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# Considerations for Vehicles With Automated Driving Systems: Seating Preference Study

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**16. Abstract**

Vehicles equipped with Automated Driving Systems (ADSs) are expected to perform part or all of the dynamic driving task. Vehicles equipped with an ADS that do not have manually operated driving controls are referred to as ADS-dedicated vehicles (ADS-DVs). At maturity, they enable novel vehicle designs, as there may be no further need for human drivers or driver-designated seating positions. This study investigated potential occupant behavior in rideshare ADS-DVs and developed a prototype human-machine interface (HMI) that considered relevant FMVSS requirements and the effective presentation of safety information to occupants. In this study, 42 participants were recruited under the guise of testing a rideshare application. Participants were accompanied by a confederate researcher who was there for safety purposes. These individuals rode in three study vehicles: a human-driven conventional vehicle, and two ADS-DV concept vehicles. The conventional vehicle and first ADS-DV were identical in layout, but the ADS-DV had no driving controls for a human driver. The second ADS-DV had an unconventional seating layout with one forward-facing and one rear-facing row of seats. In all vehicles, an HMI was developed that incorporated potential translations of relevant FMVSS from previous research. In 94 percent of the trips, participants were buckled in prior to requesting to start the ride. Those who received a seatbelt reminder (SBR) alert responded within approximately 1.5 seconds and were buckled in under 7 seconds. It was observed participants seemed to have preferred to sit in the front row of the conventional vehicle and the first ADS-DV concept. Sixty percent of participants rode facing forward while 40 percent faced rearward in the second ADS-DV concept that featured carriage-style seating. If they were to ride again, 79 percent indicated a preference for a conventional vehicle layout.

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# Executive Summary

Vehicles equipped with Automated Driving System (ADS) can enable novel vehicle designs that could influence occupant behavior. At maturity, ADS is expected to manage the entire dynamic driving task (DDT): lateral/longitudinal vehicle control and event/object detection and response. Vehicles equipped with an ADS may not feature manually operated driving controls and therefore have no driver-designated seating positions (DDSP). ADS-equipped vehicles without manually operated driving controls are defined by SAE International (2021) as ADS-dedicated vehicles (ADS-DVs). In the absence of these controls and the DDSP, vehicle designers can rethink the configuration of the cabin and their approaches to passenger comfort (Kim et al., 2016).

Tellis et al. (2016) suggested that the first deployments of ADS-DVs will likely take place in the rideshare or public transport context and assumed that all occupants who ride in ADS-DVs would be competent (responsible for their own safety in the rideshare context). Some tasks occupants in ADS-DVs may perform include:

- closing doors,
- positioning themselves in seats,
- using restraints,
- starting the ride, and
- requesting an early termination of the ride.

Occupants will likely perform these tasks via the vehicle's human-machine interface (HMI). Several Federal Motor Vehicle Safety Standards (FMVSS) currently require communicating certain information related to safety systems to the DDSP or other designated seating positions (DSPs). This study explored means to communicate safety information or signals in the ADS-DV context. The two main goals for this study were to:

1. Develop a prototype HMI that considers relevant FMVSS and the presentation of safety information in alternative ways in ADS-DVs, and
2. Observe occupant behavior in concept ADS-DVs presented to be used in rideshare operations.

This study evaluated various groups of two occupants for seat belt use, response to seat belt reminder (SBR) alerts, and seating preference while riding in a conventional vehicle and two ADS-DV concept vehicles, one of which featured conventional front-facing two-row seating and the other an unconventional carriage-style seating configuration (see Blanco et al., 2020, for a formal definition of each vehicle type). Study observations suggest occupants preferred traditional seating arrangements when riding in ADS-DVs while some did ride in the rear-facing row; and buckling rates were similar to those observed in manually driven personal vehicles.

## Concept HMI

The concept HMI was developed following the user-centered design approach as outlined in ISO 9241 (International Organization for Standardization, 2019). The user context was specified as occupants in a rideshare ADS-DV, with the occupant tasks outlined above. Design considerations were developed by reviewing related literature (Naujoks et al., 2019; Campbell et al., 2016; Chaka et al. 2021; Blanco et al., 2020; Automated Vehicle Safety Consortium, 2020). Campbell's group developed guidelines for NHTSA regarding driver-vehicle interfaces; however, this was not in the context of ADS-DVs. Naujoks outlined guidelines for HMI design in the context of ADS operation. Chaka and colleagues and Blanco's group provided translation considerations for FMVSS when applied to ADS-DVs, while AVSC's report, *Passenger-Initiated Emergency Trip Interruption* encourages best practices for passenger-initiated emergency stops. All resources were combined to provide general considerations for the concept HMI.

## Method

This study investigated occupant behavior in three rideshare vehicles.

- **Conventional Vehicle** – human-driven vehicle with manually operated driving controls and two forward-facing rows of seats.
- **First ADS-DV** – a vehicle equipped with automated features, no manually operated driving controls, and conventional seating consisting of two forward-racing rows of seats.
- **Second ADS-DV** – a vehicle equipped with automated features, no manually operated driving controls, and carriage seating with one forward- and one rear-facing row of seats, facing each other. This vehicle was not bi-directional.

Each vehicle traveled on a specific path ranging from 5 to 8 minutes long. Forty-two participants were recruited from the New River Valley[1] area of Virginia (20 female and 22 male; age $M$ = 43.98, $S.D.$ = 16.61; Min = 19, Max = 71). Two participants who were unfamiliar with each other were recruited for each trial and were told they were testing a rideshare application. A confederate researcher acted as a participant during each trial for safety. A post-ride survey was administered to participants asking them about their experience.

## Results

### *Occupant Seat Belt Behavior*

All participants were buckled before requesting to start the ride on 94 percent of trips. Fourteen percent of participants were not buckled before pressing the request-to-start-ride button in at least one of their trips. One participant was unbuckled for two of the trips prior to requesting to start, whereas five were unbuckled for one trip each. This behavior was used as a surrogate measure of willingness to ride without wearing a seat belt. Two participants did not buckle in the conventional vehicle and five did not in the first ADS-DV (non-significant difference). Of the six participants who were not buckled before requesting to start, three were in the process of buckling (e.g., were reaching for the belt) when they pressed the button. Therefore, the SBR alert was assumed not to have influenced their buckling behavior. The three participants who

[1] The dozen or so towns in the Blacksburg area, where the Virginia Tech Transportation Institute is located.

responded to the SBR began buckling within 1.29 seconds, on average, after the presentation of the SBR flashing visual telltale and auditory alert and were finished in 6.88 seconds.

### *Occupant Seating Preference*

In the conventional vehicle and the first ADS-DVs, those who entered first were more likely to sit in the front row than those who entered afterward. In the second ADS-DV, 60 percent of participants sat in the forward-facing row while 40 percent sat in the rear-facing row. Neither entry order, vehicle order, age, nor sex affected whether a participant sat in the rear-facing or forward-facing row. Sixty-two percent said the presence of other riders affected their seat choice, with most stating they would have preferred to sit in the front row of a conventional seating layout, but that choice was already taken. When asked which seating layout they would prefer to ride in again, 79 percent preferred the conventional seating layout over the unconventional layout.

## Conclusion

Results from the current study suggest occupants prefer a traditional seating arrangement when riding in ADS-DVs. Buckling rates were similar to those observed in manually driven personal vehicles; however, how riding context could affect this relationship is not fully understood. This includes taking trips with familiar riders (Han, 2017) as opposed to strangers and length of trip (Jorlöv et al., 2017; Kooti et al., 2017). The concept HMI was effective, in conjunction with a ride-interlock, at promoting seat belt use. However, the effectiveness of other SBR methods on buckling behavior should be investigated, as interlocks are not as well accepted as other modalities (e.g., persistent auditory reminders; Kidd, 2012; Kidd & Singer, 2019). Participants' willingness to ride in the rear-facing row of seats warrants further consideration in the translation of FMVSS in the context of ADS-equipped vehicles.

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# Chapter 1. Introduction

Vehicles equipped with ADS can enable novel vehicle designs that could influence occupant behavior. At maturity, ADS is expected to manage the entire DDT (i.e., lateral/longitudinal vehicle control and event/object detection and response). Vehicles equipped with ADS may not feature manually operated driving controls or a DDSP. ADS-equipped vehicles that do not have manually operated driving controls are defined by SAE International as ADS-DVs (SAE, 2021). In the absence of these controls and the DDSP, vehicle designers can rethink the configuration of the cabin and their approach to passenger comfort (Kim et al., 2016).

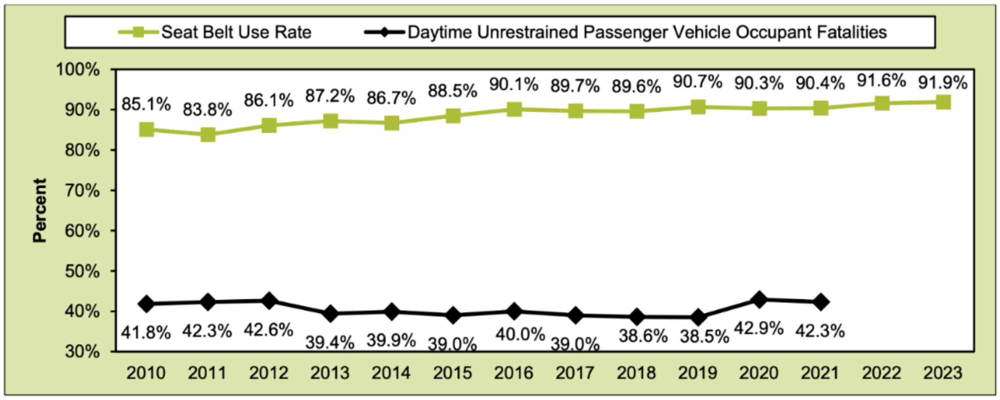
However, these novel designs could lead to challenges or barriers regarding current FMVSS that assume a DDSP and the presence of a human driver. Blanco et al.'s *FMVSS Considerations for Vehicles With Automated Driving Systems: Volume 1* (2020) defines unconventional features that create various classifications of ADS-DV designs as they transition further from conventional vehicle designs and considers what components of such designs are subject to current FMVSS. For example, some designs may feature unconventional seating configurations that reverse the forward row of seats in orientation to face the rear row (i.e., "campfire seating"). This can allow more conversation and personal connection among occupants but could present challenges in, or regulatory barriers to, meeting current FMVSS crashworthiness standards related to the front row of seats (Blanco et al., 2020). Further, without a DDSP, the communication of telltales, indicators, and alerts to vehicle occupants found in FMVSS No. 101 and related to FMVSS No. 208 will need to be considered, as they are conventionally presented to the driver in the DDSP.[2] It is important to understand occupant behavior in these novel vehicles to ensure the safe deployment of these designs.

