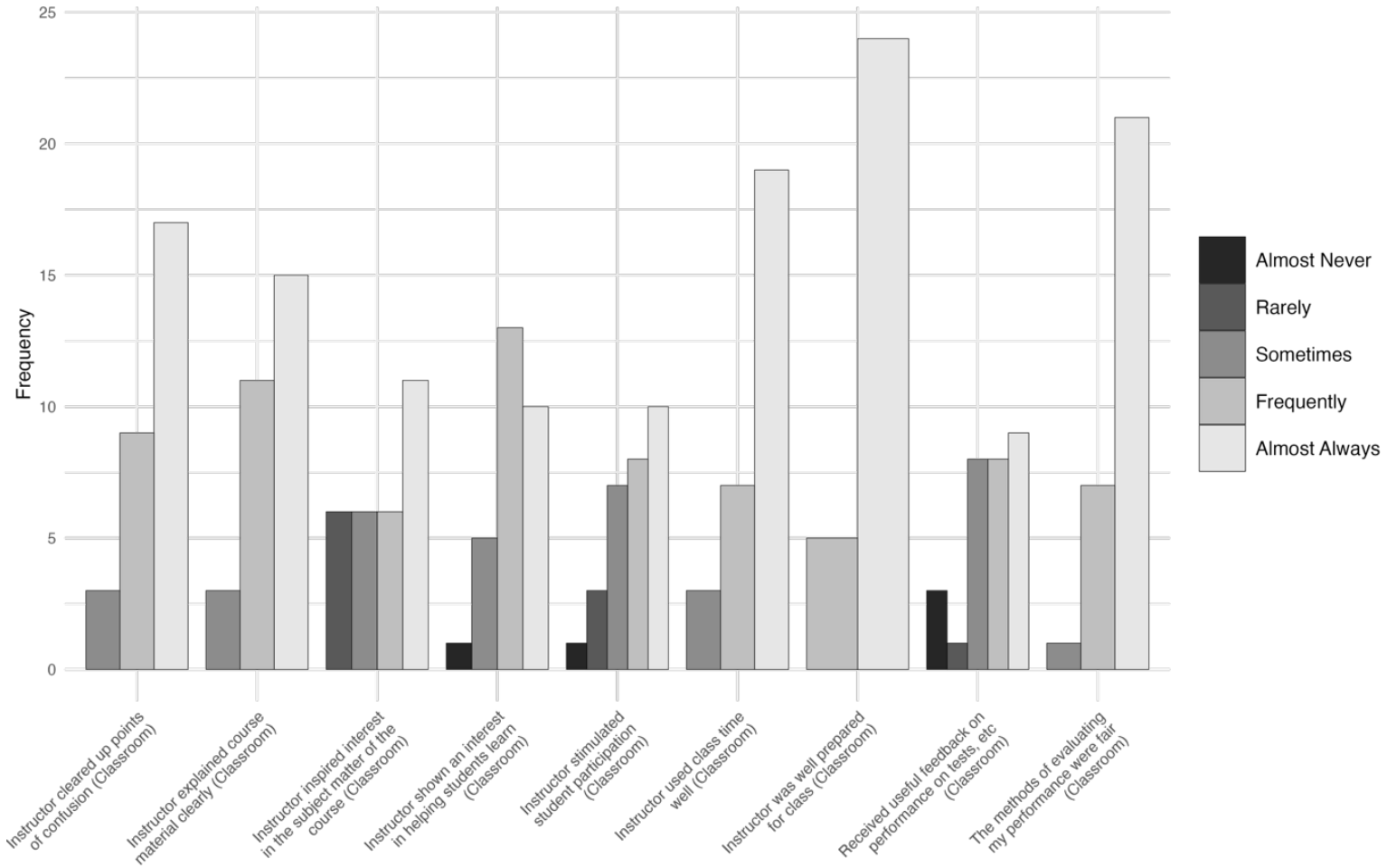

Figure 3.10: Instructor feedback for Group 1A

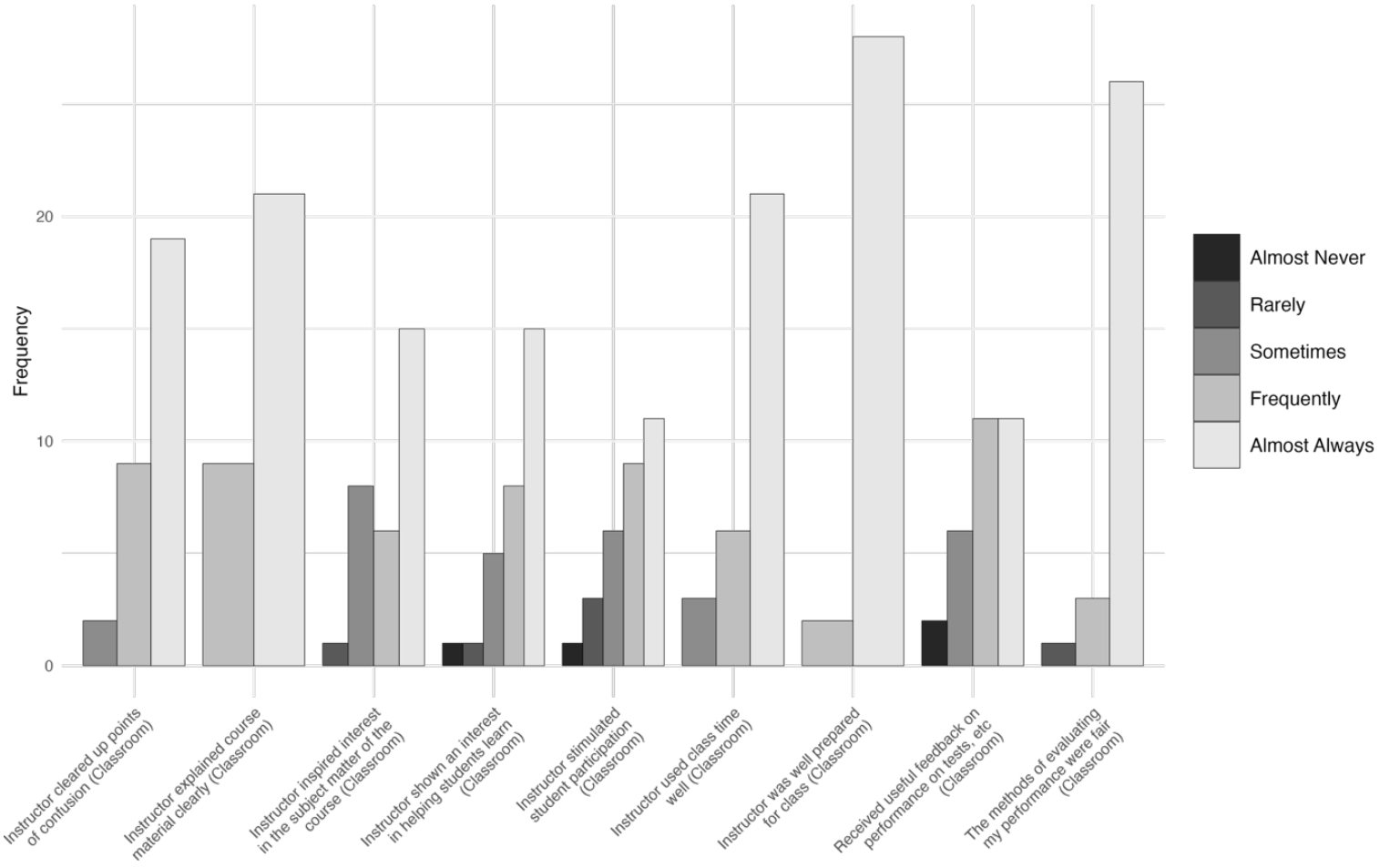

Figure 3.11: Instructor feedback for Group 1B

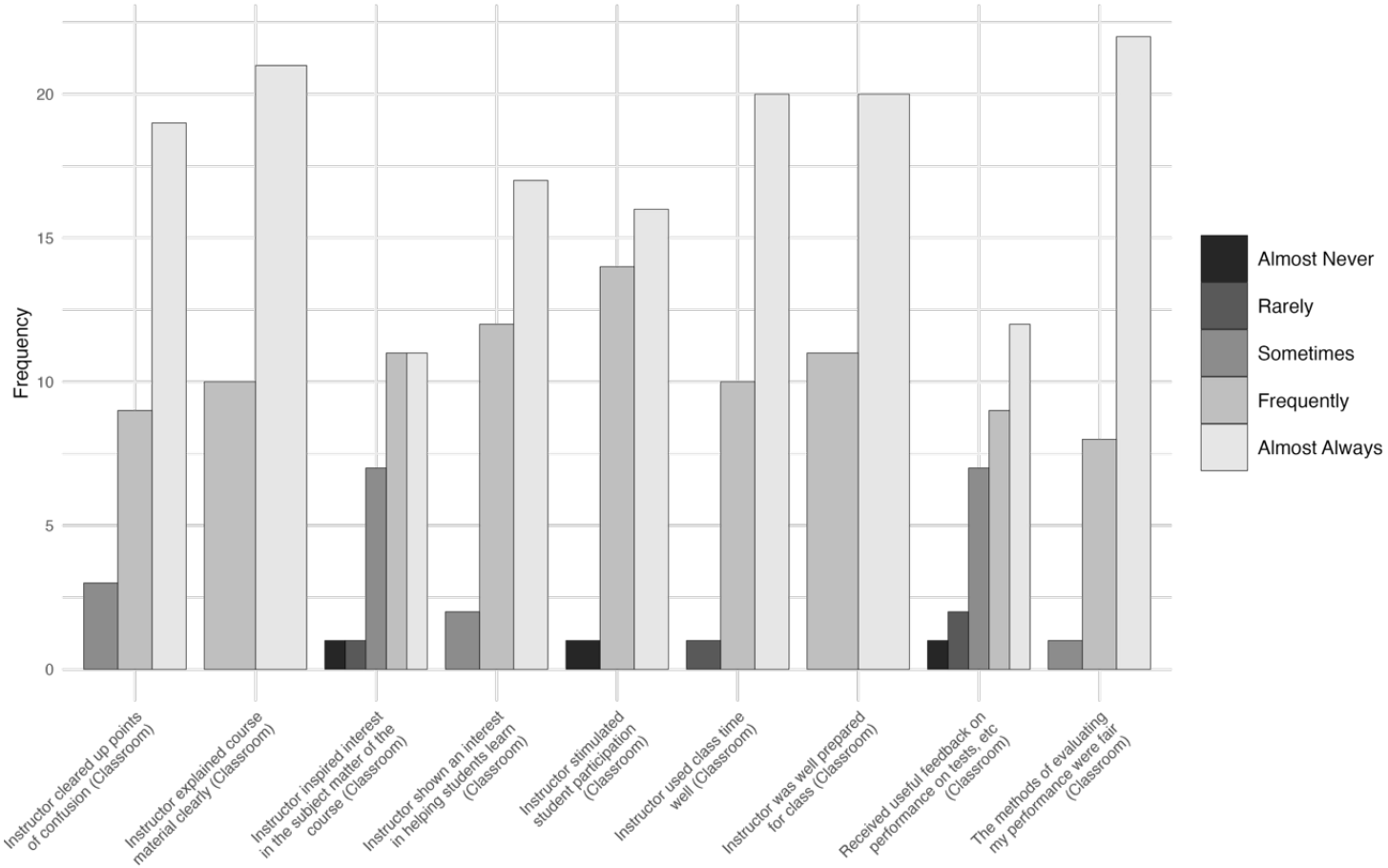

Figure 3.12: Instructor feedback for Group 2A

Students' experience with behind-the-wheel instruction (e.g., number of instructors, number of sessions, etc.) exhibited much variability. However, those differences can be attributed to the fact that teens were in varying stages of the permit process, with some just beginning behind-the-wheel instruction (e.g., brand new permit holders) and others finished with their behind-the-wheel instruction (e.g., ready to take the JOL test). As a result, those results are not highlighted here.

Similarly, the number of hours spent driving with parents/guardians may be attributed to teens stage in the permit process. However, given the importance of parents/guardians in the learning-to-drive process, as highlighted in Task 1, results are shown in Figure 3.13.

