INF 2002

Human Computer Interactions

Team 43

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Introduction

While autonomous vehicles (AV) present exciting possibilities for the future, the challenges faced by drivers of modern, non-autonomous vehicles also provide critical context for understanding the evolution of driving technology. Modern vehicles, though equipped with advanced driver-assistance systems (ADAS) such as lane-keeping assist, adaptive cruise control and automatic emergency braking, still pose significant challenges for drivers (Choi, 2016). These issues include reliance on partially automated systems, difficulty understanding or trusting ADAS functions and the risk of over-reliance on these technologies.

Drivers often experience confusion regarding the limitations of ADAS, as these systems require constant supervision and can fail to operate effectively in complex scenarios such as inclement weather or poorly marked roads. Additionally, the growing integration of technology in vehicles including touchscreens and infotainment systems, introduces distractions that can compromise safety (Nidamanuri, 2021).

This research specifically focuses on SAE Level 3 automation, where vehicles are capable of performing most driving tasks, but still require the driver to be available to take over control when requested. At this level of automation, the vehicle can manage steering, acceleration, braking, and monitoring of the environment, but the driver must be prepared to intervene in certain conditions.

Understanding the challenges faced by drivers of today's vehicles, including their concerns with partial automation, provides a foundation for exploring the adoption and implementation of Level 3 AVs. By examining drivers' perspectives on the adoption of AVs, their safety concerns, and their expectations for road safety in an automated future, this research aims to gather insights that can inform the design of AVs to build trust, enhance safety, and improve the likelihood of public adoption.

Needfinding Methods

We employed a combination of surveys, observations, and interviews to comprehensively understand user behaviours and attitudes toward autonomous vehicles (AVs). Surveys provide a broad overview of the population's perceptions, allowing us to gather data from a large number of respondents quickly. On the other hand, observations offer real-time insights into actual behaviours, while interviews allow for more in-depth exploration of individuals' thoughts and concerns. Together, these methods complement each other by providing both quantitative and qualitative data, offering a fuller picture of user needs. The age range of 20-30 years was chosen because young adults are typically early adopters of technology and are likely to drive frequently, making them a key demographic in understanding attitudes toward AVs.

Survey

Our survey targeted 38 respondents, with a focus on young adults aged 18-30, who made up 92.1% of the participants (Appendix A, Figure 1). This demographic was significant because 84.2% owned a car (Appendix A, Figure 2), and 57.9% relied heavily on personal transportation (Appendix A, Figure 3). The survey conducted online for broader reach, aimed to understand user driving patterns, as well as their concerns regarding road safety. It was conducted over two days, and this method provides quantitative data, making it easier to identify patterns or trends in how people perceive AV safety, reliability, and usability.

Surveys Results and Conclusions

As a result, most respondents identified distracted driving as the greatest threat to road safety, with 47.4% of participants sharing this view (Appendix A, Figure 5). On a scale from 1 to 5, 39.5% of respondents remained neutral regarding the helpfulness of autonomous vehicles (AVs) in reducing accidents caused by human errors (Appendix A, Figure 6). Similarly, 39.5% of respondents expressed a neutral stance on the deployment of AVs on public roads (Appendix A, Figure 7). Lastly, 92.1% of respondents emphasized that vision is one of the most critical methods for AVs to communicate effectively with drivers and pedestrians (Appendix A, Figure 8).

From the survey in Appendix A Figure 4, a variety of concerns were raised by the respondents. They can be mainly grouped into 3 main categories: The avoidable accidents that could be caused by other drivers/pedestrians such as inconsiderate drivers who may cause trouble to others, pedestrians who are not aware of their surroundings. The second is location based issues such as traffic jams and parking conditions that drivers will usually have a lack of information to foresee. The third relates more to personal and psychological issues such as having anxiety or lack of trust in driving skills

Appendix A Figure 5 focuses on the opinion of the respondent's opinion on the cause of traffic accidents. Almost half agree that distracted driving is the main cause while drunk driving and speeding each had 23.7% of respondents agreeing. These all causes are related to a lack of concern for their surroundings. Appendix A Figure 6 gave us a measure to understand their confidence with AV to improve safety. Majority of the responses were given a rating of 3 and above to indicate towards average and slightly more confidence in the capability of AV being safe on the road. Appendix A Figure 7 however, was given a rating of 3 and below from the majority of the respondent's opinion. This indicates that the current road infrastructure might not be ready in Singapore for AV usage.

Observation

For the observations, we conducted two sessions in busy traffic areas to better understand real-world driving and pedestrian behaviours. One observation took place near a expressway leading to a public general hospital at a T-junction during rush hour, where we observed a total of 42 drivers and pedestrians for an hour. (Appendix B, Figure 1 to 3) Another observation was conducted near Yio Chu Kang MRT on a Monday, focusing on road usage and behaviour for an hour, involving 20 drivers and 15 pedestrians. (Appendix B, Figure 4) These settings provided valuable insights into how drivers and pedestrians interact with traffic, helping us identify potential challenges for AV integration.

Observation Results and Conclusions

In the observations conducted at two locations, distinct behaviours were noted among drivers and pedestrians. At the T-junction near a hospital, 30 drivers and 12 pedestrians were observed over an hour. Key findings included 10 to 12 drivers failing to signal when turning, 8 to 10 drivers using phones while driving, and 4 to 6 drivers experiencing close calls with other vehicles or pedestrians. Examples such doing right turns with no signal lights which causes confusion and anxiety among drivers.(Appendix B, Figure 1). Additionally, 3 to 4 pedestrians jaywalked, and 2 to 3 crossed without waiting for the green light (Appendix B, Figure 2). Near Yio Chu Kang MRT, 20 drivers and 15 pedestrians were observed. Notably, 5 to 6 drivers failed to yield at zebra crossings. Among pedestrians, 5 jaywalked, and 2 were distracted by their phones (Appendix B, Figure 4).

These observations reveal key safety concerns like distracted driving, jaywalking, and failure to signal or yield, which create unpredictability in traffic. The frequent failure to signal and yielding issues pose risks for both drivers and pedestrians. Furthermore, the presence of non-car vehicles like e-bikes and the unpredictable actions of pedestrians, such as jaywalking, highlight the complexity of mixed-traffic environments. The need to make way for emergency vehicles adds another challenge. Autonomous vehicles (AVs) may struggle to handle these dynamic and often chaotic behaviours such as lane cutting, careless driving, quick time events like pedestrians running onto the streets with blind spots, could potentially raise concerns about their ability to ensure safety in such environments. This suggests that AV systems need to be highly adaptable and responsive to a wide range of unpredictable human actions.

Interview

The interviews were conducted with 8 young adults aged 20-30 who drive at least five times a month. Each interview lasted 30 minutes and used a mixed-method approach, combining structured and unstructured questions. A list of open-ended and closed-ended questions were given to the interviewees to gather original and unrestricted responses. Interviews were held both physically and online to the interviewee's convenience. This approach allows for more detailed and open-ended insights and can capture nuances about the interviewee's experiences. Direct interaction with users to further probe, uncovering hidden needs that may not be openly apparent. Allows for better understanding of the context where user's needs arise hence allowing for more actionable findings.

Interview Results and Conclusions

The interviews revealed that 4 out of 8 interviewees regularly use vehicle technologies like GPS and parking assistance, but 3 expressed concerns about being distracted by the technology such as carplay, android auto, and other devices that includes a screen or entertainment systems that are distracting to the driver and 2 noted navigation issues such as underground/tunnel with using GPS, unexpected road works and unreliable road pathing services. While all 6 were aware of autonomous vehicles (AVs), only 4 saw potential benefits, particularly for convenience and long drives. Our results here lean more towards to the younger demographic which might likely lean towards a more tech savvy mindset. The overall conclusion we can draw from our respondents results is that we should create and design an interface that is not distracting, and find ways to mitigate or circumvent the existing infrastructure issues with road signs, and other behaviours from drivers and pedestrians. This reflects a cautious optimism and recognise that there is a potential to address human errors and improve safety but underscores significant concerns about AV reliability in real-world conditions, unpredictable behaviours, and infrastructure adequacy. The emphasis on visual communication also signals the importance of seamless interaction between AVs, drivers, and pedestrians.

Task Analysis

Objective: Travelling from home to school/work

Task	Starting a Car	Driving a Car	Parking a Car
1	Approach the car	Adjust speed according to road conditions	Identify a parking spot.
2	Unlock the car	Check rear and side mirror every 5 to 10 seconds	Use mirrors, sensors, or reverse cameras to assist with parking.
3	Open the car door	Stop on red traffic lights	Engage the brake
4	Get in the car	Utilise indicators to signal intent to lane change, turn or overtake.	Shift gear into "park"
5	Close the car door	Stay in the centre of the lane.	Apply handbrake
6	Start the engine via key a. Put key in ignite b. Depress foot brake c. Turn key to start engine	Check GPS for directions	Turn off the engine a. Turn key to off engine b. Pull the key out
7	Adjust the seat	Abide by the traffic rules and road signage.	Exit car a. Open the car door b. Get out of the car c. Close the door
8	Adjust the mirror a. Adjust rear view mirror b. Adjust side mirrors	Check blind spots before turning or lane changing	Lock car
9	Fasten seatbelt	Prepare to stop when approaching a zebra crossing	
10	Disengage handbrake	Apply keep left rule unless overtaking	
11		Keep safe distance between cars in front of you	

Table 1: Hierarchical Task Analysis

Results and Conclusion

- System Readiness: Ensuring all the system panels are functional before starting to drive is critical to avoid accidents.