## Occupant Behavior in Vehicles and ADS-DVs

### *Seat Belt Use*

As of 2023 the seat belt use rate in the United States was 92 percent, based on the annual National Occupant Protection Use Survey (NOPUS). Figure  provides the national seat belt use rate from NOPUS and the daytime percentage of unrestrained passenger vehicle occupant fatalities (National Center for Statistics and Analysis, 2024).

[2] This research was performed prior to the January 2025 final rule that extended some FMVSS No. 208 requirements to the front outboard passenger seats.



Source: NOPUS, FARS 2010-2020 Final File, FARS 2021 ARF

*Figure 1. National seat belt use rate and daytime percentage of unrestrained passenger vehicle occupant fatalities*

However, even with a 92 percent seat belt use rate, unrestrained occupants accounted for about 42 percent of crash-related fatalities in 2021. Evidence suggests that seat belt use rate can differ depending on context. For example, front seat occupants are more likely to report seat belt use than those in the rear seats (Li & Pickrell, 2018; Taylor & Daily, 2019). Group dynamics can also influence belt use rate, as front seat occupants are more likely to buckle if the driver buckles (Gkritza & Mannering, 2008; Han, 2017). Further, the homogeneity of occupant and driver age also influences seat belt use (Williams & Shabanova, 2002). In a 2017 Insurance Institute for Highway Safety (IIHS) survey, 74 percent of surveyed adults 18 and older said they always wear their seat belts as passengers in personal vehicles; however, only 57 percent of passengers reported that they buckled up in rideshare vehicles (IIHS, 2017). Other studies show seat belt use in ridesharing as low as 26 percent (Nemire, 2017; Miller et al., 2024).

This variation in seat belt use has been shown across vehicles with manually operated driving controls and human drivers. However, little is known about seat belt use in ADS-DVs. Rates of belt use in the rear row of a conventional vehicle are low for some occupants because they falsely assume they are safer in the rear row than the front (Jermakian & Weast, 2018), though occupant fatalities still occur in the rear row (Zhu et al., 2007; Durbin et al., 2015). In an ADS-DV with unconventional seating, unbuckled occupants in the forward-facing row could pose a significant safety risk to those in the rear-facing row in the event of a frontal crash. Driver fatality risk increases significantly with unbuckled rear occupants (Bose et al., 2013); however, this effect could be magnified to all occupants if the front row of seats were oriented to face the rear row. This orientation would provide no barrier between the front and rear row of occupants in the event of a collision where an unbelted occupant is ejected from their seat. Therefore, it is important to understand how occupants buckle in a vehicle with unconventional designs.

In addition to understanding occupant buckling behavior, the communication of safety information needs to be considered in ADS-DVs (Blanco et al., 2020; Chaka et al., 2021), as these vehicles lack a DDSP where all regulated telltales, indicators, and alerts would conventionally be presented. Blanco's group suggest this information could be communicated through mounted displays, and Chaka's group posit translations of current FMVSS language that could apply to ADS-DVs and buckling. It is important to understand the implementation of these changes and how occupants interact with them.

### *Seating Preference*

Tellis et al. (2016) suggested the first deployment of ADS-DVs will likely be in the rideshare or public transport context. And indeed, current deployments of ADS-DVs are in the rideshare space. Therefore, the assumption is that occupants will be riding with other occupants (familiar or unfamiliar) whose presence could influence seat preference. Previous research suggests riders do not like sitting between two strangers on a train (McGeeham, 2005; Fried & DeFazio, 1974) due to cultural norms surrounding personal space. This violation of personal space can be so significant that it has a physiological impact on riders (increased cortisol levels; Evans & Wener, 2007). Interactions with unfamiliar occupants in a rideshare space are therefore also likely undesirable to occupants (McGeeham, 2005; Fried & DeFazio, 1974; Evans & Wener, 2007). However, there could be instances where interactions are desirable. Riding with familiar or outgoing-unfamiliar occupants could encourage interaction. In a conventional two-row, forward-facing seating layout, occupants in either row are limited to verbal communication, making indirect eye-contact through mirrors, or shifting posture to face the other occupants. Unconventional seating configurations afford the opportunity for occupants to face each other and interact more naturally during a trip. But beyond affording more natural interactions, unconventional seating configurations could also be problematic for some occupants. In ADS-DVs with unconventional seating configurations (i.e., campfire seating) and several occupants, occupants may face the choice of violating the personal space of a stranger by sitting close to them or having to sit facing the opposite direction of travel. Facing the opposite direction of travel can present challenges, most notably motion sickness, to some occupants (Diels & Bos, 2016; Wada, 2016).

In addition to motion sickness, sitting in a seat that faces the opposite direction of travel can have other implications. As mentioned above, unbuckled occupants increase driver fatalities risk (Bose et al., 2013) and this could be compounded by rows of unbuckled occupants facing each other. If occupants prefer to sit in the forward-facing and rear-facing rows of seats for the same trip in an unconventional seating configuation, this fatality risk could be further increased as there are no barriers between the occupants. Therefore, it is important to know if occupants are willing to sit in the rear-facing row if other occupants are sitting in the forward-facing row, and to understand all occupant buckling behavior.

Previous research involving several hypothetical rideshare scenarios show occupants prefer a conventional seating arrangement over other options in ADS-DVs (Koppel et al., 2019). Of all available seating locations, participants favored the front left DDSP regardless of ride context and with whom they were riding (Koppel et al., 2019). Contrary to Koppel et al. (2019), previous research suggests that occupants may be open to unconventional seating in specific contexts (e.g., short trips in urban areas; Nie et al., 2020). Both studies were performed via online survey, however, so it remains important to understand occupant behavior when actively engaging with ADS-DVs in representative environments.

## Current Study

Current ADS-DV deployments are intended for rideshare services. In this context vehicle operation is split between the owner of the vehicle (fleet provider) and the occupant of the vehicle. A fleet provider is assumed to operate an ADS-DV and to provide the appropriate fleet maintenance including vehicle readiness (e.g., fuel, tire pressure) and regular service (e.g., oil changes). Tellis et al. (2016) assumed that all occupants who ride in ADS-DVs are competent (responsible for their own safety in the rideshare context). Occupants may perform some or all of these tasks: closing doors, positioning themselves in seats, using their restraints, starting the ride, and requesting early termination. The users will largely perform these tasks using vehicle HMI.

### *Study Goals*

Due to the nature of ADS-DVs (e.g., shared responsibility of operation; lack of driver) and the potential changes to seating configurations they afford, the two main goals for this study were:

1. Develop a prototype concept HMI that considers relevant FMVSS and the presentation of safety information in ADS-DVs, and
2. Understand occupant behavior in ADS-DVs operating as rideshare vehicles.

This study evaluated groups of occupant pairs who didn't know each other for seat belt use, seat preference, and response to an SBR alert while riding in a conventional vehicle, the first ADS-DV with forward-facing seating, and a second ADS-DV with an unconventional seating configuration (see Blanco et al., 2020 for a formal definition of each vehicle type).

# Chapter 2. Concept HMI

As a disclaimer, this concept HMI was developed in the current study for the sole purpose of testing the integration of potential translations to FMVSS in the context of ADS-DVs. This HMI and its contents were not designed or intended to be used in production vehicles of any scale at any level.

## Concept HMI

The concept HMI was developed following the user-centered design approach outlined in ISO 9241 (ISO, 2019). The design approach aimed to:

- Understand and specify the user context;
- Specify the user tasks;
- Produce design solutions to meet user tasks; and
- Evaluate against the tasks.

### *Understand and Specify the User Context*

This study context was to understand occupant behavior in ADS-DVs operating in a rideshare capacity. Therefore, the user context is that of an occupant interacting with a rideshare ADS-DV.

### *Specify User Tasks*

Given the study context of ridesharing, the user of the rideshare service is not the owner of the vehicle (Tellis et al., 2016). As mentioned, there is a division of vehicle operation between the fleet owner and the occupant of the rideshare service. Rideshare vehicles are assumed to be owned by third-party fleet operators (i.e., dispatchers[3]). The dispatcher sends the vehicles out into their operational design domains to pick-up and drop-off passengers. In addition, they verify the ADS-DVs' operational readiness before they are dispatched, monitor the vehicles during a trip, and provide assistance to occupants. For this study, the researchers managing the study served as the dispatcher.

In this context, users of a rideshare ADS-DV are considered passengers. Passengers are defined by SAE as users in the vehicle who have no role in the operation of an engaged ADS-DV.[4]

In addition to the actions described above, such as positioning themselves in a seat or using their restraints, passengers may request that the ADS disengage and achieve a minimal risk condition after it is disengaged. The AVSC report (2019) defines "a passenger-initiated emergency stop (PES) as a feature onboard a vehicle system that allows a passenger to send a command to bring the vehicle to a controlled stop as a result of a passenger perceived emergency". See Table 1 for a full summary of tasks pre- and post-ADS activation.

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[3] SAE J3016 (2021), 3.6: The term "*dispatch*" as used outside of the context of ADS-equipped vehicles, is generally understood to mean sending a particular *vehicle* to a particular pick-up or drop-off location for purposes of providing a transportation service. In the context of ADS-equipped vehicles, and as used in this report, this term includes software-enabled *dispatch* of two or more *ADS*-equipped *vehicles* in *driverless operation* that may complete two or more trips involving pick-up and drop-off of passengers.

[4] See section 5.5 of SAE J3016 for additional discussion.

*Table 1. Breakdown of tasks pre-/post-ADS activation*

| | Pre-ADS Activation | Post-ADS Activation |
|---|---|---|
| **Passenger** | - Request to start ride<br>- Seat belt use<br>- Seat selection<br>- Close doors | - Open doors to exit vehicle<br>- The ability to send a PES command to the ADS |
| **Dispatch** | - Verify the ADS-DVs' operational readiness before they are dispatched | - The ability to request ADS deactivation and a minimal risk condition stop<br>- May take over vehicle performance after a requested disengagement<br>- Monitor ADS-DV during a trip<br>- Provide assistance during the trip |

## *Produce Design Solutions to Meet User Tasks*

This section draws heavily from guidelines outlined in Naujoks et al. (2019), Campbell et al. (2016), Chaka et al. (2021), Blanco et al. (2020), and AVSC (2020). Campbell's team developed guidelines for NHTSA regarding driver-vehicle interfaces; however, this was not in the context of ADS-DVs. Naujoks and colleagues outlined guidelines for HMI design in the context of ADS operation. Chaka's group and Blanco's group provided translation considerations for FMVSS when applied to ADS-DVs, while AVSC encourages best practices for PESs. All resources were combined to provide general design considerations for the concept HMI development. The numbered items are from the Naujoks group and are supplemented with information from the other sources cited here.

### General Design Considerations

#### #1 Unintentional activation and deactivation should be prevented.

The ADS would not activate until all passengers were buckled, all doors were shut, and all passengers pressed "request to start ride." Inappropriate pressing of the "request to start ride" button before those conditions were met would present telltales and alerts outlined in Seat Belt Use.

#### #2 The system mode should be displayed continuously.

Each HMI displayed the following regarding system mode (From NHTSA AV 2.0 in NHTSA, 2017).