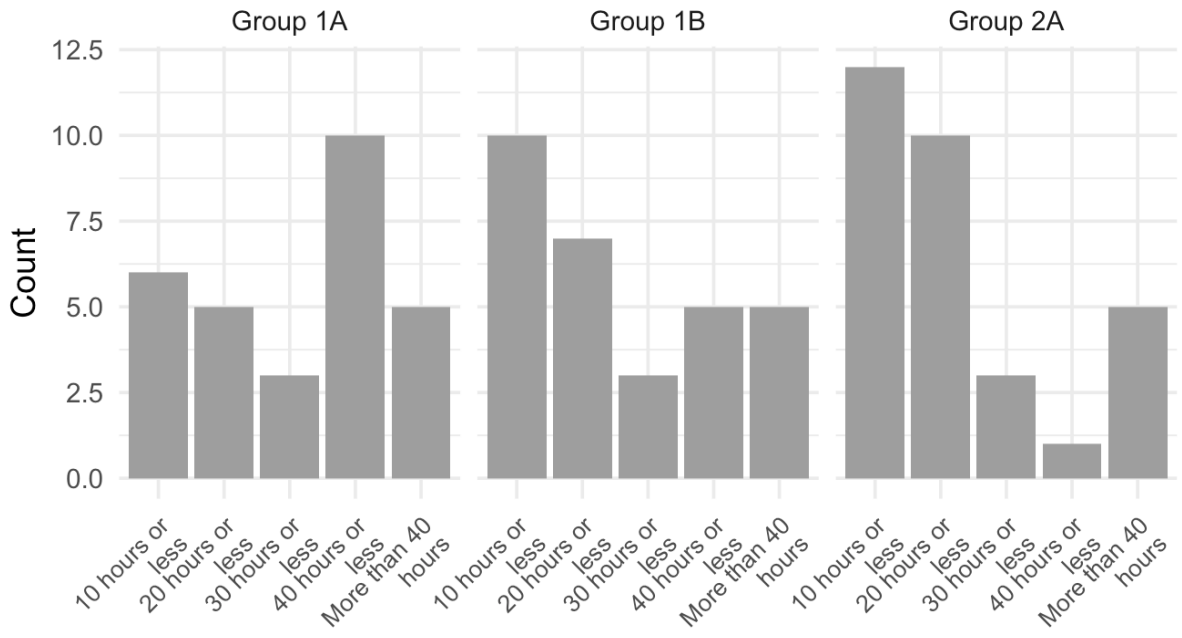

Figure 3.13: Number of hours spent driving with parent/guardian, separated by group

The teen drivers had varying relationships with their parents/guardians, as shown in Figure 3.14. Most teen drivers drive with their parents/guardians before receiving their JOL and their parents/guardians establish guidelines around their driving. However, very few parents use devices to monitor their teens driving.

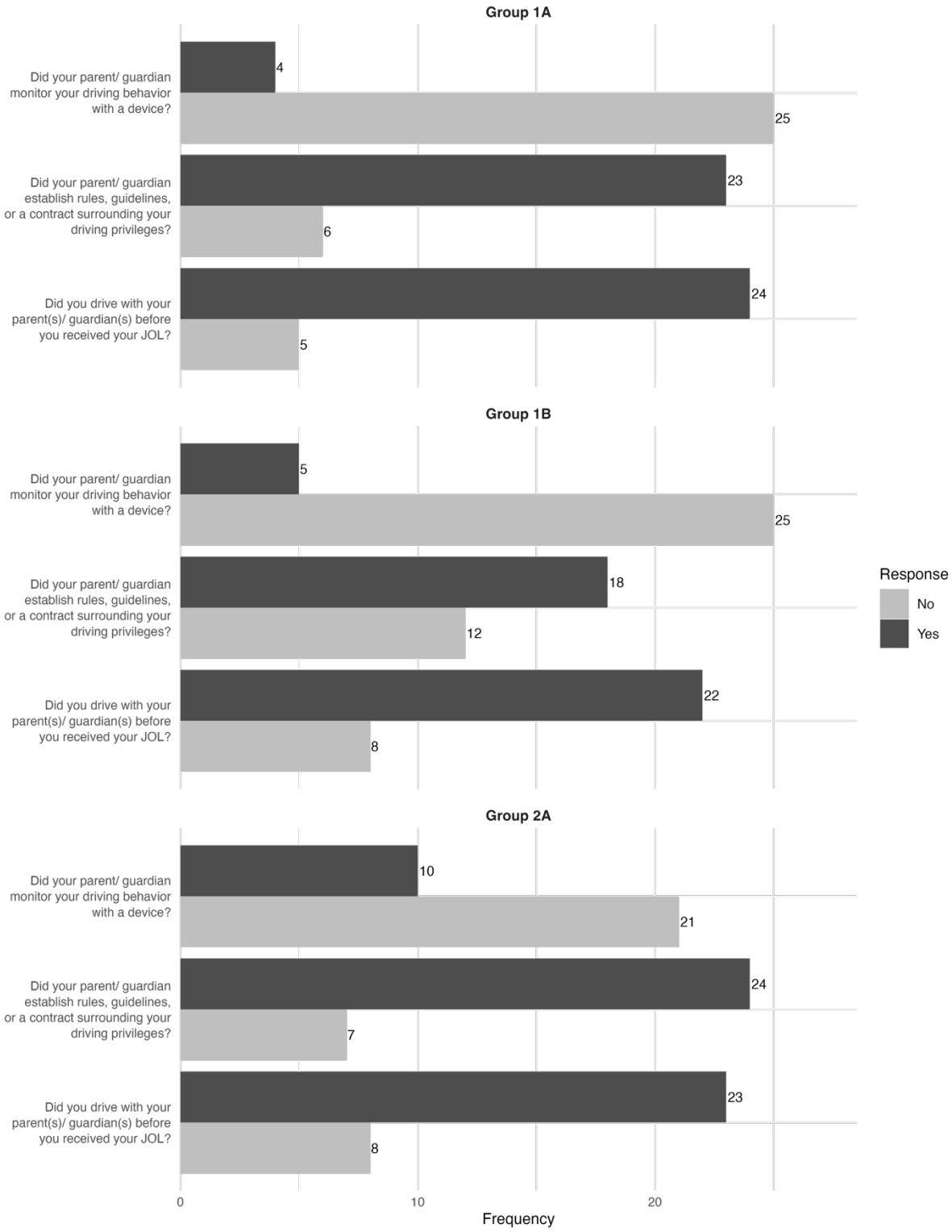

Figure 3.14: Relationship between teen driver and parent/guardian, separated by group

3.3.3 Hazard Anticipation

For each of the eight scenarios presented in the hazard anticipation and mitigation simulator drive, the teen drivers were assessed as to whether they correctly identified the hazard. A Fisher test was used to determine if there were differences in the proportion of successful hazards identified between groups (Group 2A versus Group 1A).