- Road Navigation: Obeying traffic rules and adjusting to the changing road conditions. Focus is necessary to avoid any potential obstacles and ensure safe driving.

- Handling Special Scenarios: Autonomous vehicles must be prepared to handle dynamic, unpredictable situations, such as bad weather, especially with emergency vehicles or construction zones. Continuous monitoring of road conditions, including other vehicles, pedestrians and road signs, helps to ensure safe driving.

- Parking: Requires precision and awareness of the vehicle's surroundings and the size of the vehicle itself. Also ensure that it is parked properly without causing obstructions or damage, especially in tight spaces.

User Needs

1) **Reliable and Predictive AV Systems**: Users need autonomous vehicles that can reliably handle unpredictable human behaviours, such as jaywalking, sudden lane changes, and the unexpected use of hazard lights. This would help address concerns about AVs' ability to navigate mixed-traffic environments safely.

2) **Manual Override for Emergency Situations**: Users expressed a strong need for the ability to easily regain manual control of the vehicle in critical or emergency situations. This would ensure that human judgement can still be applied when necessary, increasing trust in the technology.

3) **Effective Communication with Pedestrians and Non-Car Vehicles**: AV systems must be able to communicate clearly with pedestrians, cyclists, and other non-car vehicles using visual, auditory, and tactile signals to ensure smooth interaction and minimise risks on the road.

4) **Enhanced Safety and Navigation Features**: Users need AVs to have robust safety measures, including reliable navigation systems that can adapt to real-time conditions like roadworks or accidents. This includes ensuring the AV remains operational in challenging environments such as tunnels, where GPS signals may be lost.

5) **Integration with Emergency Services**: There is a need for AVs to effectively integrate with emergency response services, allowing for the safe and efficient passage of emergency vehicles like ambulances or fire trucks, without causing delays or road hazards.

Brainstorming

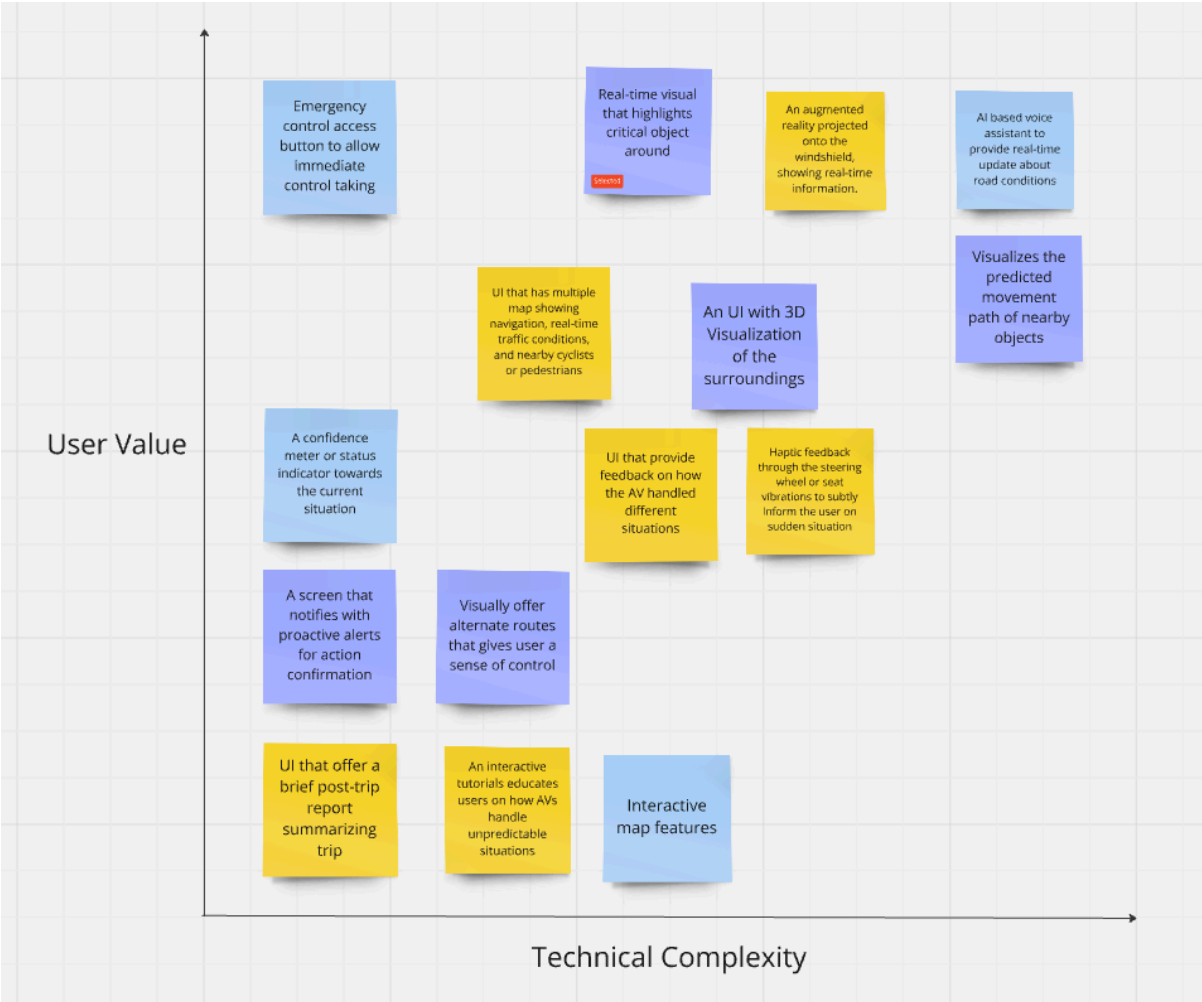


Figure 1: Idea graph with post-its

Using the insights gathered from the need-finding phase, we have identified key areas such as AV handling, user control, and safety feedback. Each member contributed ideas, like a real-time visual system to highlight critical objects and AI voice assistant for road condition updates. Solutions are focused on enhancing user control and transparency.

With the help of tools like sticky notes in Miro, the team explored a wide range of ideas, from simple features like post-trip reports to more advanced concepts like augmented reality displays.

For instance, the team discussed a real-time visual system that highlights critical objects like cyclists or jaywalking pedestrians. Another suggestion was an AI-based voice assistant that provides road condition updates and alerts in real-time. These ideas emerged from the common concern for user safety and control during AV operation.

To allow users to better understand the system’s actions and feel more in control. Other team members proposed solutions that focused on user feedback mechanisms to build trust and confidence in the AV system. For example, a design idea for an interface that provides feedback on how the AV handled sudden situations such as roadblocks or accidents.

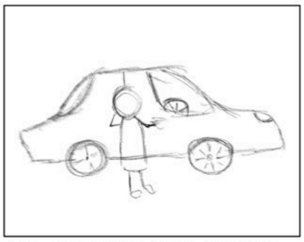
Design Idea

This design idea is **Real-time visual and Audio Feedback that highlights critical objects around**. It addresses the challenge of raising driver awareness and minimising distractions, particularly in situations where visibility is limited or where pedestrians may be at risk. Based on our findings during the needfinding phase, we identified that drivers often face difficulty spotting pedestrians, especially when they jaywalk, and distractions such as using smartphones can delay reaction times, creating dangerous situations. By providing real-time visual and audio feedback, this system helps the driver stay informed of critical objects, such as pedestrians, other vehicles, or obstacles, in the vehicle's path.

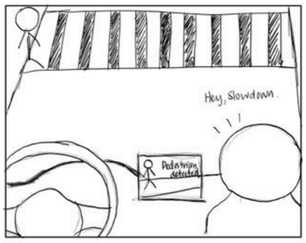
The system uses real-time feedback to alert the driver to potential hazards. The visual feedback includes highlighted markers or overlays on the car's display, while the audio feedback provides directional cues or warnings to help the driver navigate safely. These features support the driver in maintaining situational awareness and reacting more quickly to potential hazards, thus reducing the risk of accidents.

This system also addresses user needs by enhancing reliable and predictive AV systems. AV must be able to handle unpredictable human behaviours such as jaywalking, sudden lane changes, and the unexpected use of hazard lights. By providing clear feedback in real-time, the system ensures the vehicle can react to these situations, improving the safety and trust of both drivers and pedestrians.