1. Functioning properly
2. Currently engaged in an automated driving mode
3. Currently unavailable for automated driving
4. Experiencing a malfunction
5. Requesting a control transition from the automated driving system to the operator

See Appendix A for a complete flow of HMI states.

**#3 System state changes should be effectively communicated.**

Again, see Appendix A for a complete flow of HMI states. Automation activation/deactivation, emergency stop, or requested stop were all displayed clearly during each state.

**#4 Visual interfaces communicating system states should be located at suitable positions and distances. High-priority information should be presented close to the expected line of sight.**

A 95th percentile male and 5th percentile female were used when designing the location of the HMI to ensure accessibility to most users. For the conventional vehicle and the first ADS-DV, the HMI screens were placed over the center stack and on the backs of the headrests. For the second ADS-DV, the HMI was placed overhead, similar to the HMI found on some passenger airplanes. Ingress and egress from each seating position was tested in the second ADS-DV using the 95th percentile male and 5th percentile female to ensure head clearance from the HMI, including when leaning forward with seat belt on.

**#5 HMI elements should be grouped by function to support the perception of mode indicators.**

High-priority messages showing automated system state changes were given priority as the only items showing on screen. Reminders of automation state were included during vehicle motion near the route map. Ingress safety criteria (i.e., door shut, belt buckled) were shown together on the home screen upon sitting in a seat.

**#6 Time-critical interactions with the system should not require continuous attention.**

Passengers of an ADS-DV did not monitor the system.

**#7 The visual interface should have sufficient contrast in luminance and color between foreground and background.**

A black background was used for all HMI screens. To apply sufficient contrast, white and yellow were used for text color. Screen brightness for each tablet was set to maximum, and the position of each tablet removed any concerns about glare.

**#8 Texts and symbols should be easily readable from the permitted seating positions.**

A 5th and a 95th percentile female and male were used to pilot the position of the HMIs. In piloting, users of various ages were shown the tablets to ensure the screens were easily readable from all seating positions.

**#9 Commonly accepted or standardized symbols should be used to communicate the automation mode. Use of non-standard symbols should be supplemented by additional text explanations or vocal phrases.**

Since there are no standardized symbols for ADS activation in an ADS-DV, text was used to communicate ADS states to users.

**#10 The message semantics should accord with its urgency.**

System alert wording matched the urgency of the situation. Color stereotypes were followed (red is urgent, etc.).

**#11 Messages should be conveyed using the language of the users.**

All users were English-speaking, and the HMI messages were conveyed in English.

**#12 Text messages should be as short as possible but as long as necessary.**

Text messages were short, no longer than seven words, and unambiguous in what was being communicated.

**#13 No more than five colors (excluding black and white) should be consistently used to code system states.**

Red, green, and yellow were the colors used to code system state changes.

**#14 The colors communicating system states should match common conventions and stereotypes.**

The colors used to code system state changes agreed with common conventions and stereotypes (green is good, yellow is cautionary, red is safety critical).

**#15 Design for color-blindness by redundant coding and avoidance of red/green and blue/yellow combinations.**

No screens displayed red/green or blue/yellow combinations simultaneously.

**#16 Auditory output should raise the attention of the driver without being startling or causing pain.**

Auditory alerts came from General Motors (GM). They were presented locally out of each tablet to correspond to each seating position. The volume on each tablet was set to maximum and was piloted with users prior to testing to ensure no discomfort.

**#17 Auditory or vibrotactile output should match the urgency of the message.**

The GM standard seat belt auditory alert was used to remind users to buckle up or shut the doors if they had not done so prior to requesting to start a ride. This alert was used as it gained the attention of the user but did not convey a sense of critical urgency. In such instances of critical urgency, GM’s forward collision warning was used.

**#18 High-priority messages should be multimodal.**

Each safety-critical message included a visual telltale and auditory alert. Each included reminding a user to buckle, shut a door, that a controlled stop was occurring, and that an emergency stop was occurring.

**#19 Warning messages should orient the user toward the source of danger.**

Warning messages were also accompanied by auditory alerts. As these were presented locally from each tablet, this alert directed the user’s attention to the tablet to see what directions were being sent.

**#20 In case of sensor failure the consequences and required operator steps should be displayed.**

In case of sensor failure the vehicle would initiate an emergency stop and display a message asking users to remain seated while informing them the study had paused.

### Design Solutions for User Tasks

Table 1, above, outlines user tasks, which include requesting to start the ride, as well as seat belt use, seat selection, closing/opening doors pre-ADS activation, and the ability to initiate a PES post-ADS activation. Design solutions for each task are discussed below.

### Ride Initiation

As Consideration #1 says, unintentional ride initiation was avoided, as each safety condition had to be met before the user could request a ride. That is, users had to be in seats, have their seat belts latched, and all doors closed before they could request to start a ride. The ADS did not activate until all passengers met all conditions.

### Seat Belt Use

FMVSS No. 208 S7.3 outlines the telltale and auditory alert that are presented as SBRs when seat belts are not fastened at vehicle ignition. Currently, this telltale only applies to seat belt assemblies provided at the DDSP.[5] Chaka et al. (2021) posit a translation for S7.3 that each DSP (i.e., any place a passenger can sit) should have telltales and alerts if a DDSP is not present in the vehicle. In an ADS-DV, and in the context of the current study, a DDSP was not present, meaning this translation option applied. A tablet assigned to each seating position presented auditory alerts provided by GM and the seat belt telltales outlined in FMVSS No. 101 (see Figure 2).

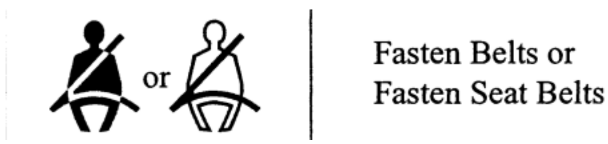


*Figure 2. Seat belt visual telltale as outlined in FMVSS No. 101*

### Seat Selection

There were no HMI elements related to seat selection.

### Close/Open Doors

FMVSS No. 206 S4.1.2.3 requires a door closure warning system that can be clearly seen by the driver when a door is unlatched. Blanco et al. (2020) suggested a potential translation of S4.1.2.3s regulatory text as having the warning system:

> be clearly seen from the driver's DSP or any passenger designated seating position, if no driver's seating position is occupied or present. For an ADS-equipped vehicle, the door closure warning system shall be communicated to the ADS.

As with the seat belt telltale, the door closure warning system was designed to be clearly seen from each seating position via the HMI available at each position. FMVSS Nos. 101 and 206 do not provide a telltale icon for door closure, and therefore, ISO 7000–2239 was used (see Figure 3). As this icon may not be familiar to users, and per Consideration #9, this icon was

[5] This research was performed prior to the January 2025 final rule that extended some FMVSS No. 208 requirements to the front outboard passenger seats.

supplemented with redundant "Close Door" text beneath it (see Figure 4 for actual implementation with redundant text).

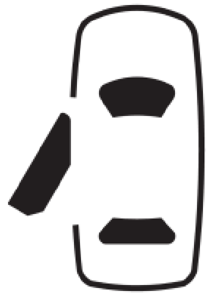

*Figure 3. ISO 7000–2239 close door telltale*

Door closure was communicated to the ADS by not allowing activation until all doors were closed (and other subsequent safety criteria were met).

### PES Command

AVSC Best Practice 3202006 (2020) suggests a PES and a passenger-initiated emergency call (PEC) be implemented in the vehicle. The PES is defined in that report as described in the section Specify User Requirements, above. A physical "Request Stop" button served as the PES function and was included with each HMI tablet (see Figure 4).


*Figure 4. Request Stop button (at left of tablet)*

When the PES button was pressed, the vehicle would come to a controlled stop. The PEC is defined as "a feature allowing passengers to contact fleet operations for support when needed during an emergency." This feature was excluded, as a confederate researcher (who was acting as another passenger through each trial) would provide this function if an emergency presented itself.

See Table 2 for a summary of each design guideline and how it mapped to each user requirement.

*Table 2. Mapping of each design guideline to user tasks*

| | | User Tasks | | | | |
|---|---|---|---|---|---|---|
| General Guidelines | | **Ride Initiation** | **Seat Belt Use** | **Seat Selection** | **Close/Open Doors** | **PES Command** |
| | #1 Activation | X | | | | |
| | #2 System Mode | X | | | | |
| | #3 State Changes | X | | | | X |
| | #4 Visual Display Position | X | X | | X | X |
| | #5 Grouping Like Elements | X | X | | X | X |
| | #6 Avoid Continuous Attention | | | | | |
| | #7 Visual Contrast/ Luminance | X | X | | X | X |
| | #8 Texts/Symbols | X | X | | X | X |
| | #9 Supplement Nonstandard Symbols | X | | | X | X |
| | #10 Message Urgency | X | X | | X | X |
| | #11 Language | X | X | | X | X |
| | #12 Succinct Text Message | X | X | | X | X |
| | #13 Color Limit | X | X | | X | X |
| | #14 Color Stereotype | X | X | | X | X |
| | #15 Color-Blindness | X | X | | X | X |
| | #16 Auditory Alert | X | X | | X | X |
| | #17 Auditory Alert Urgency | X | X | | X | X |
| | #18 Multimodal | | X | | X | X |
| | #19 Alert Orientation | | X | | X | X |
| | #20 Sensor Failure | | | | | X |

### *Evaluate Against the Tasks*

Pilot testing was used to test the design solutions for each user task. The HMI design also was reviewed by industry stakeholders who gave feedback where appropriate and was incorporated into the final HMI design.

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# Chapter 3. Method

## Participants

Forty-two participants from Virginia's New River Valley region were recruited for the current study. There were 20 females and 22 males with an overall mean age of 43.98 (S.D. = 16.61; Min = 19, Max = 71). Two participants who didn't know each other were recruited for each trial and told they were testing a rideshare application. They were recruited through the Virginia Tech Transportation Institute (VTTI) recruitment group. VTTI has a database of previous and potential participants who were leveraged, in addition to social media advertisements and flyers. Participants who self-reported susceptibility to motion sickness in vehicles were excluded. Each signed an informed consent that was approved by the Virginia Tech Institutional Review Board (IRB# 20-641) that oversees research involving human subjects. Each participant was paid $60 at the end of each session.

## Vehicles

Three study vehicles were used in the study: a conventional vehicle, one ADS-DV with forward-facing seating, and a second ADS-DV with carriage seating. Each represented an incremental increase in unconventional features in vehicle design for ADS-DVs. See Blanco et al. (2020) for a full description of each ADS-DV classification.

### *Conventional Vehicle*

This vehicle was a Cadillac SRX (Figure 5) that served as the baseline condition, as it was driven by a human driver. Cameras were installed in the vehicle cabin, HMIs were installed over the center stack and back of the headrests, and a VTTI data acquisition system (DAS) was installed for data collection.