Table 1 delineates the proportion of successful hazard identifications by group and by scenario. The third column indicates the results of the Fisher test; there were no group differences.

Table 1: Proportion of successful hazard anticipation Scenarios

Scenario Number	Proportion of participants who successfully identified the hazard from Group 2A	Proportion of participants who successfully identified the hazard from Group 1A	p value for the Fisher test to compare the two groups
1	52%	56%	p = 0.79
2	52%	48%	p = 1
3	48%	64%	p = 0.28
4	89%	84%	p = 0.7
5	7%	4%	p = 1
6	92%	100%	p = 0.49
7	60%	40%	p = 0.27
8	33%	36%	p = 1

3.3.4 Mental Models of ACC

The teen drivers' mental model scores are shown in Figure 3.15. Note that the minimum score is -60, meaning teens are extremely confident in their incorrect knowledge of ACC, and the maximum score is 60, meaning teen drivers are extremely confidence in their correct knowledge of ACC. Scores across all groups were mostly positive, which shows some knowledge of ACC. Interestingly, scores between Group 1A and Group 1B are similar despite the fact that Group 1B received additional training on ACC. Also, those in Group 2A had descriptively lower scores than Group 1A, though this difference was not formally tested for statistical significance.. As a reminder the only difference between the two groups was the format of instruction: Group 1A was in person and Group 2A was online.

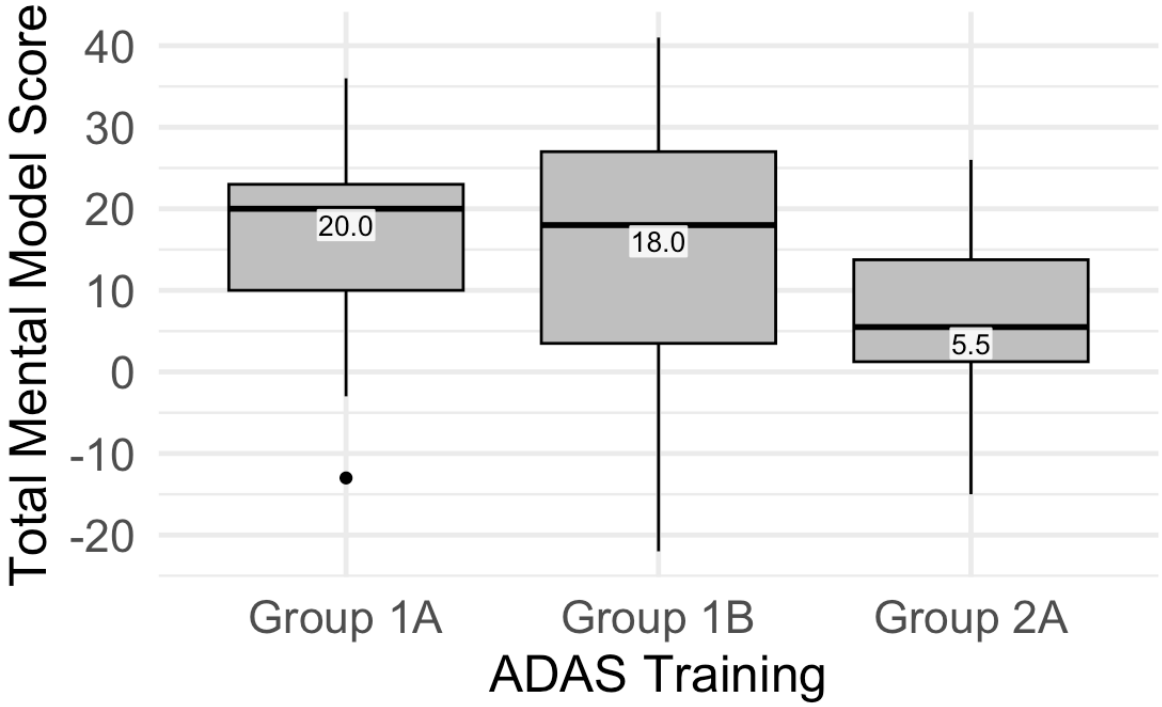

Figure 3.15: Comparison of teens' mental model score across Group

ACC mental model scores for teens and parents are shown in Figure 3.16. Similar to the teens scores, parents scores were positive, indicating some knowledge of ACC. In contrast the teens' scores, parents' scores were consistent across all three groups.

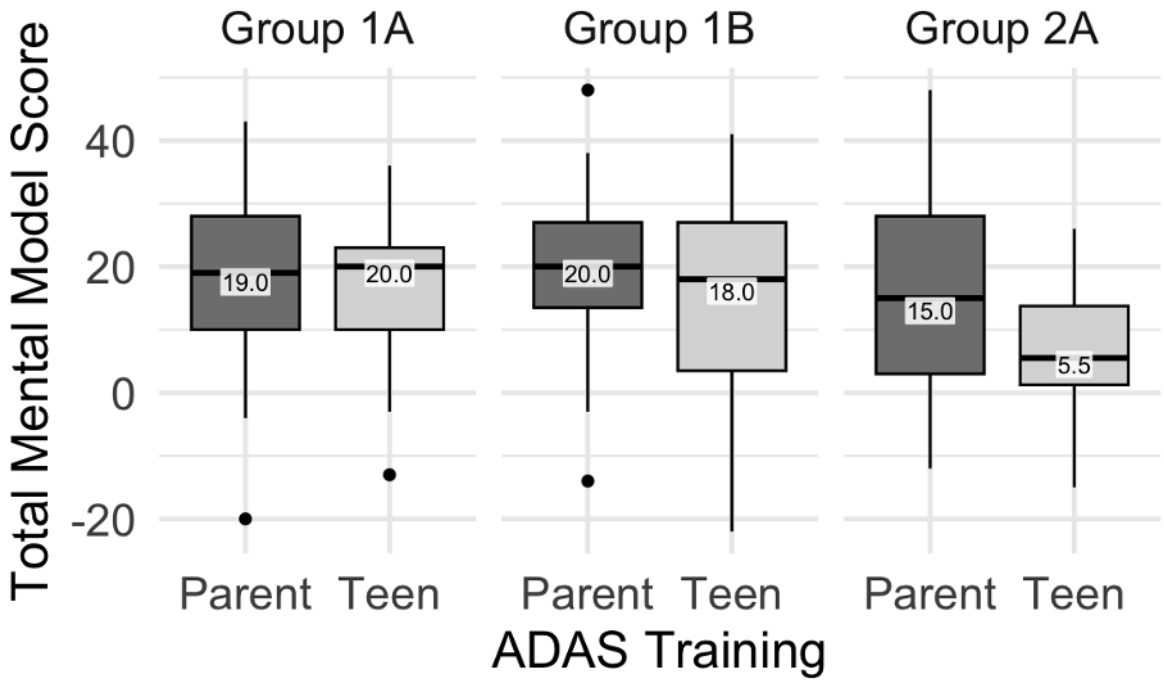

Figure 3.16: Comparison of teen versus parents mental model scores across Group

3.3.5 Eye Tracking Behavior while Using ACC

Participants across all groups primarily dedicated their visual attention to the roadway and mirrors (Figure 3.17). The percentage of total fixation duration on the roadway was highest for Group 1B (71.8%) and Group 2A (71.5%), in which the difference between them was negligible, followed by Group 1A (66.7%). Group 1A's visual attention away from the roadway appears to have been allocated instead to the speedometer, as Group 1A spent 5% more of its total fixation duration at the speedometer than Group 1B and 2A. The percent of total fixation duration on ACC HMI and ACC controls were almost identical between training groups.