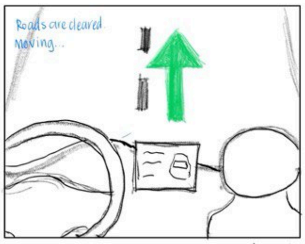
Storyboard



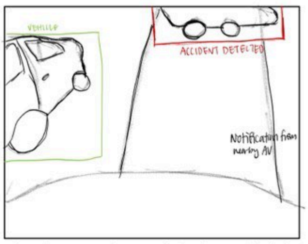
User getting into the autonomous car



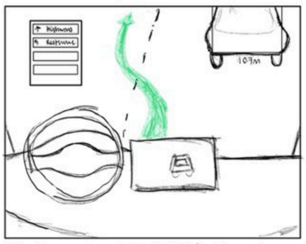
User is able to interact with AV by speaking to it to slow down if the speed is too fast



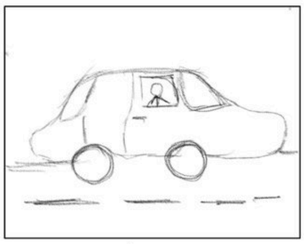
Roads are cleared. AV continues move forward



The AR screen shows and detects any obstacles or notifies any critical situation happened in the roads. This is to notify users they can choose an alternative way. Nearby AVs are able to notify each other on traffic accidents to avoid taking this way



The AR screen shows that vehicle is too slow and user can choose to take over the vehicle infront. It also shows a direction with the alternative roads and resthouses



User continues in this journey.

Figure 2: Final Storyboard

This storyboard illustrates the whole user journey and how the chosen idea fits into the user journey. First when the user gets into the AV, as they drive along they encounter a pedestrian crossing a zebra crossing. The vehicle display will show the user what the car can see and highlight pedestrians, cyclists and other vehicles. However, if the vehicle does not highlight it, the user can give commands to the car to slow down. On a clear road driving along, the vehicle displays directional arrows and text to show its intent to the user. When it comes across an accident, the vehicle display highlights and informs the user on the situation and provides the user choices for alternative ways. The AV also communicates with nearby AV to notify on the traffic accident ahead.

This storyboard was chosen to highlight the integration of real-time information and user interaction within the AV experience, ensuring both safety and transparency. By showcasing key moments like pedestrian detection, and real-time accident management, the storyboard emphasises how the AV can keep users informed and engaged in the driving process. The decision to include a feature where the user can intervene and issue commands. Additionally, the communication between vehicles regarding accidents enhances the sense of situational awareness. Overall, this approach aims to create an informative journey where the user feels secure.

Prototype

The prototype begins when the user enters the AV (Appendix D, Figure 1). The user then starts the engine by pressing the "Start" button on the AV control panel. Once the engine is on, the windscreen displays the message "Engine On" (Appendix D, Figure 2).

Next, the user selects "Navigation" on the system panel to input their destination (Appendix D, Figure 3). After entering the destination, the user can view a map showing the entire journey on the system panel (Appendix D, Figure 4). Additionally, a list of available voice commands is displayed on the windscreen inside the AV (Appendix D, Figure 5). If the user gives an incorrect command, the system will display an error message on the windscreen (Appendix D, Figure 6).

Once the journey begins, the AV detects and highlights nearby vehicles on the road, such as trucks (Appendix D, Figure 7) and cars (Appendix D, Figure 8). When approaching a zebra crossing, the system detects pedestrians and cyclists, prompting the AV to slow down (Appendix D, Figure 9).

The AV is also capable of detecting accidents on the road (Appendix D, Figure 10). If an accident is detected, the system provides the user with options to respond, such as rerouting, taking over control, or stopping the vehicle (Appendix D, Figure 11). If the user chooses to reroute, the system will display navigation updates on the windscreen (Appendix D, Figure 12). If the user selects "Stop," the vehicle will halt, and the windscreen will show the relevant status message (Appendix D, Figure 13).

There is a possibility that the AV may not detect pedestrians who jaywalk (Appendix D, Figure 14). In such cases, the user can issue a command to stop the vehicle (Appendix D, Figure 15).

Upon reaching the destination, the AV automatically parks, and the windscreen will display the parking status (Appendix D, Figure 16 and 17). When the journey is complete and the engine is turned off, the windscreen will indicate "Engine Off" (Appendix D, Figure 18).

We selected this prototype because it incorporates the 7 Norman's usability principles, which emphasise the importance of user-centred design. These principles consist of affordance, signifiers, visibility, mapping, feedback, constraints, and metaphors. This guides our approach to creating an intuitive and efficient user experience.

Affordance	The system uses visual cues such as buttons on a digital display with clear, clickable design that draws attention and invites user interaction.
Signifiers	Guided users to the correct action by displaying what this should click on for the intended action.
Visibility	Used commonly seen icons from other applications to allow the users to recognise that the specific actions were possible.
Mapping	Buttons and icons are logically mapped to their respective functions, ensuring that the design is both intuitive and that the functions are discoverable by the user.
Feedback	The navigation map comes up after the user has entered their intended destination and when they do actions like turning on the engine, it displays "ENGINE ON" to the user to indicate that the engine has started.
Constraints	To avoid confusion or errors, a limited set of voice commands and button interactions are available to the user, this not only limits the range of actions that a user can perform thus preventing unintended actions but also keeps the interface simple and focused.
Metaphors	The main menu uses a tile based icon menu designed similarly to how our mobile phone displays clickable application icons in the home page.

Table 2: Usability Principles

Using the conceptual model, the autonomous vehicle is designed to mimic the experience of operating a manually driven car while integrating advanced autonomous features such as obstacle, pedestrian and vehicle detection and voice commands. Just like a manually driven car, the system provides clear and intuitive controls for key functions like starting the engine and inputting destination. The buttons and icons are placed in similar locations as they would be in a manually driven car, making it easier for users with prior experience in manually driven cars to get used to the system without a steep learning curve. By blending these familiar manually driven car controls with AV features, this system allows the users to transition smoothly to new technologies while assuring the users by seeing common elements while the added features enhance the overall autonomous vehicle experience without overwhelming the user. This hybrid design approach allows users to feel in control of the vehicle but also benefit from the convenience and safety features of autonomous vehicles.

Heuristics Evaluation

A heuristic evaluation was conducted in a lab setting with Team 30, where each team member acted as an HCI expert to explore and assess our interface. During this session, we used a paper prototype to facilitate the evaluation, allowing the HCI experts to apply the Ten Usability Heuristics to our design.

After gathering feedback from all six HCI experts, we calculated the average severity ratings for each issue and summarised their comments and recommendations in the table below.

S/N	Heuristics	Severity Rating	Description
1	Visibility of system status	1	There were visible system status at every stage. It was not clear what the boxes meant, but I can infer that it's from
2	Match between system and the real world	0	Icons are intuitive and represent their functions well but response time to road hazards are slow, making voice commands challenging.
3	User control and freedom	1	System has a good level of control via voice inputs but, would prefer more than 1 option for a use case
4	Consistency and standards	1	● Navigation of dashboard and voice controls are consistent, but limited. ● There were overlaps between verbal commands and physical commands like touching the screen. ● Some stuff are voice activated while some stuff are operated via the control panel.
5	Error prevention	2	● The system identifies pedestrians and nearby vehicles, taking appropriate actions based on the context. If the system fails to detect these objects, the user has the option to intervene ● When prompting user to make decisions using exclusively voice control based on certain events that occur on the road, the pop ups on the windscreen UI does not indicate use of voice control (hidden affordance), user may try to choose an option via the dashboard instead. ● To a certain extent there were error

			preventions however, in an autonomous vehicle I expected that there was no need for me to execute many commands however the prototype still relies on the user extensively. ● There are some error mitigations, but I had to tell the vehicle to slow down and reroute when it approached an accident. I missed the cue for that.
6	Recognition rather than recall	2	● Experienced some difficulty understanding what kinds of commands to user for various use cases ● There were command lists for different commands that can be executed but it was not exactly user friendly to find the command list. ● I could not remember the voice commands when I needed them. They were only flashed for a brief amount of time
7	Flexibility and efficiency of use	1	● Efficient for certain cases, but the system is inflexible to other types of use. ● To a great extent, but I feel that efficiency can be improved by streamlining certain actions such as using voice commands for common actions like starting the vehicle.
8	Aesthetic & minimalist design	1	● Simple design but UI on the windscreen can get too cluttered. The Dashboard UI for the prototype is too small ● Main screen was filled with different functions which was confusing for me at the first glance
9	Help users recognize, diagnose, & recover from errors	1	● Users will be prompted by an error message of using the wrong command at a given situation but not detail. ● Do not recall much assistance for errors in the system. Just error messages given for invalid inputs.
10	Help & documentation	2	● System has command list of voice commands to use but does not have has a instruction manual on how to operate the car ● Some documentation provided for types of voice command

			• The “?” could be misleading as I did not expect to see the command list under the icon initially.Clicking on voice commands brings up what I can do with voice commands. But I don’t see any external operator help in case the built-in voice command in the car cannot handle the situation.