*Figure 5. Conventional vehicle exterior/interior*

### *First ADS-DV*

This vehicle was identical in layout to the conventional vehicle except that the manually operated driving controls were removed. Retrofitted instrumentation included a differential GPS, a VTTI DAS for data collection, and HMI tablets over the center stack and back of headrests. Participants were restricted from sitting in the driver's seat due to the lack of an air bag, as the steering wheel had been removed. See Figure 6 for interior/exterior layout.

*Figure 6. First ADS-DV exterior/interior*

### *Second ADS-DV*

This vehicle was a 2019 Chevrolet Express van modified to simulate an ADS-DV. Interior modifications included removing the middle row of seats and reversing the orientation of the front row (see Figure 7). Operating modifications included removing the manually operated driving controls. Retrofitted instrumentation included a differential GPS and a mobileEYE sensor on the front windshield. For data collection purposes, a VTTI DAS was installed.

*Figure 7. Second ADS-DV exterior/interior*

From the participants' perspective, the first and second ADS-DVs operated as if they were equipped with automated features that could perform object/event detection and response (i.e., by avoiding staged objects in roadway) and the remainder of the DDT. However, they did not actually have that level of capability. They were capable of controlling lateral and longitudinal vehicle movement but were programmed to move around staged objects in the forward roadway rather than to detect and respond appropriately to unplanned objects. To mitigate this, a VTTI researcher acting as a participant (confederate) was included as a safety precaution due to the vehicles' limitations. The confederate researcher had access to inconspicuous emergency stop buttons to make the vehicle stop in safety critical scenarios (e.g., a deer in roadway ahead).

## Procedure

Participants were told the purpose of the study was to test a rideshare application that had recently been developed by VTTI (see Appendix B). On arrival, the two participants for a given trial, who didn't know each other, were consented, given a smartphone that had this application loaded on it, and given a tutorial on how to use the app.

Once on the test track, participants used the rideshare app to call each study vehicle one at a time. The conventional vehicle was always first, with the automated vehicle order counterbalanced. This decision was made so that participants could ask the human driver questions about the HMI before going into the driverless ADS-DVs. However, no formal training or tutorial on the HMI was given. Each study vehicle followed a specific route on VTTI's Virginia Smart Roads test tracks to provide variation in roadway type, length (5 to 8 minutes), and environment (Figure 8, Figure 9, and Figure 10). Each route began and ended at the Automation Hub (shown in the noted figures).

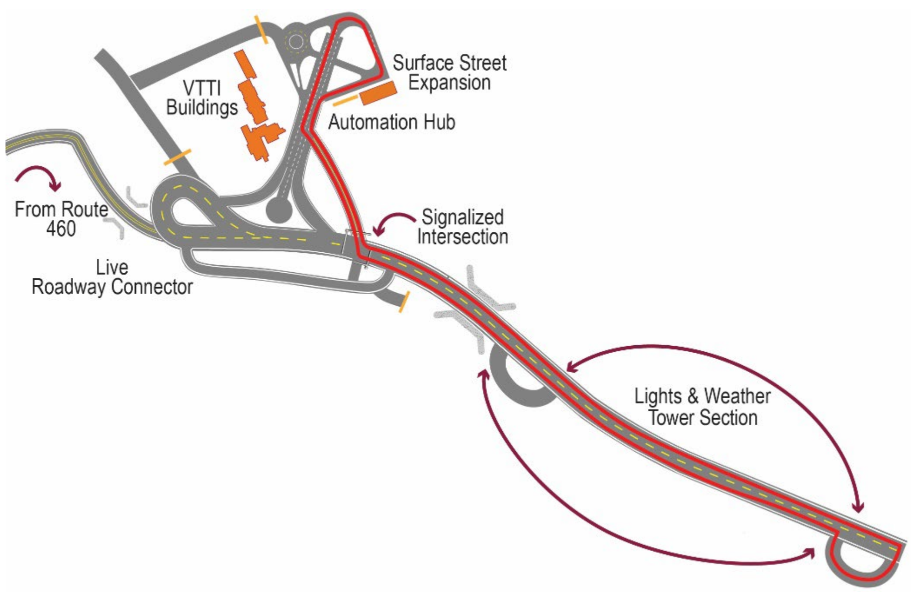


*Figure 8. Conventional vehicle path*

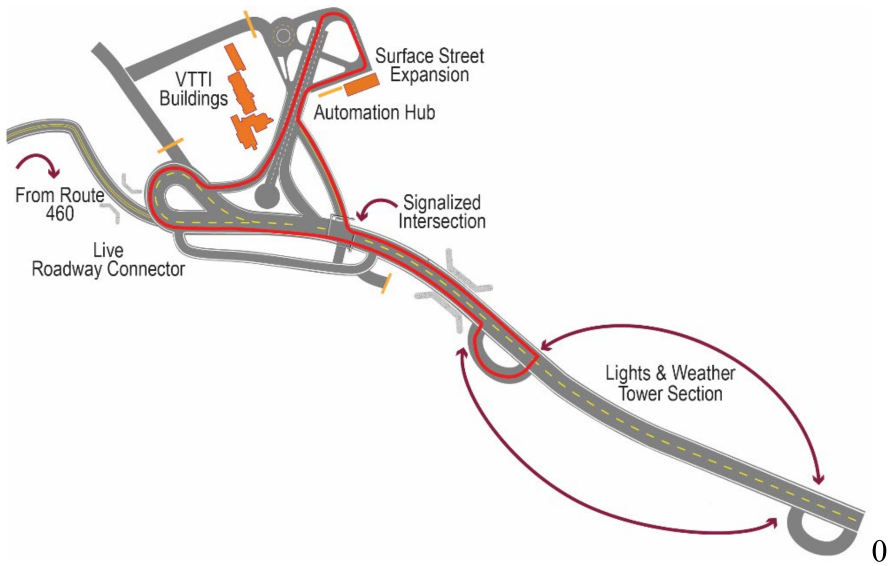


*Figure 9. First ADS-DV path*

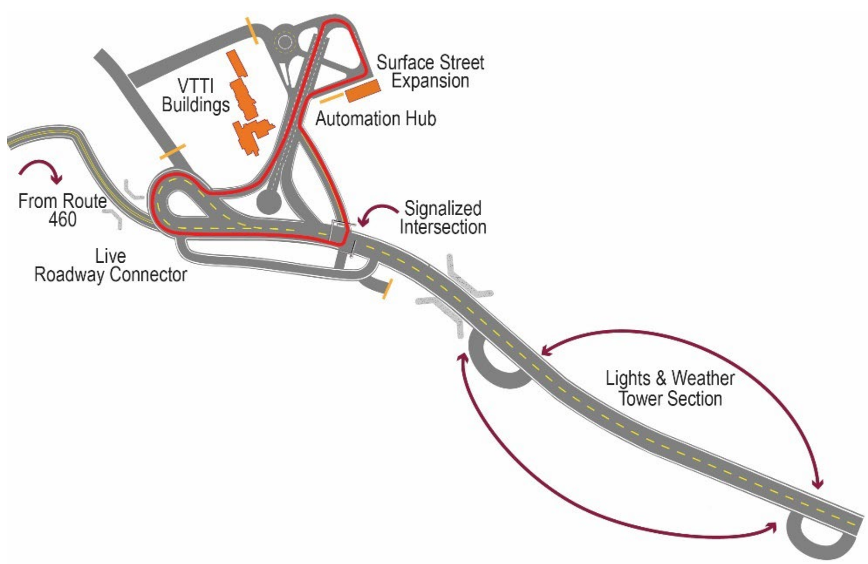


*Figure 10. Second ADS-DV path*

Using the smartphones, each participant called vehicles with the rideshare app. Once the vehicle arrived and all participants were in the vehicle, each had to meet the safety criteria outlined in Table 1. An HMI positioned in front of each seating position communicated these criteria to the participant (Figure 11). If a passenger pressed the “request to start ride” button prior to the safety criteria being met, the corresponding telltale (e.g., “Close Doors” if the door was still open) would flash and an auditory alert would chime for 8 seconds. If pressed again, the telltale chime would cycle again; in addition, “fasten seat belt” would be added underneath the seat belt telltale to provide redundancy for the required behavior (see Appendix A for an HMI flow overview).

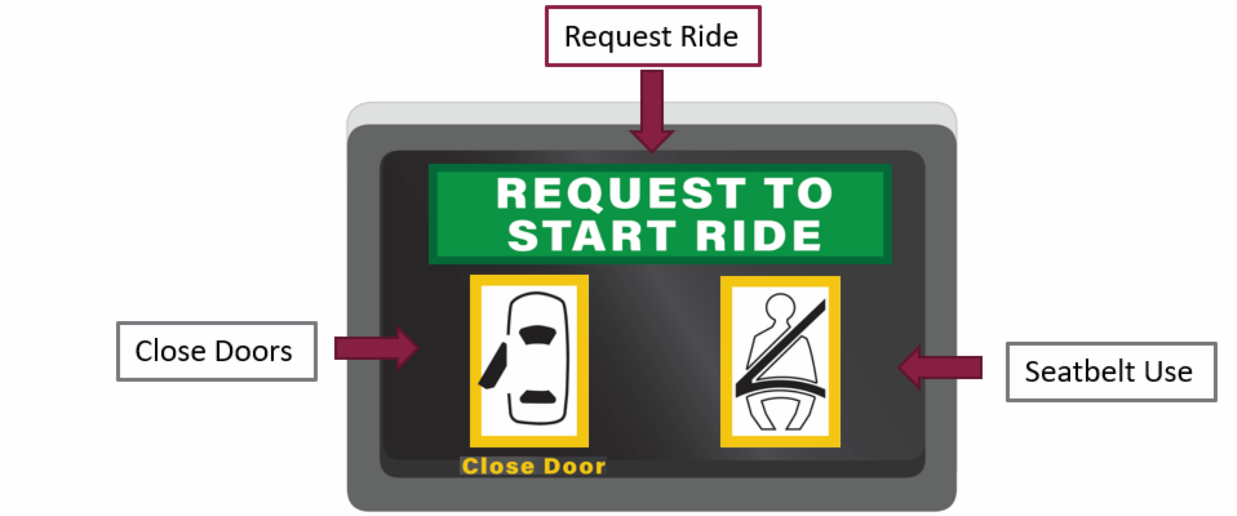


*Figure 11. HMI screen upon entry*

Once all safety criteria had been met and all participants requested to start a ride, the ride initiated and followed the specific route for that vehicle. The max speed of any vehicle (manual or automated) was 20 mph. After all rides were completed, participants completed a survey about their experience, which also included demographic information (see Appendix C).

### Variables of Interest

See Table 3 for an overview of collected independent and dependent variables for this study.