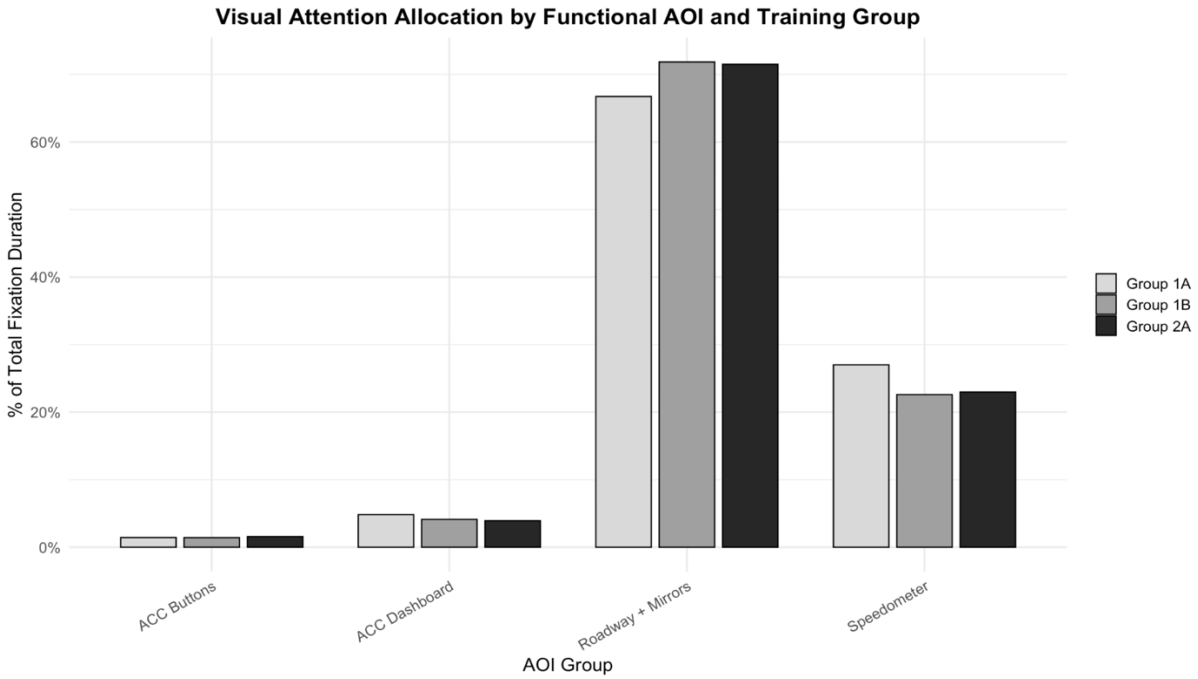

Figure 3.17: Comparison of total fixation duration across Areas of Interest (AOIs) as well as Groups

3.4 Task 4

We collected follow-up survey responses from 57 of the 90 student driver participants (66% response rate): [25] of 28 from Group 1A, [14] of 32 from Group 1B, and [18] of 30 from Group 2A. Of those 57 responses, there were 5 warnings, 1 citation, and 7 crashes reported within the first year of licensure. Of the 5 warnings, 3 were from participants in Group 1A and 2A were from participants in Group 2A. The 1 citation was for a participant in Group 1B, however, it was a parking citation, not a moving violation. Of the 7 crashes, 2 were from Group 1A, 2 were from Group 1B, and 3 were from Group 2. Given the small number of warnings and crashes, no statistically significant difference could be found between groups.

From the Massachusetts Vehicle Census data, which captures police-reported events only, 1 citation and 9 crashes were identified across the full sample of 90 participants. The 1 citation came from a participant in Group 1A. For the 9 crashes, 6 participants were from Group 1A and 3 participants from Group 2A. The discrepancy between the two sources is expected: the census captures police-reported events for all participants (including non-respondents to the survey), while the survey captures events, including those not reported to police, but only from the 57 respondents. Some events likely appear in both sources; others are unique to one. The two sources are complementary rather than directly comparable. Given the small event counts (ranging from 2 to 6 per group), these data are insufficient for meaningful group-level statistical inference. No statistically significant differences were detected, but the study was not powered to detect group differences in rare events over a 12-month window.

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4.0 Implementation and Technology Transfer

4.1 Lessons Learned

Lessons learned were collected for the entire project and for each project task. Lessons learned in Task 1 centered on understanding and improving stakeholder interactions. While we initially planned to interview all five stakeholder groups, we learned that a more focused approach was needed for two specific groups: car dealership employees and transportation safety scholars. The strategic pivot for these two groups included a switch to surveys as our primary data collection method. This led us to refine our recruitment and engagement plan: we adjusted our recruitment tactics to prioritize direct, face-to-face engagement with potential participants, finding it more effective than impersonal cold calls or emails.

In Task 2, after formalizing the training program, the biggest lesson learned was a need for a train-the-trainer approach. Based on insights from Task 1 (e.g., interviews), it was established that there was a critical need to ensure that the driver education instructors had up-to-date and complete knowledge and background about the ADAS domain and topic, including safety related issues, how to use ADAS, and its associated capabilities and limitations. In addition to ensuring updated knowledge, this also resulted in consistent delivery of the instructional content given that the educators themselves are basing the instruction on a common set of principles and facts. As such, an important sub-task within Task 2 was to design and implement a 'train-the-trainer' procedure to ensure that the instructional material and content were well understood by the persons who would be delivering it to the teen drivers.

In Task 3's recruitment proved to be a prolonged and challenging process. Our initial strategy involved continuously enrolling interested and eligible participants through email coordination for eligibility screening and scheduling. This approach, while sufficient for Group 1A and Group 1B, did not yield the desired speed of enrollment. A necessary pivot became evident when the mobile trailer was relocated to a new site for Group 2A, a location with limited parking. To ensure data collection proceeded as quickly and efficiently as possible, we implemented a revised recruitment plan. This updated strategy focused on identifying and enrolling eligible participants within minutes of their expressed interest. Furthermore, we streamlined the consent and survey process for parents, enabling them to complete the necessary documentation prior to the experiment. This refined approach to recruitment and enrollment significantly accelerated data collection throughput for Group 2A. Subsequently, we applied these optimized procedures to complete the remaining data collection for Group 1A and Group 1B.

In Task 4, the most important lesson learned was the critical importance of adaptable processes and robust procedures, particularly concerning data access and management. Due to a change in state law that occurred during this study, usual access to crash, citation, and warning data was restricted while required protections were put in place and access re-established. Upon successful restoration of access to this vital data, it became clear that the pre-existing procedures for querying and extracting information were no longer optimal, or even functional, given the updated access protocols and potentially revised data structures. Consequently, a comprehensive

modification of our census query processes was imperative. This involved the development of revised query scripts and methodologies to ensure efficient, accurate, and compliant data retrieval. The experience ultimately reinforced the need for continuous vigilance regarding legal and technical changes that impact data accessibility, and for building agile processes that can quickly adapt to such shifts.

4.2 Technology Transfer

Through monthly meetings with the project champions, the findings from Task 1-4 have been shared and have informed decision making and spurred research project ideation. As one concrete example, findings from Task 1 were shared with MassRMV's Professional Driving Unit, which aided in formulating next steps from the national assessment of MA driver education, conducted by the National Highway Traffic Safety Administration (NHTSA) in 2024-2025. As another example, preliminary findings from the project were presented during the 2025 AAA Foundation for Traffic Safety's Safe Mobility Symposium. While there, we were able to network with colleagues from other states who were interested in driver education research. Last, results from Task 1 were presented at the 2025 Transportation Research Board meeting (37) and published as a journal article in the Journal of Safety Research (24).

4.3 Implementation Plan

Beyond traditional academic publications that detail the specific results of Tasks 3 and 4, we are committed to a robust and multi-faceted dissemination strategy to ensure the findings reach a broad audience. This expanded approach will leverage a variety of platforms including lectures, webinars, workshops, and presentations at relevant conferences and symposia. This continuous engagement aims to foster dialogue, encourage the adoption of best practices, and contribute to the broader body of knowledge in teen driver education.

The nature of the research findings dictates the scope of their dissemination. Insights pertaining to driver education methodologies and broader aspects of teen driver behavior possess a wide applicability and will therefore be shared on a regional, national, and even international scale. This global reach will facilitate the exchange of knowledge with researchers, policymakers, and educational institutions worldwide, contributing to universal efforts to enhance road safety among young drivers.

Conversely, the nuances and specific implications for teen driver education within Massachusetts will be tailored for local dissemination. This targeted approach will involve direct engagement with Massachusetts-based driver education schools, state transportation agencies, and local community organizations. The objective is to provide actionable insights and practical recommendations that can be directly integrated into local curricula and safety initiatives, addressing the specific challenges and opportunities within Massachusetts' driving environment.

Finally, to ensure that this research resonates with the broader public and informs everyday conversations about road safety, we will actively pursue opportunities for public-facing communication initiatives. This will involve collaborating with editors and other media professionals to create accessible articles for popular platforms, such as *The Conversation*. By translating complex research findings into engaging and understandable narratives, we aim to raise public awareness about critical aspects of teen driving, foster a culture of safety, and empower parents, educators, and communities with evidence-based information. This strategic outreach will maximize the real-world impact of our research, extending its influence far beyond academic circles.

4.4 Guidance on Implementation and Deployment

The output generated from Task 2 is primed for broader implementation and deployment, particularly in the realm of driver education. The developed lecture materials—comprising both slides and comprehensive notes—are ideally suited for dissemination to driving education schools across the state. The primary goal is to effectively inform teen drivers about ACC. By integrating this material into existing curricula, we can equip new drivers with crucial knowledge about ADAS, fostering a deeper understanding of its functionalities and limitations.

However, simply sharing the materials isn't enough. To ensure the content is delivered accurately and effectively, it's vital that the lecture package is provided in conjunction with a train-the-trainer session. This crucial component will empower driving instructors with the necessary knowledge and pedagogical tools to teach the ACC material appropriately. These sessions will cover not only the technical aspects of ACC, but also best practices for conveying this information to a young audience, addressing potential misconceptions, and facilitating engaging discussions. This dual approach—providing both the educational content and the means to teach it correctly—is important for successful, large-scale implementation and will help ensure a consistent and high-quality learning experience for all teen drivers.