Table 3: Heuristic Evaluation

Results of heuristics evaluation

Key usability strengths

- Visibility of system status: System effectively displays important information, such as vehicle location and obstacles.
- Aesthetic and minimalist design: Clean interface, uncluttered and easy to navigate making it visually appealing and accessible
- Consistency and standards: System maintains a consistent design in navigation and voice commands, aiding user familiarity

Major usability issues

- User control and freedom: While voice commands offer good control, users desire more options for specific tasks such as alternative ways to perform a function
- Flexibility and efficiency: System is efficient for certain tasks but lacks flexibility in handling varied use cases, which impacts overall user experience.
- Match between system and real world: Users find response times to road hazards slow when using voice commands, leading to usability challenges in real-world situations.
- Error prevention: While the system validates inputs effectively, there is a need to improve detection and handling of critical situations like road hazards.

Areas of improvement

- Some users struggle with recalling appropriate voice commands for various tasks, indicating a need for better cues or assistance in the system.
    - Solution: If the user says an incorrect command, the AV will display three commands similar to what the user intended.
- Documentation and help features are present but not comprehensive which can lead to confusion about voice commands and system functions.
    - Solution: Provide a demo video of different scenarios and what to do in those scenarios.
- Improvement on more critical display methods like high rated HUD visibility.
    - Solution: Warning lights and sounds to alert the user who may not be focused on the windscreen.

Think-Aloud Evaluation

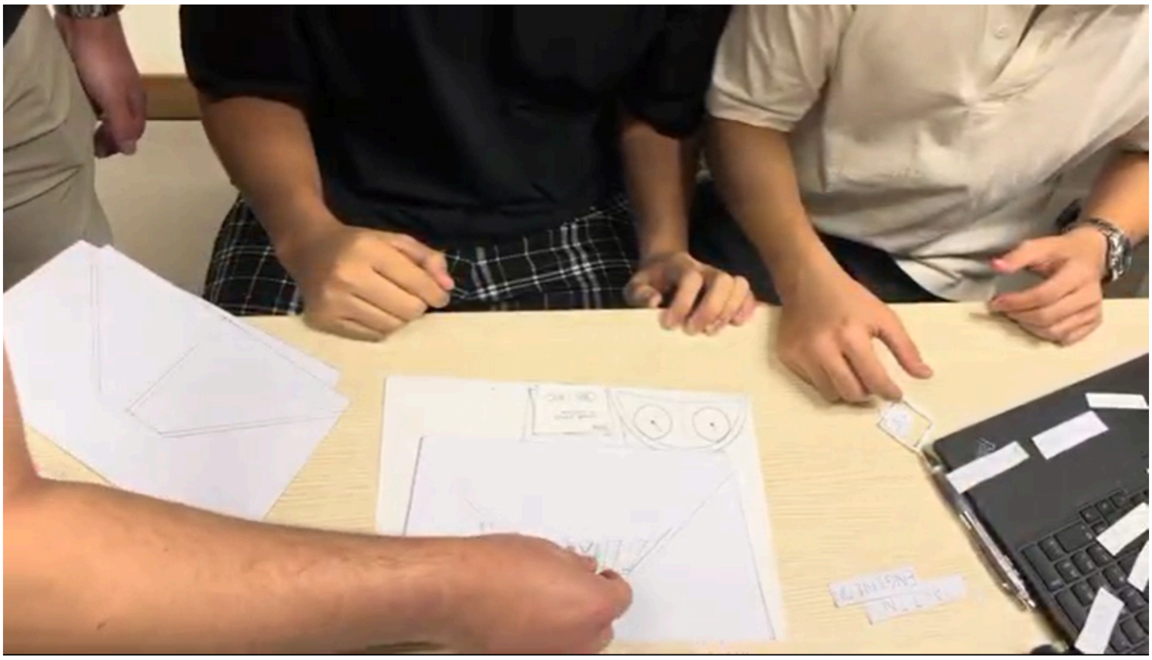


Figure 3: Conducting Think-Aloud Evaluation in a lab

The Think-Aloud evaluation was conducted with Team 17, where each member interacted with a paper prototype of the Autonomous Vehicle system. The scenario involved travelling from home to school, with participants performing a series of tasks to assess both the user experience and the system's responses to various commands and external events.

One team member acted as the narrator, guiding the user through each task, while another served as the note-taker, documenting the user's actions and feedback. The remaining team members assisted with adjusting the scenes of the paper prototype as needed throughout the evaluation.

The main objectives of the test were to start the AV, input and confirm a destination, use voice commands to interact with the system, observe the AV’s reactions to obstacles, pedestrians, and road incidents, and successfully reach the destination and park. Participants performed tasks such as starting the AV, entering a destination, issuing voice commands, observing the system’s responses to road conditions, and completing the journey by parking. As participants verbalised their thoughts, the team gathered valuable insights into the system’s usability and effectiveness.

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Task	Description	Issues	Solution
1	Start Car/Engine	1. Task performed without issue	1. NIL
2	Input Destination	1. Task performed without issue	1. NIL
3	Viewing available voice commands on the Windscreen	1. Question Mark symbol was not a clear indicator to bring up Instruction/Voice command List 2. User did not know to use the back to menu button to close the Command List displayed on the WindScreen	1. Change Question Mark symbol to “Microphone” symbol (Appendix I, Figure 1) - It is a more accurate representation of voice command 2. State clearly at the bottom of the command List “Click back to Menu to close Command List” (Appendix I, Figure 2) - Ensure user is well aware of this option
4	Response to AV not detecting obstacles (Pedestrians)	1. Driver unable to verbalise proper command in time during quick-time events (AV about to collide with an obstacle it could not detect)	1. User to be taught on Emergency Commands that are intuitive and short (fast enough) to say during emergencies. - Instead of using “Hey Auto, slow down” - Use “STOP”
5	Respond to to traffic accidents (Possible actions to choose from is labelled on the WindScreen)	1. User unaware they can choose their response to action via voice command 2. User Expected AV to make the decision, and just wanted to reach destination quickly	1. Have clear instructions on the WindScreen to choose Action via voice command eg. “Use Voice command to select Action (Appendix I, Figure 3) - Ensure user is aware of this option 2. AV to automatically choose a default option if the user does not respond within a certain time - This allows AV to make the decision without user intervention
6	Parking the Car	1. User unaware that parking of car can be done via voice command	1. Upon reaching the Destination, User to be prompted on the WindScreen to use Voice command to initiate parking (Appendix I, Figure 4) - Ensure user is well aware of this option
7	Turn off Engine	1. User tried using voice command to turn of Engine a. *Engine call only be turned off in the main menu*	1. Windscreen clearly states “ON/OFF engine control can only be done in the main menu” (Appendix I, Figure 5) - Ensure user is well aware of the correct action to take to turn off engine

Table 4: Think Aloud Task Result

Implementation

Software tools used

- HTML: used for structuring the content and layout of the prototype
- CSS: used to style and design the visual aspects, ensuring the interface is aesthetically pleasing and user-friendly
- JavaScript: utilized for interactivity, logic and handling any button clicks which enables dynamic elements like animations and real-time feedback

Justification

Quick and easy to develop with and relatively simple to implement. These tools allow for rapid prototyping and are well-suited for implementing interactive user interfaces.