*Table 3. Independent and dependent variables of interest*

| Variable | Definition | Levels |
|---|---|---|
| **Independent Variables** | | |
| **Vehicle** | Study vehicle used for a given ride | • Conventional vehicle<br>• First ADS-DV<br>• Second ADS-DV |
| **Age Group** | Age of participant split at the sample median | • Young (< 45 years of age)<br>• Old (> 45 years of age) |
| **Sex** | Self-reported sex of participant | • Male<br>• Female |
| **Vehicle Order** | Study vehicle order of presentation | • Order 1: First ADS-DV, Second ADS-DV<br>• Order 2: Second ADS-DV, First ADS-DV |

| Variable | Definition | Levels |
|---|---|---|
| **Dependent Variables** | | |
| **Buckled before Request Ride** | Participant buckled before requesting to ride | • Yes<br>• No |
| **Seat Location** | Where a participant sat in a study vehicle | • Seat letter |
| **Alert Start to Buckle Movement** | Time from SBR start to participant beginning the buckling process | • Time in seconds |
| **Alert Start to Buckle Completion** | Time from SBR start to participant finishing the buckling sequence | • Time in seconds |
| **Row** | Vehicle row selected upon entry | • Front row<br>• Rear row |
| **Sat Backwards** | Participant sat in the rear-facing row in the second ADS-DV | • Yes<br>• No |
| **Entry Order** | Order of vehicle entry | • 1<br>• 2 |
| **Buckle Order** | Order of buckle completion | • 1<br>• 2 |

## Analytic Approach

All results report only the behavior of participants and exclude confederate researcher actions. The confederate researcher only performed study actions (i.e., entry, buckle, request ride) after each participant performed them so as not to influence participant behavior.

McNemar's test was used to compare differences for within-subjects variables and categorical dependent variables. The chi-squared test of independence was used to compare differences for between-subject variables on categorical variables. An independent samples t-test was used to compare differences across survey responses for continuous variables.

# Chapter 4. Results

Participants generally felt safe while riding in the automated vehicles (*M* = 5.57; *SD* = 1.84; max score of 7) and this did not differ by age ($t(40) = -0.26$; $p = .80$) or sex ($t(40) = -0.95$; $p = .35$). When asked, 24 percent of participants reported they were unsure they would feel safe if the vehicle were to operate at higher speeds or with ambient traffic around the vehicle.

## *Occupant Seat Belt Behavior*

Eighty-three percent of participants disagreed that they would be less likely to wear their seat belt in an automated vehicle compared to a vehicle with a human driver. All participants were buckled before requesting to start the ride on 94 percent of trips. Fourteen percent of participants were not buckled before pressing the request to start ride button in at least one of their trips. Of those participants, one was unbuckled for two of the trips prior to the start ride request, whereas five were unbuckled prior to requesting for one trip each. This behavior was used as a surrogate measure of willingness to ride without wearing a seat belt. Two participants did not buckle in the conventional vehicle and five did not in the first ADS-DV. This difference was not significant ($\chi^2(1, 84) = 0.56$, $p = .46$). Age and sex could not be tested for differences due to low cell counts (i.e., < 5). Of the six participants who were not buckled before requesting to start the ride, three were in the process of buckling (e.g., reaching for the belt) when they pressed the button. Therefore, the SBR alert was assumed not to have influenced their buckling behavior. The three participants who responded to the SBR began buckling within 1.29 seconds, on average, after the presentation of the SBR flashing visual and auditory alert and were finished buckling in 6.88 seconds.

While 60 percent of all participants felt the HMI did not prompt them to wear their seat belts, 84 percent of those said they always put their seat belts on upon entry, implying they never saw the prompt. Most participants (88%) felt the notifications presented through the HMI were helpful and 91 percent felt they were easy to understand. One participant commented that the HMI made that person wear their seat belt in a situation where that person normally wouldn't wear one.

## *Occupant Seating Preference*

The seating distribution for each study vehicle is shown in Figure 12. For each study vehicle the out-board seats were most frequently selected. In the conventional and first ADS-DV, the front row corresponds to seat location A and the rear row to seats B, C, or D. In the second ADS-DV, the forward-facing row corresponds to seat location D, E, or F while the rear-facing row corresponds to seats A, B, or C.

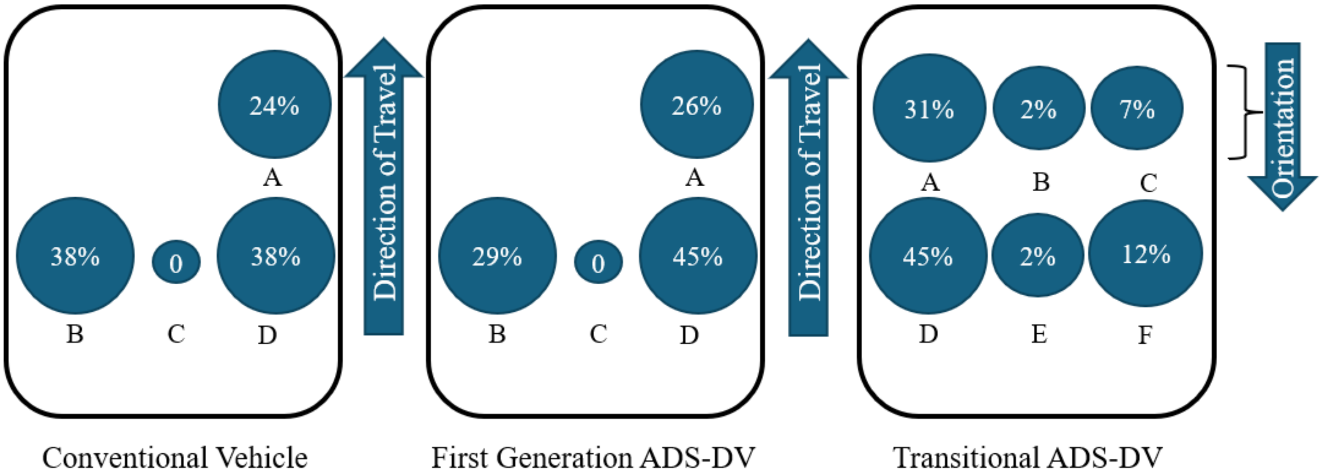


*Figure 12. Seating preference for all study vehicles*

In the conventional vehicle, those who entered the vehicle first were more likely to sit in the front row than those who entered afterward ($\chi^2(1,\ 42) = 9.03$, $p$ <.01). Sex ($\chi^2(1,\ 42) = 0.31$, $p$ = .58) and age ($\chi^2(1,\ 42) = 0.81$ $p$ = .37) did not affect row selection (see Figure 13).

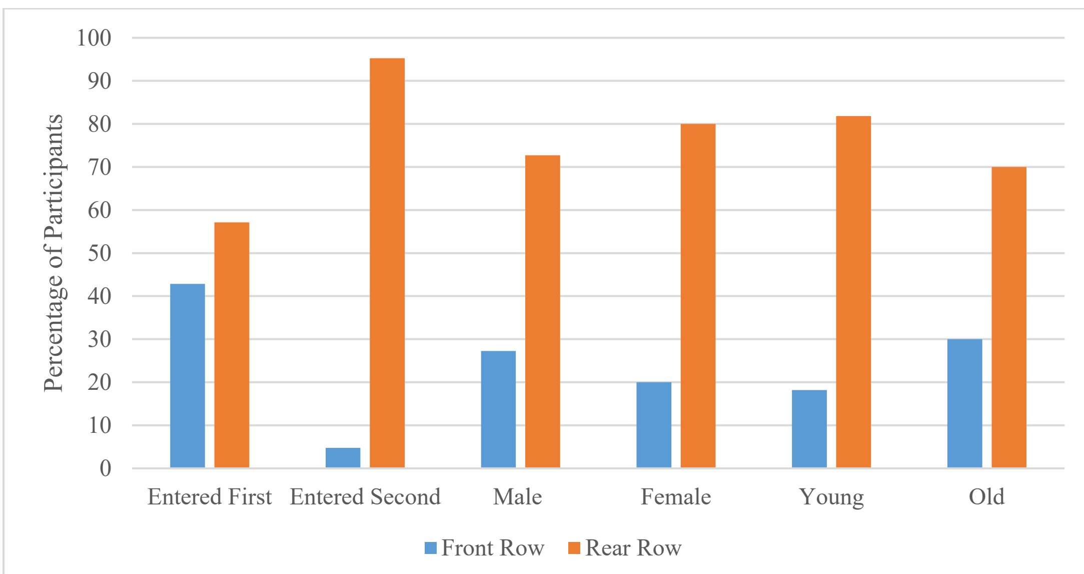


*Figure 13. Conventional vehicle row selection*

In the first ADS-DV, those who entered the vehicle first were more likely to sit in the front row than those who entered second ($\chi^2(1,\ 42) = 8.33$, $p$ <.01). Sex ($\chi^2(1,\ 42) = 0.03$, $p$ = .87), age ($\chi^2(1,\ 42) = 0.29$ $p$ = .59), and vehicle order ($\chi^2(1,\ 42) = 0.03$, $p$ = .87) did not affect row selection (see Figure 14).

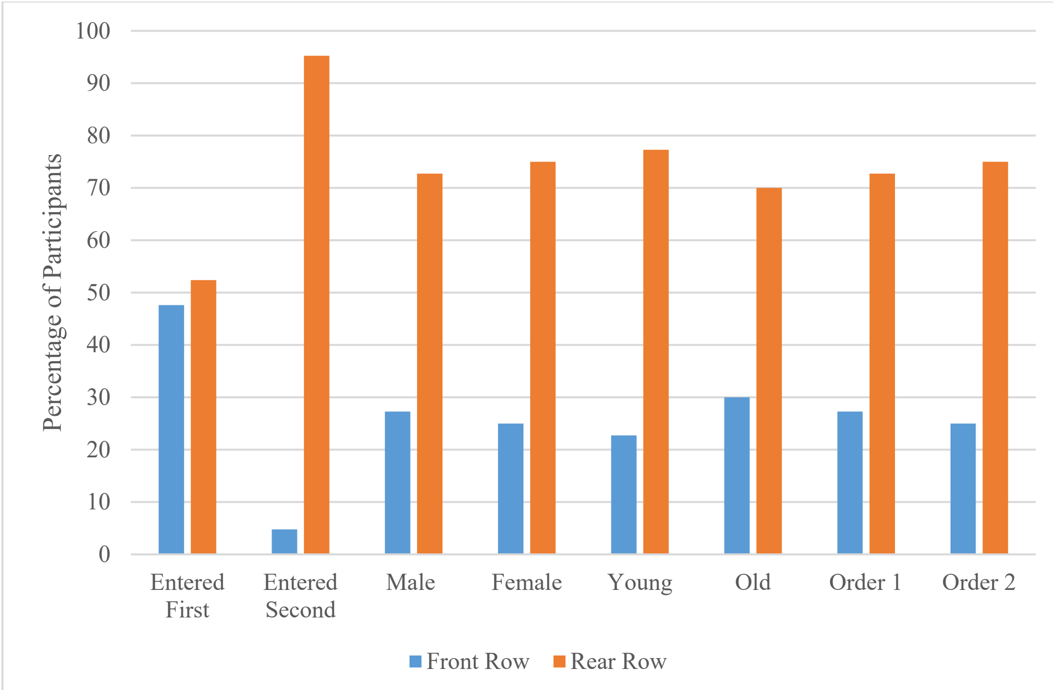


*Figure 14. First ADS-DV row selection*

Preference for the front row was supported by the post-ride survey, with 71 percent of participants reporting they would select the driver or front passenger seat if they were to ride in a first ADS-DV again. No participants attempted to sit in the driver's seat of the first ADS-DV or seat location C in either the conventional or first ADS-DV. It's important to note that these vehicles only had one front row seat available, and this caused a higher percentage of participants to sit in the rear row out of necessity. Seat preference from the conventional vehicle to the first ADS-DV did not change ($\chi^2(2, 84) = 0.88$, $p$ = .87; see Figure 15).