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5.0 Conclusions

The goal of this research was to evaluate driver education and training as well as how such education and training can contribute to improving the use and understanding of ADAS. Through a multi-pronged approach with four tasks, we uncovered significant insights into: (1) the current state of driver education as well as its effectiveness with respect to teen driver behavior; and (2) the role and impact of ADAS training in teen driver education.

For Task 1, key themes emerged from the interviews and surveys and included the importance of: (1) a focus on safety for teen drivers; (2) ADAS training for teen drivers; (3) parents/guardians in the learning how to drive process; and (4) driver education pedagogy. In Task 2, a training program on ACC was developed based on past research as well as findings from Task 1. To optimize integration with the current driver education curriculum, the training program was delivered in a similar format *and* by current driver education instructors. Task 3 focused on evaluating different driver education curricula approaches as well as the effectiveness of the training program on ACC.

The analyses found that while one group (Group 1B) received the ACC training module it did not demonstrate higher ACC mental model scores than the one that did not receive it (Group 1A). Several plausible explanations can help interpret this, although the data cannot provide a definitive adjudication among them: (a) Training duration: The ACC module was approximately 20–30 minutes of classroom lecture. This duration, while realistic for curriculum integration, may have been insufficient to produce measurable changes in mental models without reinforcement or hands-on experience; (b) Prior exposure: Participants in Group 1A may have encountered ACC information through family vehicles, media, or peers, partially narrowing the knowledge gap; (c) Retention interval: Time elapsed between training delivery and assessment may have allowed for decay of training-specific gains; or, (d) Assessment alignment: The mental model survey measures general ACC understanding and may not have been sufficiently sensitive to the specific content covered in the training module. This finding highlights the challenge of producing measurable knowledge gains through brief, standalone classroom interventions and suggests that future iterations should explore reinforcement strategies, hands-on components, or longer training formats.

The study did not identify consistent or statistically significant differences in the measured outcomes attributable to instructional format or ACC training. With the group sizes employed, failure to detect a difference does not establish equivalence. The small number of crashes, citations, or warnings identified in Task 4 were insufficient for meaningful group-level inference.
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5.1 Recommendations

Based on findings from Task 1-4, we have the following recommendations:

1) Periodic reviews into the state of driver education (e.g., content, delivery, format, structure, etc.) are necessary in order to maintain an accurate perception and understanding of what teens are being taught.
2) Relatedly, periodic evaluations of driver education program effectiveness are also needed. Evaluations can by multi-modal in nature. Ideally, they will include multiple forms of data collection (i.e., subjective and objective) and from multiple evaluators (e.g., students, instructors, regulatory agencies, and external evaluators).
3) While the data collected here can be broadened to other states outside of MA, what may be even more compelling are periodic working group meetings with representation from across the country. In this way, best practices for driver education can be shared and disseminated.
4) Given the proliferation of ADAS technologies provided in automobiles, both new and used, training teen drivers on their usage will continue to be a growing need. Training should continuously be developed as new technologies emerge (and change with time).

5.2 Limitations and Future Research

The training program used in Task 2, was designed to be similar to current driver education training approaches to ensure integration. Future research should consider other training approaches (e.g., using virtual reality or behind-the-wheel training).

Across Tasks 1, 3, and 4, the limited number of participants may not fully represent the broader population. Future research should include more participants and more stakeholder groups (for Task 1) as well as more teen drivers who experience different forms of driver education (for Tasks 3 and 4). Additionally, the comparison of in-person versus online instruction may be confounded with driving school site and geographic region. Future research could employ randomized assignment within a single school or a matched-school design to better isolate the effect of delivery method. Assignment to Group 1A versus 1B was based on enrollment timing rather than randomization, which introduces potential cohort effects that should be considered. Task 3 relied on a driving simulator experiment to assess driving behavior. While the relative validity of driving simulator experiments has been proven, real world or naturalistic data collection with teens on actual roadways would further validate the findings. Finally, Task 4 focused on crashes, citations, and warnings over a 12-month period. Though this time period is comparable to past research, records may need to be gathered for an extended period (e.g., 2 or 3 years) to accurately assess long term effectiveness.

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Appendices

Appendix A – Interview Questions and Surveys for Task 1

Goal 1: Driver education delivery and format

For Driver education instructors

1. How is driver education delivered (e.g., videos, lectures, group activities, quizzes, or online)?
    a. How have things changed during/since the COVID-19 pandemic?
2. Instructors
    a. Does one person deliver all the content?
    b. Is there a particular instructor for classroom training and a different instructor(s) for behind the wheel training?
    c. Are there guest lectures?
    d. How many years of experience do the instructors have?
3. Timing
    a. How long does driver education last?
    b. How frequent are the lessons?
4. Modules
    a. Are each of the 16 modules delivered in the same format? *(Note that module 16 is parent training.)*
    b. Are some modules combined and taught in one lesson?
    c. Based on your experience, which module is the most effective?
    d. How long is each module?
5. Based on your experience, what aspect of driver education is the most/least effective?
    a. Why is it the most/least effective?
    b. How can it be improved?
6. Behind the wheel training
    a. How does behind the wheel training compare to classroom training?
    b. What is being measured/assessed to determine readiness for the road test?
    c. How do you know when a teen is ready for the road test?
7. Parent training
    a. What sort of parent training/education is done?
    b. What is taught?
    c. How is it taught?

For MassRMV employees

1. Instructors
    a. How many years of experience do the instructors have?
    b. Is there any certification instructors must go through (from the RMV) before they instruct drivers?
2. Examiners
    a. How many years of experience do the examiners have?

    b. Is there any certification examiners must go through (from the RMV) before they test drivers?
3. *(If applicable, depending on experience)* How is driver education delivered (e.g., manuals, videos, lectures, group activities, quizzes, or online)?
    a. How have things changed during/since the COVID-19 pandemic?
4. *(If applicable, depending on experience)* Timing
    a. How long does driver education last?
    b. How frequent are the lessons?
5. *(If applicable, depending on experience)* Based on your experience, which module is the most effective?
    a. Why is it the most/least effective?
    b. How can it be improved?
6. Based on your experience, what aspect of driver education is the most/least effective?
    a. Why is it the most/least effective?
    b. How can it be improved?
7. Parent training
    a. What sort of parent training/education is done?
    b. How can it be improved?
8. Modules
    a. How often is the guide for teen drivers education (called "Driver Education Program") updated? *We have a version from 05/2017.*
    b. How do you decide to add/remove a module?
    c. What sort of guidance is provided when new modules are added/revised (e.g., the revised parent module or the new cannabis module)?
9. Interacting with driver education schools
    a. What are typical points of confusion working with driving schools?
    b. What are the schools most FAQs?

For Law enforcement

1. With respect to teen driver citations, what are the most common (and most rare) offenses?
    a. Do they frequently violate the JOL restrictions? If so, which ones?
2. With respect to teen driver crashes, what are the most common (and most rare) offenses?
3. In terms of warnings, what are the most (and least) common offenses for teens?
4. Have you pulled over teen drivers when they are "practicing" with their parent/guardian?
    a. If so, how often?
    b. How frequently do you think this occurs?
    c. How do you think this affects teen driver's perspective on "how to drive"?
5. Have you pulled over adult drivers who have teens in the vehicle?
    a. If so, how often?
    b. If not, how frequently do you think this occurs?
    c. How do you think this affects teen driver's perspective on "how to drive"?
6. When you pull over a teen driver, what is their emotional state (e.g., aloof, surprised, scared)?
    a. What is their typical response? What do they say (e.g., do they immediately try to pay the ticket)?

For Dealership employees

1. How frequently do you sell vehicles to teens (or their parents)?
2. When you sell vehicles to teens (and their parents), what are their most common concerns?
    a. What features are parents looking for when they buy a teen a vehicle?
    b. Is there a connection between features parents requests and safety?
    c. Do parent's concerns vary between new versus used cars?
3. Do you have any special features for teen drivers (e.g., a key or an app)?
    a. Are there features specific to or include ADAS?
    b. Is this a feature many parents request?
4. Do you give any training to consumers when they purchase a vehicle?
    a. Does every consumer receive the training?
    b. How long is the training?
    c. What format is the training?
    d. When does it occur?
    e. Where does it occur?
    f. Who gives the training and how much experience do they have?
    g. Are there follow-up sessions?
    h. Can consumers ask questions/get more training after they leave the lot?
    i. Does it differ based on a new versus used vehicle?
    j. Who trains the trainers?
    k. What training do consumers refuse/reject?
    l. Are you required to give training to consumers (from the OEM)?

Goal 2: Driver education to promote ADAS understanding

For all participants

1. Do you have any ADASs in your vehicle?
    a. If yes, how does your experience using ADAS in your vehicle impact your view on the technology?
    b. If no, would you be interested in getting ADAS in your next vehicle?
2. What training currently exists for ADAS?
    a. If yes, is it appropriate for all age groups and all levels of driving experience (e.g., in terms of how people learn, where we can reach them, etc.)
    b. If yes, does it align with current driver education curricula?
    c. If not, how do we close the gap between what drivers need to know and what drivers actually know when it comes to ADAS?
3. How should teen drivers be trained to use and understand ADAS?
4. How should driving instructors be trained about ADAS?
5. Where do you (on your own initiative) look for information about ADAS?