Implementation Plan

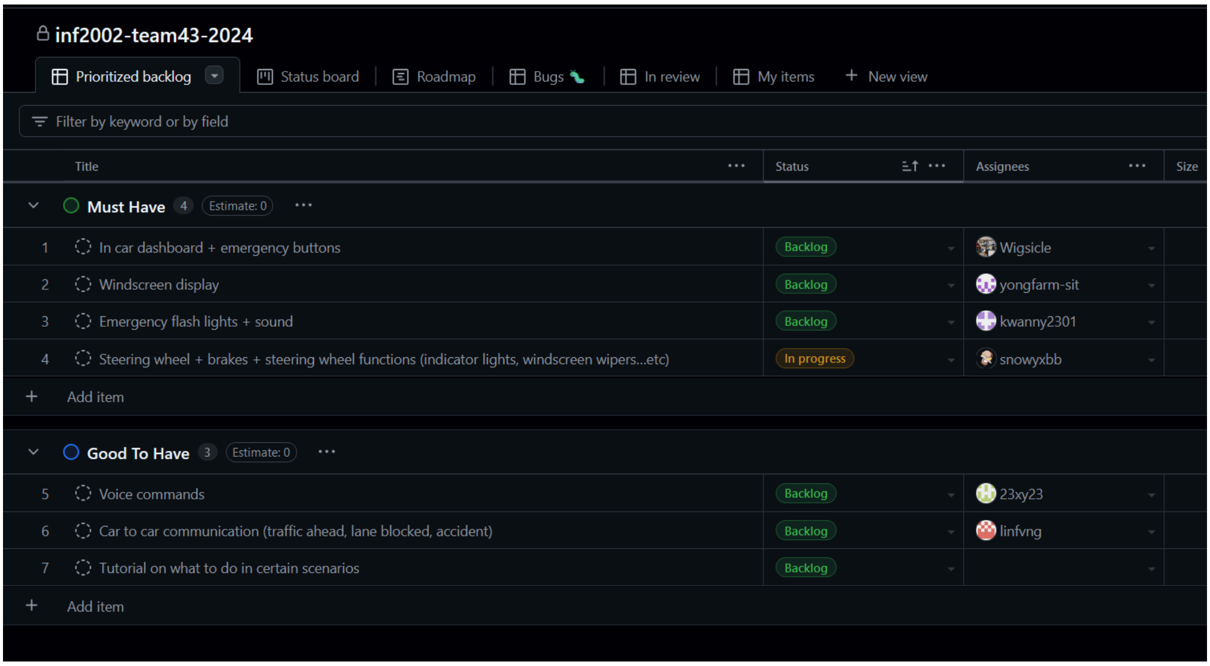

Figure 4: GitHub backlog

Member	Responsibility	Time Taken (Hrs)
Lin Feng	Initial Setup	4
Farm Yong Wei	Program Flow (Car Detection)	6
Tan Kwan Yee	Emergency Alarm (Car Accident)	4
Peters Richard Aksarachai	Program Flow (Car Parking)	6
Fan Xinyu	Experiments Feature (In-vehicle display)	8
Sng Xue Bin	Voice Commands	5

Table 5: Implementation Responsibility

Lin Feng responsible for the initial setup, which forms the backbone of the interface. Farm Yong Wei focused on developing the car's ability to detect obstacles on the road, such as other vehicles, cyclists, and pedestrians. Tan Kwan Yee implemented the emergency alarm system, ensuring it activates in the event of a car accident. Peters Richard Aksarachai worked on the car parking functionality, while Fan Xinyu was in charge of implementing in-vehicle display features for the experimentation section. Finally, Sng Xue Bin developed the voice command feature for the car, enhancing user interaction.

Block diagram (Program Flow)

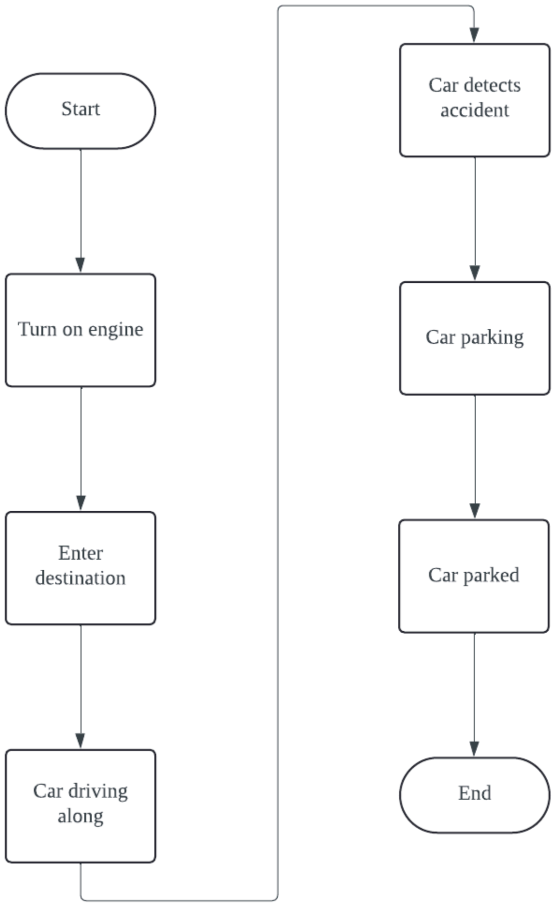

Figure 5: System flowchart

Implementation vs Prototypes

- Removal of engine status indicator on the windscreen.
  Reason: The engine status indicator was removed from the windscreen display as it provides redundant information. Ambient noise, subtle vibrations and visual cues from the dashboard are sufficient to convey the vehicle's status. In addition, reducing unnecessary clutter enhances the clarity of the windscreen.

Experimentation

Hypothesis:

Drivers will be more satisfied with augmented reality displaying driving information compared to an in-vehicle display.

Null Hypothesis:

Drivers will not experience greater satisfaction with augmented reality displaying driving information compared to an in-vehicle display.

Independent Variables

- Augmented reality display
- In-vehicle display

Dependent Variable

- Driver Satisfaction

Control Variables

- Driving environment
- Display content
- Driver Experience

Confounding Variables

- Driver's Cognitive Load
    - Cognitive load can be a confounding variable because the mental effort required to process information from the display may vary among participants.
- Personal Preference
    - Individual preferences can confound the results as it may lead some participants to favour one display type over the other based on their personal tastes rather than the display's actual effectiveness.

Experiment Design

We will use a within-subjects design to enhance comparisons and reduce group variability. By having the same participants experience both the augmented reality and in-vehicle display conditions, individual differences are controlled, allowing direct and reliable comparison of satisfaction levels between the two display types. This approach minimises the risk of variability between groups, where different participants might have varying baseline characteristics, such as preferences for certain technologies or familiarity with specific display systems. Thus, any observed differences in satisfaction are the impact of the display type, rather than external factors or inherent differences among participants, resulting in valid and accurate conclusions.

The method for data collection in this study will be a survey, where participants will be asked to rate their satisfaction with two different display types: augmented reality (Experiment A) and in-vehicle display (Experiment B) stated in Appendix J. The type of comparison being made is a difference comparison, as we are interested in examining the difference in satisfaction between the two display types. The data collected will be ordinal, as participants will provide satisfaction ratings on a Likert scale, which is treated as ordinal data.

The *Wilcoxon Signed-Rank* Test will be conducted to analyse the data collected from the satisfaction ratings of the augmented reality display and in-vehicle display. Firstly, the data collected from the Likert scale survey is ordinal, meaning that the responses represent an ordered ranking. The Wilcoxon Signed-Rank Test is well-suited for ordinal data, unlike parametric tests that assume interval or ratio-level data. Secondly, the test is ideal when the data does not meet the assumption of normality, which is common with small sample sizes or non-normally distributed data. Since the study uses a within-subjects design, where the same participants experience both conditions, the Wilcoxon Signed-Rank Test will compare the differences in satisfaction scores for each participant between the two display types.

The statistical test will be conducted in a structured procedure to ensure reliable and accurate results. First, we will schedule a meeting with 10 participants to meet at a lab, where they will sign a consent form (Appendix L, Figure 1) to confirm their voluntary participation. After explaining the purpose of the study and distributing a task information sheet (Appendix M, Table 1), participants will engage in the experiment, using both the augmented reality and in-vehicle displays to complete a set of driving tasks. Once they have finished using both display types, participants will complete a survey to rate their satisfaction with each system.

Experiment Analysis

In-vehicle display	Augmented reality display	Difference	Abs Diff	Sign	Rank - Abs diff	W-	W+
4	7	3	3	+	5.5		**5.5**
10	10	0		-			
7	5	-2	2	-	3.5	**3.5**	
8	9	1	1	+	1.5		**1.5**
8	6	-2	2	-	3.5	**3.5**	
6	10	4	4	+	7.5		**7.5**
7	6	-1	1	-	1.5	**1.5**	
10	10	0		-			
5	9	4	4	+	7.5		**7.5**
6	9	3	3	+	5.5		**5.5**
Total:						**8.5**	**27.5**

Figure 6: Data used to calculate W value

The survey data will then be used to calculate the differences between the satisfaction ratings for each participant (Appendix N, Figure 1). These differences will be ranked by their absolute values, and the ranks for the positive and negative differences will be summed separately. The statistical significance of these differences will be assessed by comparing the sum of the ranks to a critical value from the Wilcoxon Signed-Rank Test distribution. This process will allow us to determine whether there is a statistically difference in satisfaction between the two display types, providing insights into the effectiveness of the augmented reality display compared to the traditional in-vehicle display.

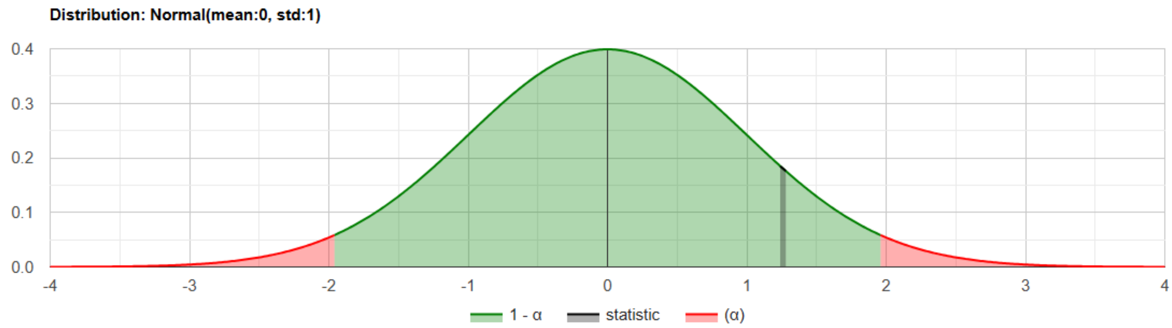

Figure 7: Distribution Graph

The results of the Wilcoxon Signed-Rank Test indicate that the p-value is 0.2053 (Appendix O, Figure 1), which is greater than the significance level (α = 0.05). Therefore, we fail to reject the null hypothesis. The test statistic (Z) was calculated as 1.2665 (Appendix O, Figure 1), which falls within the 95% acceptance region of [-1.96, 1.96] in Figure 7. The observed effect size (r) is 0.45 (Appendix O, Figure 2), which suggests a medium effect, indicating that the magnitude of the difference in satisfaction between the two display types is moderate.