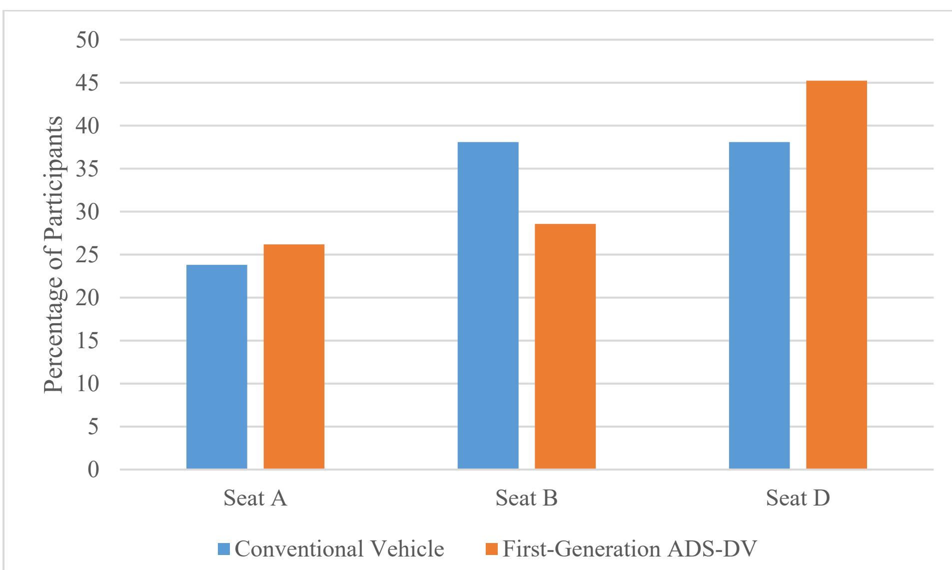


*Figure 15. Seat location across the conventional vehicle and first ADS-DV*

In the second ADS-DV, 60 percent of participants sat in the forward-facing row and 40 percent sat in the rear-facing row oriented opposite the direction of travel. Entry order ($\chi^2(1,\ 42) = 0.10$, $p = .75$), sex ($\chi^2(1,\ 42) = 0.48$, $p = .49$), age ($\chi^2(1,\ 42) = 0.48$ $p = .49$), and vehicle order ($\chi^2(1,\ 42) = 0.05$, $p = .95$) did not affect whether a participant sat in the rear-facing row (see Figure 16).

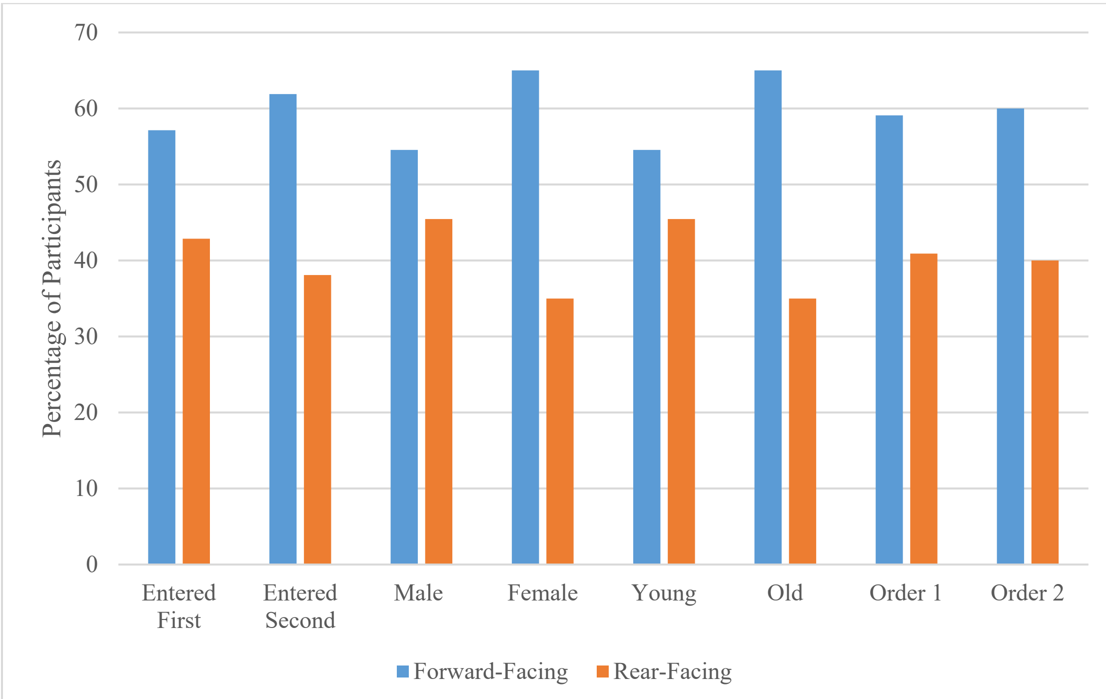


*Figure 16. Second ADS-DV row selection*

In 24 percent of rides no participant chose to sit in the rear-facing row and for one ride, both participants chose to sit rear-facing. In the post-ride survey 67 percent of participants indicated they would ride in the forward-facing row of the second ADS-DV again, whereas 33 percent would choose to ride facing backwards. Sixty-two percent of participants said seat orientation did not influence their seat choice. For the 38 percent who were influenced, they frequently cited wanting to see the forward roadway as a factor.

Thirty-eight percent of participants said the presence of other passengers did not affect where they sat, whereas 62 percent said other passengers' presence did affect their seating choice. For those who were affected, most said they would have chosen the front seat (implied as the front row in a conventional vehicle) instead of where they ended up sitting but could not because that seat was already occupied. Fifty-five percent said that they did not change their seating preference due to riding in an automated vehicle. For those who did (N = 19), 16 percent said they felt safer sitting in the front row while 21 percent said they felt safer in the back row. Other responses were related to general seat preference ("I prefer the front") as opposed to responding specifically about changes when riding in an ADS-DV.

When asked which vehicle layout they would prefer to ride in again, 79 percent of participants preferred a traditional seating layout (i.e., two forward-facing rows) as opposed to the unconventional seating arrangement (neither age nor sex affected layout preference ([$\chi^2(1,\ 42) = 0.05$ $p = .83$]; see Figure 17).

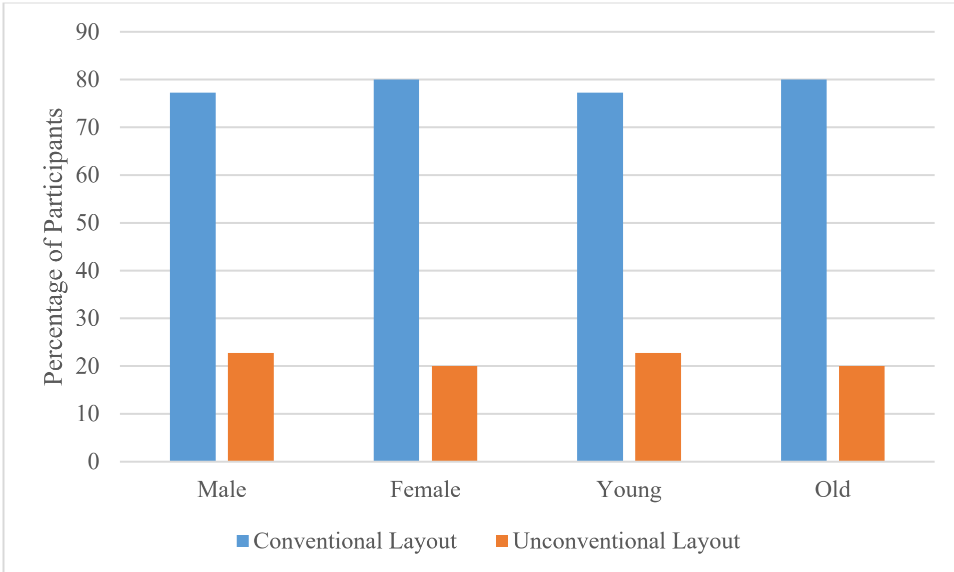


*Figure 17. Seating configuration preference*

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# Chapter 5. Discussion

This study tested occupant behavior in a rideshare scenario across three study vehicles: a conventional vehicle, the first ADS-DV with conventional seating, and a second ADS-DV with carriage seating. Seat belt behavior was captured, as was seating preference. A post-ride survey provided context to some of the occupant behavior seen in the vehicles.

## Occupant Seat Belt Behavior

Across all vehicles, 100 percent of participants were buckled before a vehicle started to move. This was by design, as the HMI prevented the automated features from initializing in the ADS-DVs and the conventional vehicle driver was instructed to not start driving until all safety conditions were met (i.e., seat belt latched, and all doors closed) and all request to start ride buttons were pressed. All participants were buckled before requesting to start the ride on 94 percent of trips. This is similar to the 92 percent buckling rate found in personal vehicles (National Center for Statistics and Analysis, 2024). Some participants suggested they do not typically wear their seat belt in the rear of a vehicle but felt compelled to in this study so that the trips would begin. Requesting to start the ride was used as a surrogate for willingness to allow the vehicle to move without having a seat belt buckled. For participant safety, the test vehicles were restricted from moving until all participants were buckled. Riding in the rear row of seats is a common reason for not wearing a seat belt (Jermakian & Weast, 2018), especially in rideshare scenarios (Nemire, 2017; Miller et al., 2024).

Although effective in promoting belt-compliance in the current study, interlocks may not be the most optimal design decision to encourage seat belt use. Seat belt interlocks requiring all front seat occupants in personal vehicles to be buckled before engine ignition were mandated in 1973; however, consumers rejected the feature en masse and it was repealed by Congress in 1974. Differences in SBR design can lead to varying effectiveness in buckling behavior. For example, Kidd and Singer (2019) compared belt rates when occupants received an indefinite reminder and a 90-second audible reminder, finding that these strategies increased belt use by 34 percent and 30 percent compared to an intermittent reminder (i.e., three 7-second periods of chiming with a minute or more between periods of chiming) and was more effective than a gearshift interlock (16%). Further investigation would be useful to understand the effectiveness of various SBR designs in promoting seat belt use in ADS-DVs while achieving user acceptance.