For Driver Education Instructors

1. ADAS
    a. Hypothetically, if you had to do behind the wheel training for ADAS, how would it be done?

b. How comfortable are you with learning about ADAS so you can teach it to students?

For MassRMV employees

1. In the future, do you see the MassRMV adding a component to the road test focused on whether people use ADAS appropriately?

For Dealerships employees (modify the questions below to focus on teens if a dealership employee indicates they frequently sell vehicles to teens)

1. In general, do you think that you get enough information (from car manufacturers, importers, your car dealership, holding, a nearby dealer or wholesaler) to provide customers with information about ADAS?
2. How do you train new vehicle owners about ADAS in their vehicle?
3. What information do you expect to support you in providing information about ADAS to customers?
4. When interacting with potential customers:
    a. When do you give them information about ADAS?
    b. How do you inform customers about ADAS information?
    c. What information do you give them about ADAS?

For all participants

1. Are there any additional thoughts you have on driver education and training or ADAS specific driver education and training?

1.1.1 Transportation Safety Scholar Survey

1. What are the main differences between training and education when it comes to teens? **Select all that apply**
    1. Training focuses on theoretical knowledge
    2. Education emphasizes hands-on practice
    3. Both training and education are similar for teens
    4. Other
2. How do we measure the efficacy of education and training from the teen's performance? **Select all that apply**
    1. By evaluating their overall driving skills
    2. By measuring their proficiency in dealing with different scenarios
    3. By comparing their performance before and after education/training
    4. Other

3. Based on your experience, what should driver education primarily focus on? In other words, what can teen drivers benefit the most from learning about driver education? **Open Response**

4. How can parents and/or guardians be better incorporated into the driver education process? **Open Response**

5. Based on your experience, what aspect of the current driver education curriculum is the most effective? **Open Response**

6. Based on your experience, what aspect of the current driver education curriculum is the least effective? **Open Response**

7. What instructional methods or tools do you recommend for teaching teen drivers how to use ACC safely and effectively? **Select all that apply**
    1. Interactive driving simulations with ACC scenarios
    2. Hands-on practice with real vehicles equipped with ACC
    3. Video tutorials demonstrating ACC operation and best practices
    4. Classroom instruction
    5. Other

8. In the context of teen drivers, which components should be included in a training program that covers the effective use of ADAS like ACC? **Select all that apply**
    1. Understanding ACC technical specifications
    2. Practicing ACC in diverse road conditions
    3. Learning about ACC maintenance and repairs

4. Recognizing the abilities and limitations of ACC
5. Other

9. Are there specific challenges or difficulties that arise when learning how to use ACC? **Select all that apply**
    1. Over reliance on ACC leading to decreased driver alertness
    2. Difficulty adjusting to ACC sensitivity and following distance settings
    3. Limited understanding of ACC limitations and functionalities
    4. Other

10. How can these challenges or difficulties be effectively addressed? **Open Response**

11. How can the training of ACC be tailored to different levels of driving experience, from novice to experienced drivers? **Select all that apply**
    1. Providing separate training modules of each level of experience
    2. Offering personalized coaching sessions based on individual driving history
    3. Conducting group training sessions with mixed experience levels
    4. Other

12. How can the training of ACC be integrated with other ADAS to ensure a holistic understanding of vehicle technology? **Select all that apply**
    1. Offering comprehensive courses covering all driver assistance systems, including ACC
    2. Providing resources for self-paced learning on different vehicle technologies
    3. Conducting workshops focusing on integrating ACC with other systems
    4. Other

13. Do you have any insights on how the adoption of ACC impacts teen driver overall driving behavior and attitudes towards automated driving technologies? **Select all that apply**
    1. Increased trust in automated systems leading to less attentive driving behavior
    2. Improved driving confidence and reduced stress during long journeys
    3. Heightened awareness of the benefits and limitations of automated technologies
    4. Other

14. Please rank the following safety considerations when incorporating ACC training into driver education programs from most to least important. **Rank the following**
    1. Emphasizing the importance of maintaining situational awareness while using ACC

2. Highlighting the need for drivers to be prepared to take over control when necessary
3. Addressing potential risks and limitations of ACC technology
4. Other

15. How can driver education programs leverage technology to enhance the training of ACC and other advanced driver assistance systems? **Select all that apply**
    1. Implementing virtual reality training environments for hands-on experience
    2. Utilizing driving simulators with ACC functionality for realistic practice
    3. Offering online courses with interactive modules on ACC and other systems
    4. Other

16. How can educators effectively incorporate driving education for automated driving technologies into the existing curriculum for teenage students? **Select all that apply**
    1. Introducing dedicated ACC courses in the curriculum
    2. Integrating ACC education within regular driving lessons
    3. Conducting seminars on ACC benefits and risks
    4. Other

17. Are there any specific measures parents should keep in mind when it comes to the training and education of teenage drivers, with respect to driving overall and for automated driving technologies? **Select all that apply**
    1. Setting clear rules and expectations for ACC usage
    2. Monitoring teen driving behavior using technology
    3. Encouraging independent exploration of ACC features
    4. Other

18. In terms of parental education, what resources should be provided to parents to help them better understand automated driving technologies like ACC, helping them guide their teen drivers? **Select all that apply**
    1. Online tutorials on ACC features and operation
    2. Workshops on effective parental guidance for ACC usage
    3. Videos demonstrating real-life ACC scenarios
    4. Other

19. How do we infer a teen's knowledge of ACC from their performance? **Select all that apply**
    1. By evaluating their reaction time in different scenarios
    2. By assessing their familiarity with ACC features
    3. By monitoring their adherence to ACC guidelines
    4. Other

20. What specific and good outcome measures are needed to evaluate a teen's education on ACC? **Select all that apply**
    1. Increased confidence in using ACC
    2. Reduced incidents of sudden braking
    3. Improved understanding of ACC limitations
    4. Other

21. Are there any additional thoughts you have on driver education and training or ADAS specific driver education and training? **Open Response**

22. Briefly describe your expertise/background in the transportation safety field. **Open Response**

23. How many years have you worked in the transportation safety field? **Open Response**

24. Briefly describe your expertise/background in driver education, driver training, or training for ADAS. **Open Response**

25. What personal experience do you have with ADAS – advanced driving assistance systems? **Open Response**

1.1.2 Car Dealership Employee Survey

1. How frequently do you sell vehicles to teens (or parents looking for their teens)? **Multiple choice**
    1. At least once a week
    2. 2-3 times a month
    3. Once every 1-2 months
    4. Once every 2-3 months
    5. 2-3 times a year

2. When you sell vehicles to teens (and their parents), what are their most common concerns? **Select all that apply**
    1. Safety
    2. Price
    3. Reliability
    4. Looks or Design
    5. Brand (Make and Model)
    6. Other

3. For the vehicles you sell, are there any special features that are targeted toward teen drivers (e.g., a key or an app)? **Multiple choice**
    1. Yes
    2. No
    3. I don't know

Training is a tool to teach drivers certain knowledge and skills about vehicle handling, vehicle maneuvering, and staying safe on the roadway.

4. Do you give any training to consumers when they purchase a vehicle? **Multiple choice**
    1. Yes
    2. No
    3. Sometimes

5. Are you required to give training to customers (from the manufacturer or as a dealer policy)? **Multiple choice**
    1. Yes
    2. No
    3. Other

6. Does every customer receive the training? **Multiple choice**
    1. Yes
    2. No

7. Do customers refuse the training? **Multiple choice**
    1. Yes
    2. No
    3. Other

8. Can customers get more training after they leave the lot? **Multiple choice**
    1. Yes
    2. No
    3. Other

9. What information is included in the training? **Select all that apply**
    1. Basic vehicle controls
    2. Bluetooth connectivity
    3. Entertainment system
    4. Vehicle safety systems (like adaptive cruise control or blind spot monitoring)
    5. Other

10. Does the training differ based on if a customer buys a new vehicle versus used vehicle? **Multiple choice**
    1. Yes
    2. No

11. When does the training occur? **Multiple choice**
    1. Before vehicle purchase
    2. After vehicle purchase
    3. Other

12. What format is the training? **Multiple choice**
    1. In the car
    2. In the showroom
    3. On the internet
    4. Other

13. How long is the training? **Multiple choice**
    1. 30 minutes or less
    2. 30 minutes to 1 hour
    3. 1 hour to 2 hours
    4. 2 hours or more

14. Who gives the training? **Multiple choice**
    1. Salesperson
    2. Manager
    Other

15. How much experience does the trainer have in giving training to customers? **Multiple choice**
    1. None at all
    2. A little
    3. A moderate amount
    4. A lot
    5. A great deal

16. Who trains the trainers? **Multiple choice**
    1. Manufacturer
    2. Online Tutorial
    3. Someone else at the dealership
    4. Other

17. Are there follow-up sessions with the customer after the initial training session? **Multiple choice**
    1. Yes
    2. No
    3. If the customer desires

4. Other

ADAS, short for "Advanced Driver Assistance Systems", is a broad term that encompasses a range of features within a vehicle designed to aid drivers while they drive. These include but are not limited to forward collision warning (FCW), lane keep assist (LKA), and adaptive cruise control (ACC). Collectively, these features aim to enhance the driver's experience during everyday driving.