Based on the results of the Wilcoxon Signed-Rank Test and the corresponding p-value (0.2053), we fail to reject the null hypothesis. This means there is insufficient evidence to conclude that driver satisfaction differs significantly between the augmented reality display and the in-vehicle display. Although the observed effect size is medium, the result is not statistically significant, suggesting that the difference in satisfaction levels between the two display types is not large enough to be considered meaningful at the 95% confidence level. Therefore, we cannot claim that augmented reality displays offer a significantly better driving experience in terms of satisfaction compared to traditional in-vehicle displays.

Experiment Conclusion

Based on the ladder of validity, the limitation of the experiment is external validity. Specifically, the use of a simulated driving environment instead of real-world driving conditions limits the ability to generalise the results to actual driving scenarios. Participants may behave differently in a controlled simulation than they would in real traffic, where factors like road conditions, distractions, and traffic flow come into play, affecting the findings.

Conclusion

This study has explored the interaction between drivers and SAE Level 3 autonomous vehicles, addressing the critical factors for their effective adoption. Through a comprehensive examination of user needs, gathered via surveys, observations, interviews and usability evaluations, it is evident that the successful integration of AVs into the society hinges on addressing several key concerns.

Drivers value reliable and predictive systems that can navigate unpredictable scenarios, emphasizing on the necessity for advanced safety and communication features. The demand for manual override capabilities highlights the importance of maintaining driver confidence and control, especially in critical conditions. Additionally, the need for effective communication between AVs and other road users underscores the role of intuitive and transparent design in fostering trust and safety.

The design and evaluation of a prototype showcased innovative features, such as real-time visual and audio feedback to enhance safety and user interaction. However, the study also identified areas for improvement including the end for better error handling, more intuitive command systems and enhanced emergency responsiveness.

While AVs hold significant potential to improve road safety and reduce driver stress, addressing these concerns is crucial for achieving the widespread acceptance towards society. By focusing on human-centric design principles, continuous testing and iterative improvements, AV technology can better align with user expectations and environmental challenges. This research provides a foundation for future advancements in autonomous vehicle development, aiming for a safer and more efficient transportation ecosystem.

References

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Appendix

Appendix A: Needfinding Survey Results

Figure 1: Survey result on participants age group

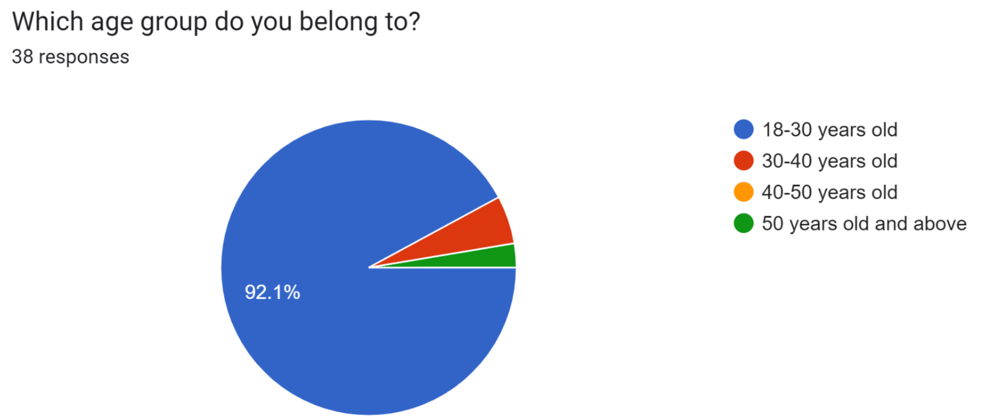


Figure 2: Survey result on owning a car

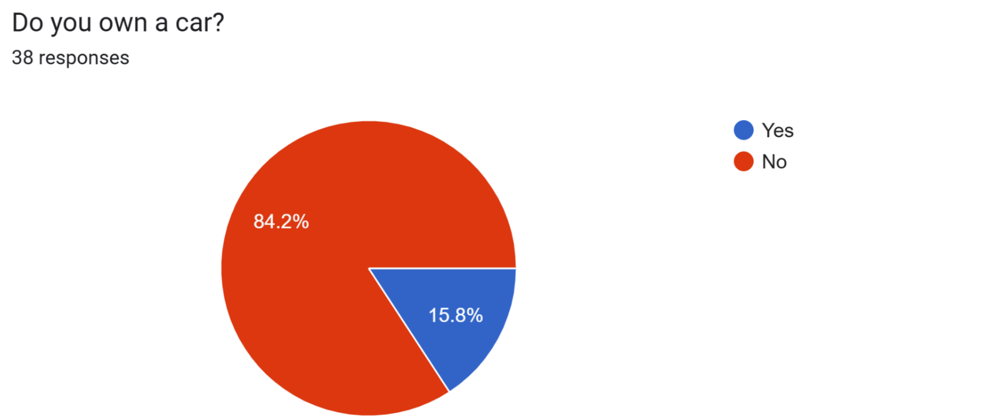


Figure 3: Survey result on participants driving frequency

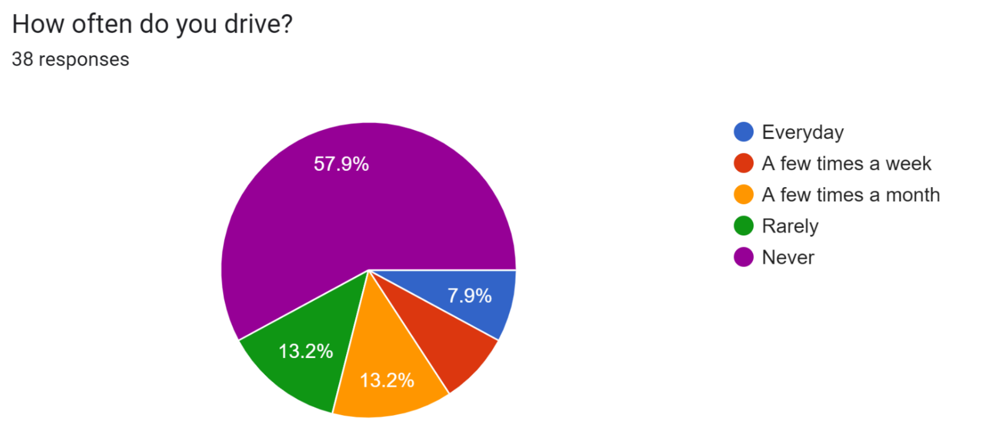


Figure 4: Survey result on issue faced by driver

What problem do you face the most while driving?
stupid drivers and jay walking pesdastrains!!!!
small areas
safety
reckless driver
parking
nil
Unpredictable motorist behaviors resulting in stupid decisions made and unnecessary accidents happening.
Traffic most of the time for local
Traffic jam
Tired with long distance driving
Tired during long hour drive
The fact that I don't own a car
Slow traffic, impatient drivers, careless pedestrians
Scared of road accidents
Scared
Safety on the road
Other drivers being reckless
Optimised driving route for petrol/time
Obnoxious drivers who have 0 awareness
Not applicable
No parking space
No Car no license
Nil
NIL cause i dont drive, but i guess for my friends its the IU card reader?
NIL
NA
Lane change with no signal
Jam brake
Inconsiderate drivers refusing to give way when I signalled to lane change
I don’t even have a license
Having to react to unpredictable road users
Cutter
Buses and reckless drivers
Blindspots
Anxiety over other drivers behaviour

Figure 5: Survey result on the views on road safety issue

What do you believe is the biggest current threat to road safety?
38 responses

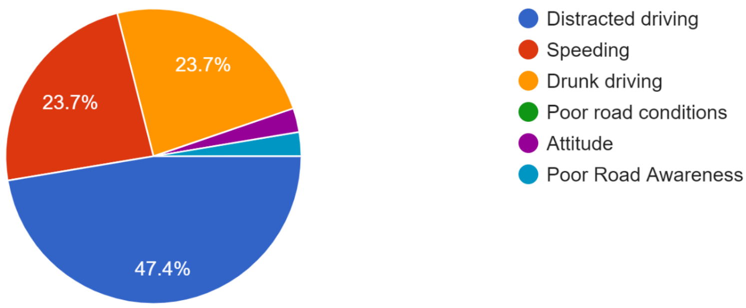


Figure 6: Survey result on the views on AV reduce road accident

On the scale of 1 to 5, how helpful do you think autonomous vehicles could reduce accidents caused by human error?
38 responses