The concept HMI used in the current study followed translation options for the presentation of safety information proposed in Chaka et al. (2021) by providing all seating positions with the information that would conventionally be presented to the DDSP only. Most participants felt the information presented on the HMI was easy to understand and helpful. Although 60 percent of participants said they did not think the HMI prompted them to wear their seat belt, the majority of those said they habitually buckle as soon as they get in a vehicle. This implies they did not look at the HMI until after they were buckled, and thus did not see the seat belt telltale.

Seat belt use in ADS-DVs in occupants who are considered part-time users is not fully understood. That is, occupants who only wear their seat belt in certain scenarios and not at all times in a vehicle (Jermakian & Weast, 2018; Yates et al., 2011). Previous research shows various design considerations that need to be made to address this population (Kidd, 2012) and these should be investigated in ADS-DVs.

## Occupant Seating Preference

Most participants preferred the conventional, two-row seating configuration over the unconventional seating arrangement. This is supported by previous research showing favoritism towards this configuration when imagining riding in hypothetical automated vehicles (Lopez-Valdez et al., 2020). No participant sat in any of the middle seats of any vehicle if one of the outboard seats was occupied by another participant. This assumes an intention to give that outboard seated participant the acceptable personal space typical on public transport (McGeeham 2005; Evans, & Wener, 2007; Fried & DeFazio, 1974). Indeed, previous research shows use of most seats in a subway car only happened with a load factor of 120 percent (i.e., more occupants onboard than seats), suggesting occupants sit in unfavorable locations out of necessity rather than preference (Berkovichv et al., 2013).

For participant safety reasons, those who self-reported motion sickness in vehicles were excluded from this study. However, this propensity could influence seat preference, especially in vehicles with unconventional seating that afford the option to sit in a rear-facing seat (Dam & Jeon, 2021). Not paying attention to the forward direction of travel in vehicles equipped with automated features, whether activity based (Le et al., 2020) or design based (Salter et al., 2019), can trigger feelings of motion sickness. The acceptance of unconventional seating arrangements might be low for this population and could affect broad appeal of this design, as motion sickness is estimated to impact nearly half of the population (Reason & Brand, 1975; Schmidt et al., 2020).

Participants were willing to ride in the rear-facing row of the second ADS-DV. Blanco et al. (2020) and Chaka et al. (2021) did not consider unconventional seating configurations in their translation options of various FMVSS. Willingness to ride in such configurations supports the further examination into how this design change can impact various FMVSS (e.g., airbag and seat belt configurations). Previous research also shows that occupants are willing to wear novel seat restraints when sitting in unconventional seating configurations (Koppel et al., 2019).

## Limitations

This study was conducted on a closed-course track in a trio of test vehicles. This controlled environment could have influenced participant behavior (e.g., Hawthorne Effect). Rideshare passenger behavior could change in a naturalistic setting (e.g., instrumented ADS-DVs on public roads.

Most rideshare/public transit experiences occur with other occupants present (Rayle et al., 2016). Although the current study had groups of occupants, these occupants were not familiar with each other. Previous research shows the presence of familiar riders could change occupant behavior (Han, 2017). Other research shows that occupants are more amenable to unconventional seating configurations depending on riding context (e.g., familiar with other occupants; Lopez-Valdez et al., 2020; Nie et al., 2020).

The routes that were traveled were good representations of a brief shuttle ride (~ 8 minutes); however, they did not represent other rideshare use-case scenarios. Other research suggests the median ride time for an Uber passenger is 14-minutes (Kooti et al., 2017) and that length of the ride can influence seat preference (Jorlöv et al., 2017). Research shows that access to ridesharing services decreases the amount of drunk driving in an area (Young & Farber, 2019), implying that users under the influence of alcohol hail a rideshare service rather than risk driving. The influence of alcohol on seating position and seat belt use in this rideshare scenario is not well understood.

## Conclusions

Results from the current study suggest occupants prefer a traditional seating arrangement when riding in ADS-DVs. Buckling rates were similar to those observed in manually driven personal vehicles; however, track testing used in this study limits understanding how riding context could affect this relationship. The concept HMI was effective, in conjunction with a ride-interlock, at preventing rides if any occupant was not wearing a seat belt, but the effectiveness of other SBR methods on buckling behavior should be investigated while considering their user acceptance.

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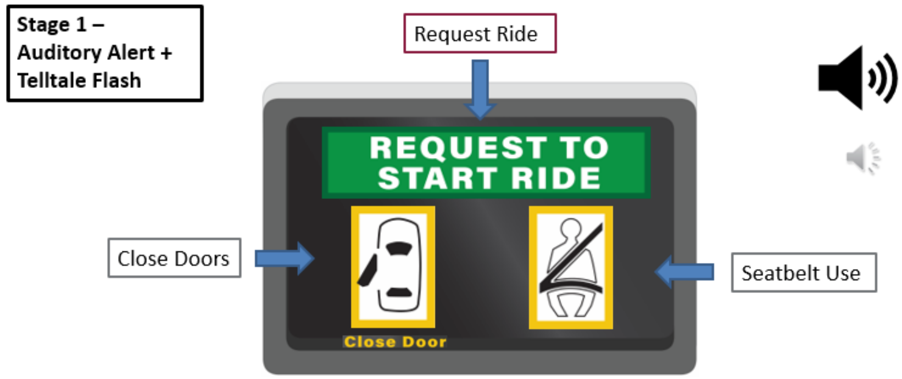
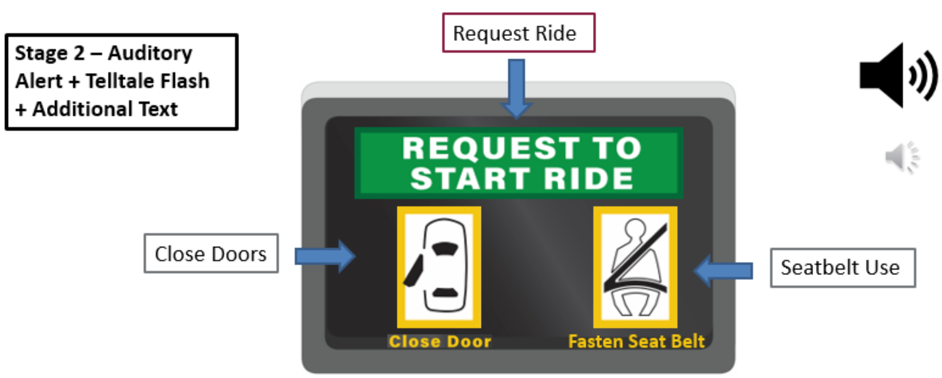
# Appendix A: HMI Flow

# Reference HMI – Boarding




# Reference HMI – Boarding



## Reference HMI – Boarding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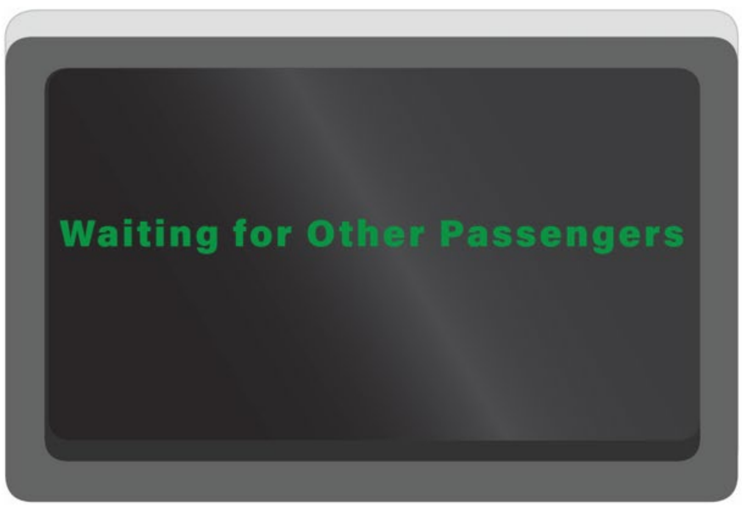
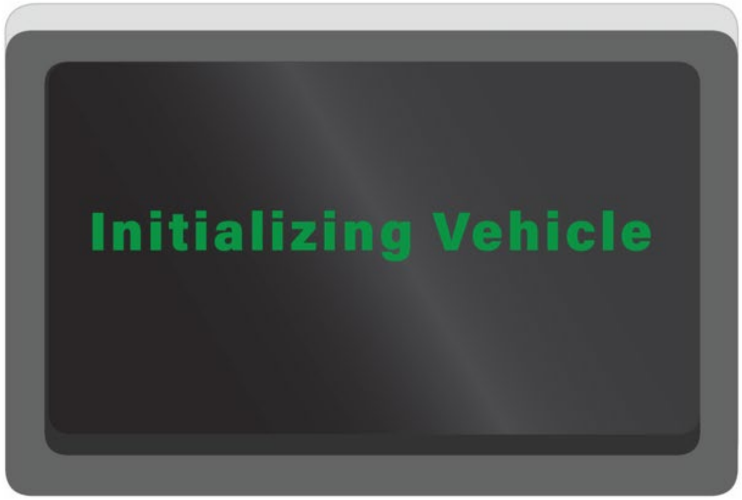
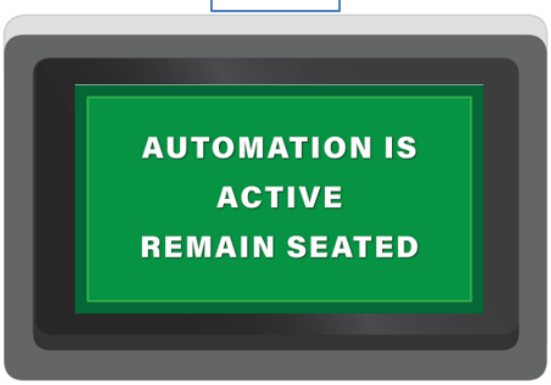