18. Do you have ADAS in your personal vehicle? **Multiple choice**
    1. Yes
    2. No
    3. I don't know

    18a. If yes, Do you use the ADAS in your vehicle? **Multiple choice**
        1. Always
        2. Most of the time
        3. About half the time
        4. Sometimes
        5. Never

    18b. If not, Would you be interested in having ADAS in your next vehicle? **Multiple choice**
        1. Definitely not
        2. Probably not
        3. Might or might not
        4. Probably yes
        5. Definitely yes

19. Where do you (on your own initiative) look for information about ADAS? **Open Response**

20. In general, do you think that you get enough information (from car manufacturers, importers, your car dealership, holding, a nearby dealer or wholesaler) to provide customers with information about ADAS? **Multiple choice**
    1. Definitely not
    2. Probably not
    3. Might or might not
    4. Probably yes
    5. Definitely yes

21. What training currently exists for ADAS? **Multiple choice**
    1. None at all
    2. A little
    3. A moderate amount
    4. A lot
    5. A great deal

22. Is it appropriate for all age groups (e.g., teen drivers to older drivers) and all levels of driving experience (e.g., in terms of how people learn, where we can reach them, etc.) **Multiple choice**
    1. Definitely not
    2. Probably not
    3. Might or might not
    4. Probably yes
       Definitely yes

23. How do we close the gap between what drivers need to know and what drivers actually know when it comes to ADAS? **Open Response**

When interacting with potential customers:

24. When do you give them information about ADAS? **Select all that apply**
    1. In the showroom when introducing the cars
    2. During the test drive
    3. After they purchase the car
    4. Other
    5. I do not give information about ADAS

25. How do you inform customers about ADAS information? **Select all that apply**
    1. Telling them
    2. Showing them
    3. Letting them read it on a brochure
    4. Other

26. What information do you give them about ADAS? **Open Response**

27. How do you train new vehicle owners about ADAS in their vehicle? **Open Response**

28. How should teen drivers be trained to use and understand ADAS? **Open Response**

29. Are there any additional thoughts you have on driver education and training or ADAS specific driver education and training? **Open Response**

Appendix B: Training Program Slides for Task 2

Appendix C – Surveys for Task 3

Screening Survey

Thank you for your interest in the Driver education study.

This is a questionnaire to determine your eligibility for participation.

If you are under 18, please check that your parents are OK with you doing this screening survey.

What is this form?

- This form determines if you are eligible to participate in the "Driver Education Study."
- It should take you no more than 5 minutes to complete.
- If you are ineligible to participate, your responses will be destroyed.
- If you are eligible to participate, your responses will become part of the study materials, and we will protect your information as confidential and safeguard it from unauthorized disclosure.

Only research personnel will have access to the information contained in your screening questionnaire.

If you are eligible to participate, we will contact you to schedule a time for your participation in the study.

If you have any questions, please email us at driver.training.umass@gmail.com and mention "Driver Education Study" in the subject line.

1. Please enter your name: Text entry
2. Please enter your email: Text entry
3. How old are you?
    a. If the participant is > 18 or < 16, then reject
4. Do you have a valid US driver's permit?
    a. If no, then reject
5. Where do/will you attend driving school?
    a. If not one of the two schools, then reject
6. When do/will you attend driving school?
    a. If not within the defined time period, then reject
7. Are at least 1 of your parents/guardians willing to participate in the study?
    a. If no, then reject

If the participant is eligible to participate in the study, "Thank you for completing the survey. As you meet the requirements of the survey, a member of our research group will contact you to confirm the experiment session times" will be displayed.

If the participant is ineligible to participate in the study, "Thank you for participating in the survey. Unfortunately, you do not meet the requirements of the study. Your information has not been saved. Please exit the survey " will be displayed.

Demographics Survey for Teen

1. What is your driver's license number – Text entry Question
2. When was your driver's license issued? – Text entry question
3. What is your home address, city, state, and zip code? – Text Entry Question
4. Age - Text Entry Question
5. How do you identify your gender? – Multiple Choice Question
    a. Woman
    b. Man
    c. Non-binary
    d. Transgender
    e. Nonconforming
    f. Not listed, please describe _____
    g. Prefer not to answer
6. Are you of Hispanic or Latino/a origin? – Multiple Choice Question
    a. No
    b. Yes, Mexican, Mexican American, or Chicano
    c. Yes, Puerto Rican
    d. Yes, Cuban
    e. Yes, another Hispanic or Latino/a origin _____
    f. Prefer not to answer
7. What is your race? - Select all that apply question
    a. American Indian/Alaskan Native
    b. Asian/Pacific Islander
    c. African American/Black
    d. Asian American
    e. Caucasian/White
    f. Native Hawaiian or Other Pacific Islander
    g. Other _____
    h. Prefer not to answer
8. What type of car do you drive most often? – Text Entry Question
9. Does the car you regularly drive have any of the following features? – Select all that apply question
    a. Adaptive Cruise Control
    b. Lane Keeping Assistance
    c. Rearview Camera/Rear Parking Assistance
    d. Automatic Emergency Braking (to avoid a collision)
    e. Blind Spot Detection
    f. Drowsiness Monitoring
    g. Other _____

1.1.3 Demographics Survey for Parent/Guardian

1. What is the highest level of education either you or your spouse/partner have completed? – Multiple Choice Question
    a. Middle school or some high school
    b. High school diploma
    c. Some college
    d. College degree (AA, AS, BA, BS, etc.)
    e. Some graduate school
    f. Graduate degree (PhD, JD, MD, etc.)
    g. Other _____
2. What is your household income? – Multiple Choice Question
    a. Less than $10,000
    b. $10,000 to $24,999
    c. $25,000 to $49,999
    d. $50,000 to $74,999
    e. $75,000 to $99,999
    f. $100,000 to $149,999
    g. $150,000 or more
    h. I don't know or prefer not to answer
3. What type of car do you drive most often? – Text Entry Question
4. Does the car you regularly drive have any of the following features? – Select all that apply question
    a. Adaptive Cruise Control
    b. Lane Keeping Assistance
    c. Rearview Camera/Rear Parking Assistance
    d. Automatic Emergency Braking (to avoid a collision)
    e. Blind Spot Detection
    f. Drowsiness Monitoring
    g. Other _____

Driver Education Instruction Survey for Teen

Overall

1. How much do you feel you learned in this driving education course?
    a. Much more than expected
    b. More than expected
    c. As expected
    d. Less than expected
    e. Much less than expected
2. What is your overall rating of this driving education course?
    a. Extremely effective
    b. Very effective
    c. Moderately effective
    d. Slightly effective
    e. Not effective at all

Classroom instruction

3. What was the format for your driver education course? (check all that apply)
    a. Online
    b. In-person
4. In total, how long was classroom instruction, i.e., how long did you spend in the classroom, either online or in-person?
    a. 10 hours or less
    b. 20 hours or less
    c. 30 hours or less
    d. More than 30 hours
5. In total, how many days was classroom instruction, either online or in-person?
    a. 1 week or less
    b. 1 – 2 weeks
    c. 2 – 3 weeks
    d. 4 weeks or more
6. On average, how long did you spend in the classroom, either online or in-person, for each day of instruction?
    a. 2 hours or less
    b. 2 – 4 hours
    c. 4 – 6 hours
    d. 6 – 8 hours
    e. 8 hours or more
7. Did you watch videos during classroom instruction, either online or in-person?
    a. Yes
    b. No
8. Did you have any quizzes or tests during classroom instruction, either online or in-person?
    a. Yes
    b. No
9. Did you have an accompanying workbook or a handbook that went along with the classroom instruction, either online or in-person?

a. Yes
b. No

10. Did you ever work in small groups with other students during classroom instruction, either online or in-person?
    a. Yes
    b. No
11. How many students were in your class, either online or in-person?
    a. 1-10 students
    b. 11-20 students
    c. 21-30 students
    d. 31-40 students
    e. 41 or more students

Classroom Instructors

12. How many classroom instructors did you have?
    a. 1
    b. 2
    c. 3
    d. 4 or more

Thinking of all your classroom instructors, either in person or online, please rate the following:

13. Instructor was well prepared for class.
    a. Almost always
    b. Frequently
    c. Sometimes
    d. Rarely
    e. Almost never
14. Instructor explained course material clearly.
    a. Almost always
    b. Frequently
    c. Sometimes
    d. Rarely
    e. Almost never
15. Instructor cleared up points of confusion.
    a. Almost always
    b. Frequently
    c. Sometimes
    d. Rarely
    e. Almost never
16. Instructor used class time well.
    a. Almost always
    b. Frequently
    c. Sometimes
    d. Rarely
    e. Almost never
17. Instructor inspired interest in the subject matter of the course.

a. Almost always
b. Frequently
c. Sometimes
d. Rarely
e. Almost never

18. Instructor shown an interest in helping students learn.
    a. Almost always
    b. Frequently
    c. Sometimes
    d. Rarely
    e. Almost never
19. Received useful feedback on performance on tests, etc.
    a. Almost always
    b. Frequently
    c. Sometimes
    d. Rarely
    e. Almost never
20. The methods of evaluating my performance were fair.
    a. Almost always
    b. Frequently
    c. Sometimes
    d. Rarely
    e. Almost never
21. Instructor stimulated student participation.
    a. Almost always
    b. Frequently
    c. Sometimes
    d. Rarely
    e. Almost never