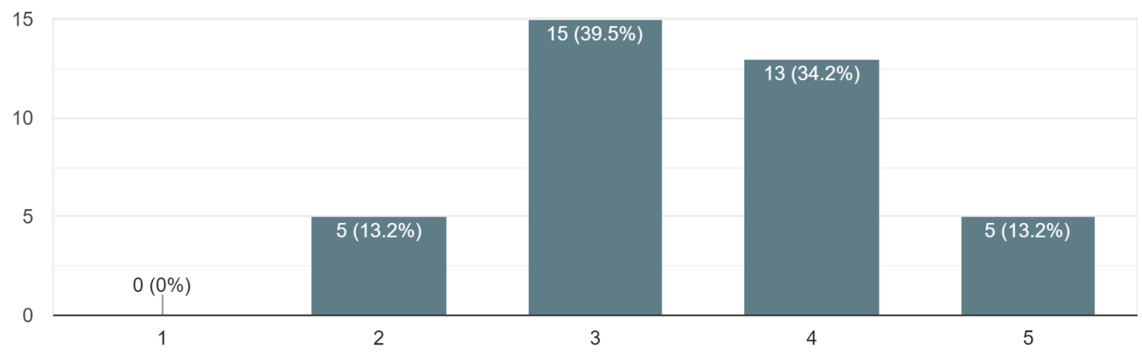


Figure 7: Survey result on the view on deployment of AV on road

On the scale of 1 to 5, how ready is autonomous vehicles to be deployed on the current road infrastructure (signage, markings, etc.)?
38 responses

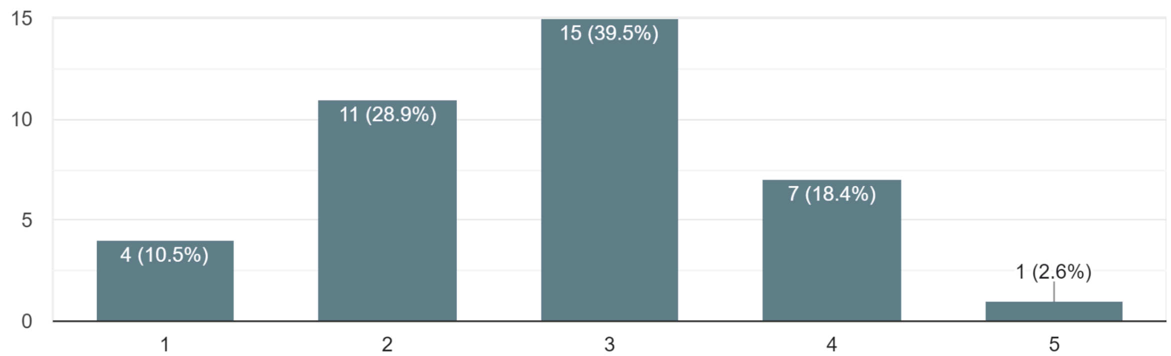
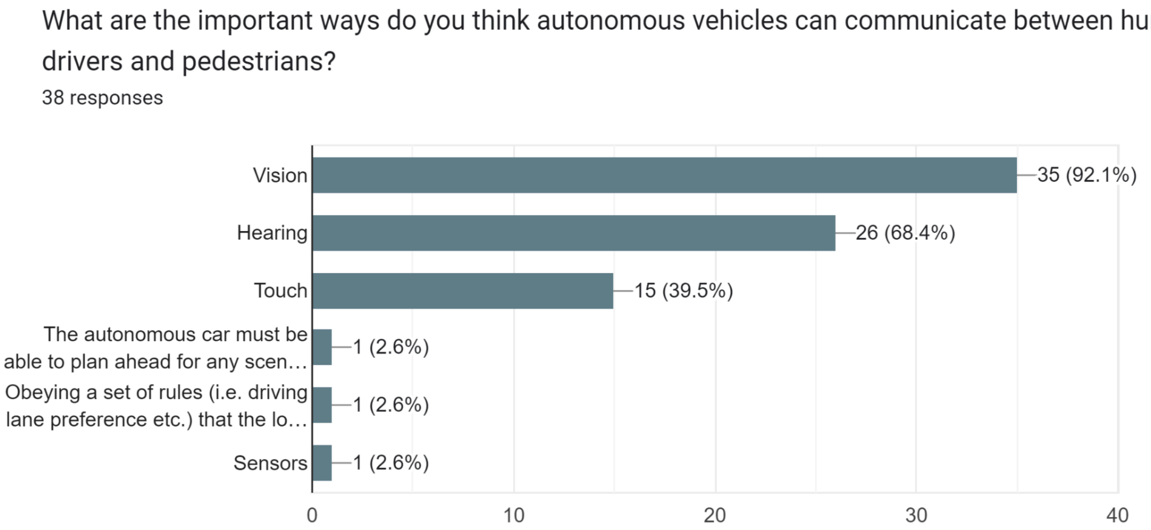


Figure 8: Survey result on ways to communicate between drivers and pedestrians



Appendix B: Observation Result

Figure 1: Car turning without signal light turning from Sengkang East Ave to Compassvale St

Figure 2: Pedestrians and Cyclist jaywalking near Sengkang Community Centre

Figure 3: Man using phone while waiting for traffic light near Sengkang General Hospital

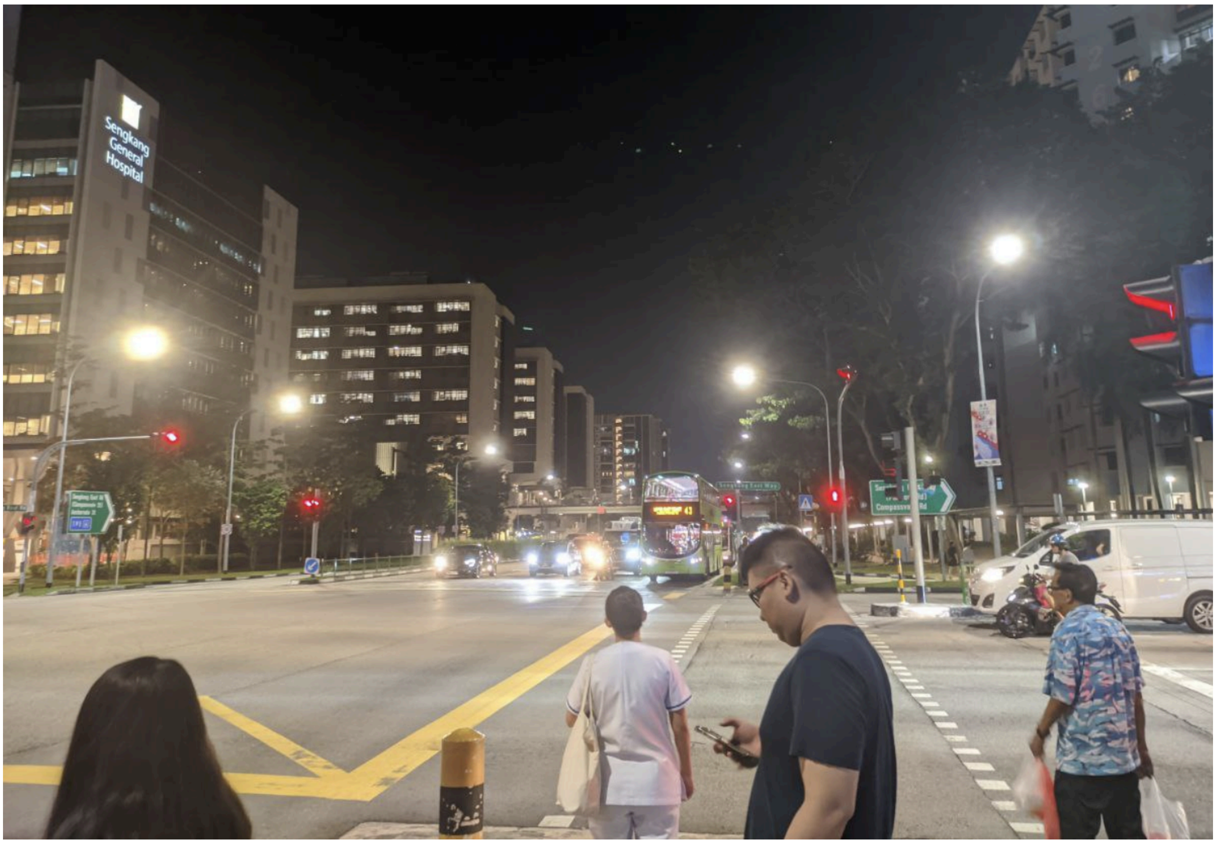


Figure 4: Man jaywalking near Yio Chu Kang MRT

Appendix C: Interview Transcripts

Table 1: Interviewee 1 transcripts

S/N	Question	Answer
1	May I roughly know your age?	I'm about 21.
2	Do you drive and how often do you drive?	I just got my licence a while back. I drive on and off, maybe 2 times a week, mainly to university or training.
3	Could you describe to me what your commute is like?	It usually takes about 15 to 20 minutes longer than usual during peak hours, mainly on Mondays and Fridays. I usually drive around 5 PM for training.
4	Do you face any particular challenges when you drive during these hours?	It's more of an inconvenience with slower traffic, jams, and occasional accidents causing delays.
5	How do you interact with the technology in your car?	I mainly use the built-in tablet in the car for music and navigation.
6	What specific technology features do you use the most while driving?	Music and navigation apps like Waze.