## Reference HMI - Boarding

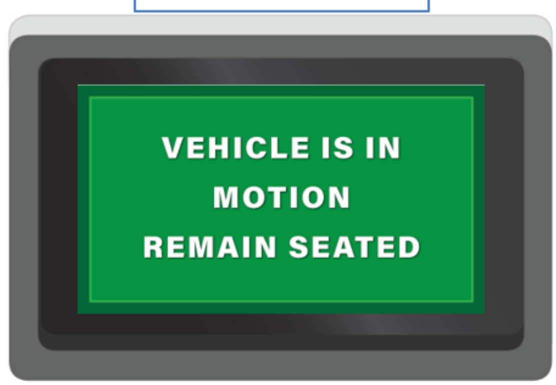



## Reference HMI – Riding

ADS-DVs

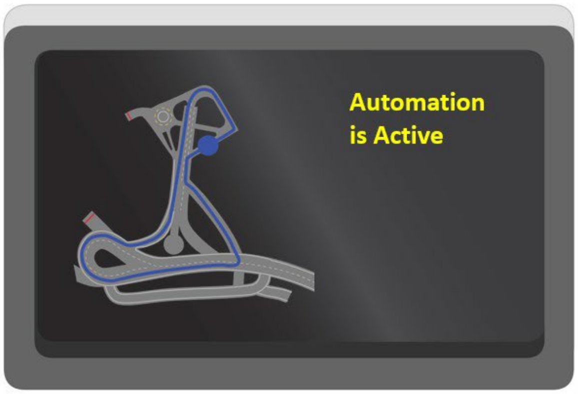



Conventional Vehicle



# Reference HMI – Riding

ADS-DVs

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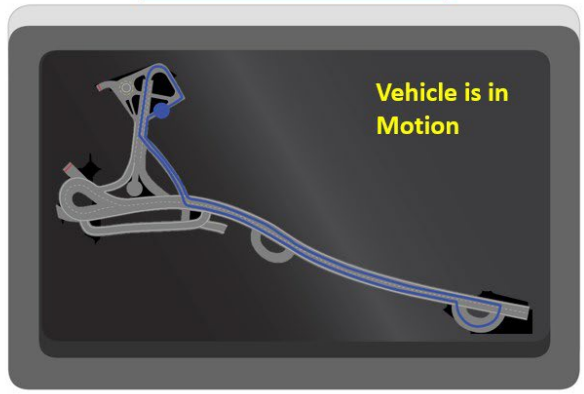
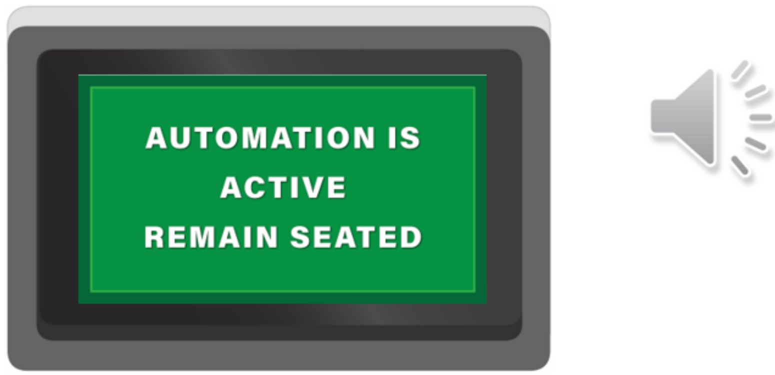



# Reference HMI – Arrival

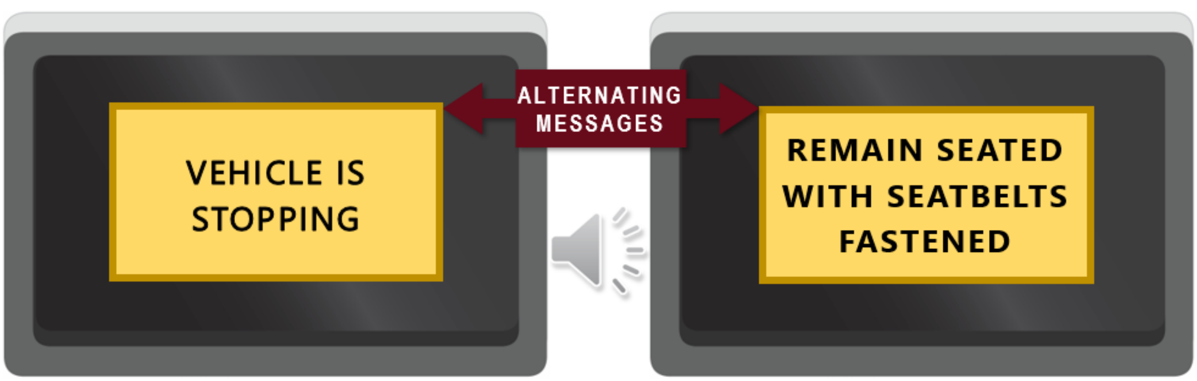
## Reference HMI – Critical States

Soft Stop



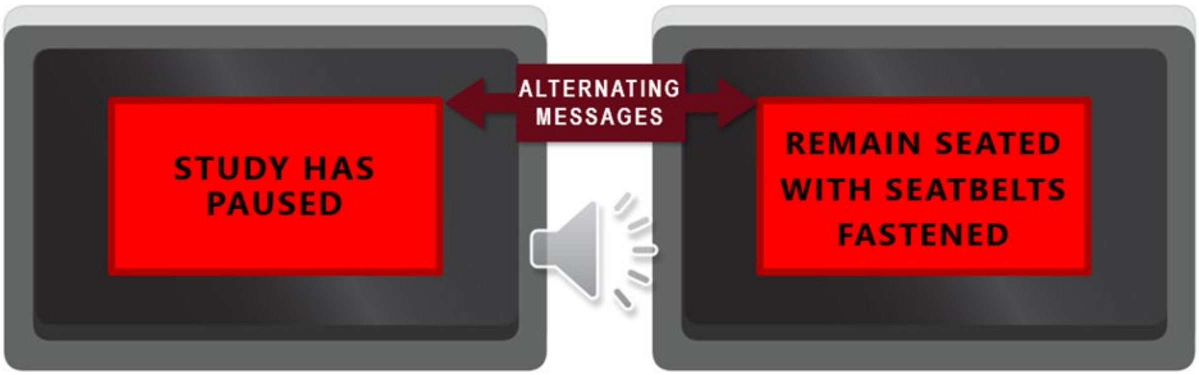

## Reference HMI – Critical States

Hard Stop



# Reference HMI – Critical States

E-Stop



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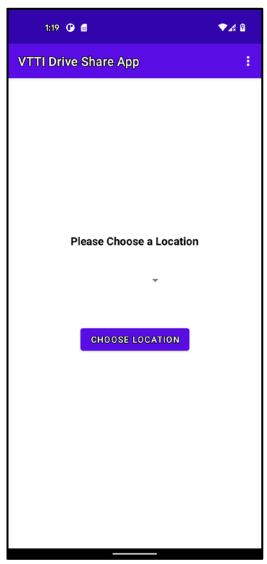
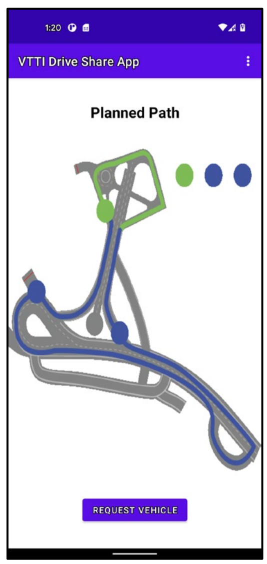
# Appendix B: VTTI Rideshare Application


Page 1 – Welcome screen

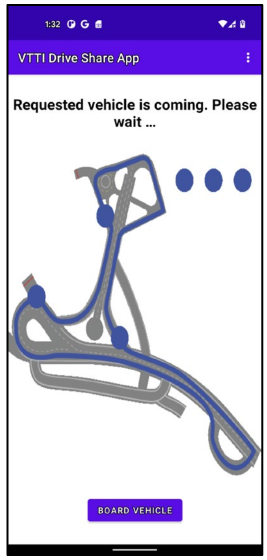



Page 2 – Choose location

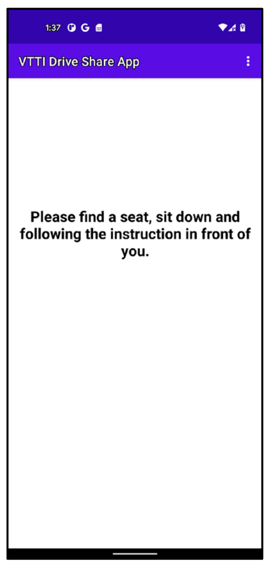

Page 3 – Specify location



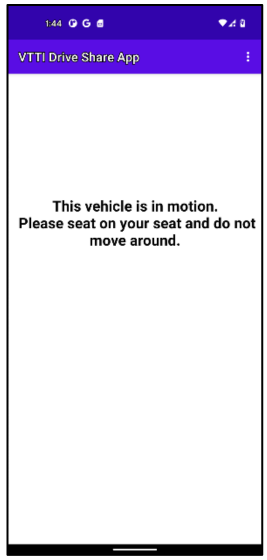

Page 4 – Request vehicle



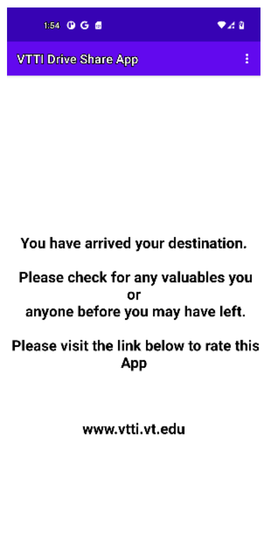

Page 5 – Vehicle requested




Page 6 – Entering vehicle instructions




Page 7 – Riding instructions




Page 8 – Destination arrival instructions

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# Appendix C: Post Experiment Questionnaire

**Date: __________**
**Participant Number: __________**

I felt safe riding in the driverless vehicle

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

1b) Explain your response

I changed where I would sit in the driverless vehicle compared to where I would sit if riding with a human driver

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

2b) Explain your response

I found the vehicle notifications to be helpful.

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

3b) Explain your response

The notifications were easy to understand

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

4b) Explain your response

I would be less likely to wear a seat belt in a driverless vehicle, compared to a vehicle with a human driver

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

5b) Explain your response

1. Did the presence of a driver affect your choice of seat?

   YES NO

   Follow up with clarification about the response.

2. Did the presence of other passengers affect your choice of seat?

   YES NO

   Follow up with questions/comments

3. Do you think the orientation of the passenger seats affected your seat belt use?

   ` YES NO

   Follow up with questions/comments

4. Do you think the orientation of the passenger seats affected your seat choice?

   YES NO

   Follow up with questions/comments

5. Do you think the vehicle notifications prompt you to wear your seat belt?

   YES NO

   Follow up with questions/comments

6. Do you think the position of the touchscreen affect where you decided to sit?

   YES NO

   Follow up with questions/comments

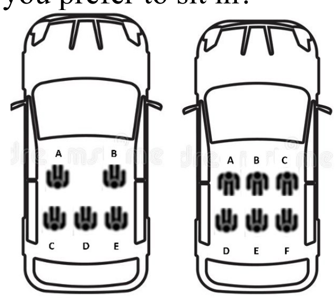
7. Do you have any comments on the position of the touchscreen display (whether or not it affected your seat choice)?

8. Regarding the information presented on the touchscreen, can you provide any feedback on whether or not the information presented was easy to understand?

   13a) Was there any information on the touchscreen display that was confusing in any way?

   13b) Are there any other comments regarding the touchscreen display that you would like to share?

9. If you were to ride in a driverless vehicle like the ones you rode in today, which vehicle would you prefer to sit in?




A B

Where would you choose to sit in your selected vehicle?

A B C D E (F)

12b) Please explain your response

10. Is there anything else about your experience with the driverless vehicle that you would like to share?

11. Were you aware of the researcher disguised as a participant during the study?

YES NO

DOT HS 813 793
August 2026

U.S. Department
of Transportation

National Highway
Traffic Safety
Administration

NHTSA

16932-080726-v4