Behind the wheel instruction

22. In total, how long was behind-the-wheel training with the driving instructor, i.e., how long did you spend driving in the car with the instructor?
    a. 6 hours or less
    b. 9 hours or less
    c. 12 hours or less
    d. More than 12 hours
23. How many behind-the-wheel sessions did you have?
    a. 4 or fewer
    b. 5 – 8
    c. 9 – 12
    d. 13 or more
24. On average, how long was each behind-the-wheel session?
    a. 30 minutes or less
    b. 30 minutes to 1 hour

c. 1 hour to 1.5 hours
d. More than 1.5 hours

25. How many behind the wheel instructors did you have?
    a. 1
    b. 2
    c. 3
    d. 4 or more

Behind the wheel instructors

Thinking of all your behind the wheel instructors, either in person or online, please rate the following:

26. Instructor was well prepared.
    a. Almost always
    b. Frequently
    c. Sometimes
    d. Rarely
    e. Almost never
27. Instructor explained material clearly.
    a. Almost always
    b. Frequently
    c. Sometimes
    d. Rarely
    e. Almost never
28. Instructor cleared up points of confusion.
    a. Almost always
    b. Frequently
    c. Sometimes
    d. Rarely
    e. Almost never
29. Instructor used time well.
    a. Almost always
    b. Frequently
    c. Sometimes
    d. Rarely
    e. Almost never
30. Instructor inspired interest in the course.
    a. Almost always
    b. Frequently
    c. Sometimes
    d. Rarely
    e. Almost never
31. Instructor shown an interest in helping students learn.
    a. Almost always
    b. Frequently
    c. Sometimes
    d. Rarely

e. Almost never

32. Received useful feedback on performance on tests, etc.
    a. Almost always
    b. Frequently
    c. Sometimes
    d. Rarely
    e. Almost never
33. The methods of evaluating my performance were fair.
    a. Almost always
    b. Frequently
    c. Sometimes
    d. Rarely
    e. Almost never
34. Instructor stimulated student participation.
    a. Almost always
    b. Frequently
    c. Sometimes
    d. Rarely
    e. Almost never

Parent/Guardian Training

35. Did you drive with your parent(s)/guardian(s) before you received your JOL?
    a. Yes
    b. No
36. How long was behind-the-wheel training with your parent(s)/guardian(s), i.e., how long did you spend driving in the car with your parent(s)/guardian(s)?
    a. 10 hours or less
    b. 20 hours or less
    c. 30 hours or less
    d. 40 hours or less
    e. More than 40 hours
37. Did your parent(s)/guardian(s) establish rules, guidelines, or a contract surrounding your driving privileges? Note that these rules, guidelines, or contract could be formal or informal.
    a. Yes
    b. No
38. Did you ever drive in the following situations with your parent(s)/guardian(s)?
    a. At night
    b. On the highway
    c. During high traffic periods
    d. With other passengers in the car who were your friends and not your family
    e. In inclement weather (e.g., rain, fog, hail, or snow)
39. Did your parent(s)/guardian(s) monitor your driving behavior with a device, e.g., smart phone app, in vehicle data recorder, cameras, etc.?
    a. Yes

b. No

Driver Readiness Survey for Teen

Responses are made on a 5-point Likert scale, with 1 indicating "not at all comfortable" and 5 indicating "very comfortable".

Right now, how comfortable would you be doing the following?

1. Use turn signals, windshield wipers, and headlights
2. Turn right onto a moderately busy street
3. Stay in their lane
4. Understand traffic signals
5. Keep up with traffic
6. Pull into a parking space
7. Back safely out of a parking space
8. Drive in good weather
9. Drive safely around pedestrians
10. Turn left across one lane of traffic
11. Pass a bicyclist safely
12. Drive in light rain
13. Drive on a narrow country road
14. Drive in a construction zone
15. Merge onto an interstate highway
16. Exit from an interstate highway
17. Drive while listening to music
18. Drive while talking with a passenger
19. Change lanes in moderate traffic
20. Drive at night
21. Drive in rush hour (heavy) traffic
22. Drive with sun glare
23. Drive in an unfamiliar place
24. Pass a vehicle on a two-lane rural road
25. Change lanes in heavy traffic
26. Make a left-hand turn crossing several lanes of on-coming traffic
27. Follow instructions from a navigation system (e.g., GPS) while driving
28. Drive in fog
29. Deal with the unexpected (like someone cutting you off)
30. Stop in time if the car is in front suddenly slammed on the brakes
31. Drive in heavy rain
32. Drive on a snowy/icy road
33. Using adaptive cruise control, which automatically speeds up and slows down the car to keep a set following distance relative to the car ahead
34. Using lane keeping assistance, which keeps the car in the lane
35. Can back up and park without using cameras or parking technology

Driver Readiness Survey for Parent/Guardian

Responses are made on a 5-point Likert scale, with 1 indicating "not at all comfortable" and 5 indicating "very comfortable".

Right now, how comfortable would you be with your teen doing the following without you in the car?

1. Use turn signals, windshield wipers, and headlights
2. Turn right onto a moderately busy street
3. Stay in their lane
4. Understand traffic signals
5. Keep up with traffic
6. Pull into a parking space
7. Back safely out of a parking space
8. Drive in good weather
9. Drive safely around pedestrians
10. Turn left across one lane of traffic
11. Pass a bicyclist safely
12. Drive in light rain
13. Drive on a narrow country road
14. Drive in a construction zone
15. Merge onto an interstate highway
16. Exit from an interstate highway
17. Drive while listening to music
18. Drive while talking with a passenger
19. Change lanes in moderate traffic
20. Drive at night
21. Drive in rush hour (heavy) traffic
22. Drive with sun glare
23. Drive in an unfamiliar place
24. Pass a vehicle on a two-lane rural road
25. Change lanes in heavy traffic
26. Make a left-hand turn crossing several lanes of on-coming traffic
27. Follow instructions from a navigation system (e.g., GPS) while driving
28. Drive in fog
29. Deal with the unexpected (like someone cutting you off)
30. Stop in time if the car is in front suddenly slammed on the brakes
31. Drive in heavy rain
32. Drive on a snowy/icy road
33. Using adaptive cruise control, which automatically speeds up and slows down the car to keep a set following distance relative to the car ahead
34. Using lane keeping assistance, which keeps the car in the lane
35. Can back up and park without using cameras or parking technology

ACC Mental Model Survey for Teen and Parent/Guardian

Mental Model Assessment

The following questions will ask you about your current understanding of Adaptive Cruise Control (ACC). You may have previous experience with ACC systems, but it is important that you focus on the information provided and drives experienced today to answer these questions. For each question, please indicate whether the statement is "True" or "False". Please answer the following questions regarding ACC.

The statement about ACC is…	True	False
Maintains the speed that you have set when there are no vehicles detected in the lane ahead	❍	❍
Brakes and accelerates to maintain a following gap from the vehicle ahead	❍	❍
Adjusts the speed to match faster vehicles ahead	❍	❍
Will accelerate if a slower vehicle ahead moves out of the detection zone	❍	❍
Will provide steering input to keep the vehicle in its lane	❍	❍
Will correctly detect motorcycles and other smaller vehicles not driving in the center of the lane	❍	❍
Is meant to be used on highways and interstates	❍	❍
May not correctly detect stopped vehicles in your lane	❍	❍
Reacts to stationary objects on the road (construction cone, tire, ball)	❍	❍
Works well on curvy roads and hills	❍	❍
Is meant to be used in slow and heavy traffic	❍	❍
Adjusts the speed when there are slower moving vehicles detected ahead	❍	❍
Will react immediately to vehicles merging onto the road in front of you	❍	❍
Reacts to oncoming traffic	❍	❍
Adjusts the vehicle speed when approaching tight curves	❍	❍
Is meant to be used on rural roads	❍	❍
May not correctly detect vehicles ahead travelling at much slower speeds	❍	❍
Works even when the radar sensor is dirty	❍	❍
Can be activated at a standstill	❍	❍
Can handle operating in all weather conditions	❍	❍

Confidence in Knowledge Assessment

After each item of the Mental Model Assessment, the participants will be asked to indicate their confidence level of answering the question items. The confidence level is measured by a 3-point confidence rating, i.e., low confidence, medium confidence, and high confidence, for each response.

12 Month Follow Up Survey for Teen

1. What date did you receive your license or JOL? – Text entry
2. Have you received any warnings since you received your license? – Multiple Choice Question
    a. Yes
    b. No
3. (if yes to question 2) Please describe what happened when you received the warning (e.g., were you speeding, were you distracted, were their passengers in the car, were you using any advanced vehicle technologies, etc.).
4. Have you received any citations since you received your license? – Multiple Choice Question
    a. Yes
    b. No
5. (if yes to question 4) Please describe what happened when you received the citation (e.g., were you speeding, were you distracted, were their passengers in the car, were you using any advanced vehicle technologies, etc.).
6. Have you been involved in any crashes since you received your license? – Multiple Choice Question
    a. Yes
    b. No
7. (If yes to question 6) Please describe what happened during the crash (e.g., was anyone injured, did you call the police, was the car totaled, were you distracted, were you using any advanced vehicle technologies, etc.).