7	Do you have any frustration while using technology?	It can be difficult to use the tablet while driving as it requires taking attention off the road, which is unsafe.
8	How often do you rely on parking assistants or reverse cameras?	I use parking assistance occasionally, especially when it rains, but I mostly rely on my traditional methods of parking.
9	How does this impact your confidence while driving?	Parking assistance is useful as a safety net but doesn't greatly impact my confidence.
10	How do you see yourself minimising distraction?	Minimising distraction would be easier if I didn’t need to focus on driving, as a driverless car would let me focus solely on other tasks.
11	Do you think if you are distracted with your phone, you will be able to take control of the car fast enough?	Yes, I believe I can react fast enough, especially if alerted in advance.
12	Can you describe to me your whole process of driving, from the time that you get into the car?	First, I unlock the car, start it, let it warm up, then adjust the brake pedal and shift into the desired gear before driving.
13	Are you driving an automatic car or manual car?	I’m driving an auto car.
14	Have you had any experiences with semi-autonomous features such as adaptive cruise control or lane keeping assist?	No, I haven't had any experience with such features.
15	Would you feel more comfortable with an AV driving in heavy traffic compared to normal driving conditions?	I would feel comfortable as long as the AV notifies me in advance when I need to take over.
16	What are your main concerns about the safety of AVs?	If AVs are legalised in Singapore, I trust that they would be safe, as they would have passed all necessary tests.
17	Do you think AVs can reduce accidents?	Yes, AVs can reduce accidents as they follow traffic rules and can gauge distances better than human drivers.
18	Do you think AVs can help to improve emergency vehicle response times?	Yes, AVs could potentially improve emergency response times if they communicate with other AVs on the road to clear the way.

19	How do you think AV technology could adapt to behaviours like jaywalking or aggressive drivers?	AVs could foresee jaywalking pedestrians or react faster to aggressive drivers. They can follow rules better and have quicker reaction times.
20	What are some of the AV technologies that you have heard of?	I've mostly heard about Tesla in terms of AV technology.
21	What's the most common system alert you encounter in your car and how do you respond to it?	Alerts for speed cameras and red light cameras are the most common, and I slow down when I get these alerts.
22	Can you describe a situation where the system did not help or hindered your driving experience?	When approaching an orange light, if alerted to a red-light camera ahead, I may have to stop instead of accelerating, which can sometimes hinder my driving.

Table 2: Interviewee 2 transcripts

S/N	**Question**	**Answer**
1	May I roughly know your age?	I'm about 21.
2	How often do you interact with vehicle technology, and in what capacities do you find yourself using it (as a driver, passenger, etc.)?	I drive on and off, maybe 2 times a week, mainly to university or training, interacting mainly with the built-in tablet for music and navigation.
3	Could you describe how technology is integrated into your daily commute and any specific interactions you have with vehicle technology?	It usually takes about 15 to 20 minutes longer during peak hours. I use apps like Waze for navigation and music to make the drive smoother.
4	Do you face any technology-related challenges during your commute, particularly with the vehicle's automation features?	The main challenge is the inconvenience of slower traffic and occasional accidents, which can delay the commute.
5	Can you detail your typical interactions with your car's technology, focusing on touchscreens, voice commands, or gesture controls?	I mainly interact with the built-in tablet for navigation and music, but it can be distracting to use while driving.
6	Which user interface features do you find most beneficial while driving, and why?	The navigation app like Waze and the music player are the most useful. They help manage my time and keep the drive enjoyable.

7	What are your main frustrations with the current UI in your car, especially related to automated features?	It's challenging and unsafe to use the tablet while driving as it requires taking my attention off the road.
8	How does the UI for parking assistants or reverse cameras enhance or complicate your driving experience?	I use parking assistance occasionally, especially in challenging conditions like rain. It acts as a safety net.
9	How do UI features in your vehicle impact your confidence, particularly in complex driving scenarios?	While useful as a safety net, parking assistance doesn't greatly impact my overall driving confidence.
10	What UI features could help minimise distractions while you're driving, especially with in-car technology like infotainment systems?	A driverless car would allow me to focus on tasks other than driving, minimising distractions significantly.
11	How could UI changes ensure a quick and safe transition from autonomous to manual control when distracted?	I believe I can react fast enough to take control, especially if the system alerts me well in advance.
12	Can you walk me through how you interact with your vehicle's UI from the moment you enter, especially with respect to starting the car and engaging automated features?	I start by unlocking the car, starting it, letting it warm up, adjusting the brake pedal, and then shifting into the desired gear.
13	Does your car have automated features, and how do these interact with traditional controls?	I'm driving an automatic car but haven't had any experience with semi-autonomous features.
14	How do you interact with semi-autonomous features like adaptive cruise control or lane keeping assist, and how intuitive do you find the UI?	No, I haven't had any experience with such features.
15	How could the UI in AVs be designed to make you feel more comfortable and secure during heavy traffic conditions?	I would feel comfortable as long as the AV system notifies me in advance when I need to take over, especially in heavy traffic.
16	How do you think UI design could address your safety concerns about fully autonomous vehicles?	If AVs are legalised in Singapore, I trust they would be safe, as they would have passed all necessary tests.
17	What role do you think UI design in AVs can play in reducing accidents?	Yes, AVs can reduce accidents as they consistently follow traffic rules and gauge distances better than humans.

18	How could UI innovations in AVs facilitate quicker and more efficient responses from emergency vehicles?	AVs could potentially improve emergency response times if they communicate effectively with other AVs on the road to clear the way.
19	What UI solutions could help AVs adapt better to unpredictable behaviours like jaywalking or aggressive driving?	AVs could be programmed to foresee and react faster to behaviours like jaywalking or aggressive driving, enhancing safety.
20	Describe the most common system alert in your car's UI and how effectively you can respond to it based on the interface design.	Alerts for speed and red light cameras are most common, and I typically slow down when I receive these alerts.
21	Can you recall any specific instances where the UI in your vehicle either hindered or failed to assist your driving experience effectively?	When approaching an orange light, if alerted to a red-light camera ahead, I may have to stop instead of accelerating, which can sometimes hinder my driving.
22	Is there anything else you would like to add?	No, I think that covers everything. I appreciate the focus on user interface design as it's crucial for enhancing the safety and usability of autonomous vehicles. I'm particularly interested in seeing how advancements in UI can make these vehicles more intuitive and responsive to real-world driving conditions.

Table 3: Interviewee 3 transcripts

S/N	Question	Answer
1	May I roughly know your age?	20-30 years old
2	Do you drive? And how often do you drive? What is your commute like?	Almost everyday, at least 5-10km for work, both day and night depending on the working hours
3	Can you walk me through a typical driving session, and how you interact with current vehicle technologies?	- Open door - Check for petrol tank - Start engine - Check GPS connection - Start driving
4	Rank the level of importance to you: Distraction free, Easily navigable, Convenience	3Distraction free 1Easily navigable 2Convenience
5	What problem do you face the most often while driving?	Inexperienced driver, navigating apps being insensitive with the traffic conditions

6	Have you heard of Autonomous Vehicles (AV)?	Yes
7	What are your main concerns about the safety of autonomous vehicles?	At the current stage of AV, it is still considered the early and exploring stage in Singapore, which is not fully established yet where accuracy is a doubtful issue
8	Do you think an AV can solve your problems? How?	Yes, as a driver, can foresee AV's future, saving time and improvement in convenience
9	What makes you feel safe and unsafe when interacting with an AV as a driver. What are your main concerns about the safety of autonomous vehicles?	Making the wrong command might affect the outcome and safety of passengers
10	How do you see autonomous vehicles influencing emergency response services such as fire trucks, ambulances, and law enforcement?	Delaying the arrival time of emergency response services would likely happen if alarming sensors not done configured correctly. This would cause a big havoc to road safety too.
11	How do you handle system alerts or warnings when driving? How effective do you think these alerts are?	Stop the vehicle at a safe place and check whether the vehicle is still safe for driving. Very effective, it acts as signal before hazard

Table 4: Interviewee 4 transcripts

S/N	**Question**	**Answer**
1	May I roughly know your age?	24 years old
2	Do you drive? And how often do you drive? What is your commute like?	Yes, roughly once every two weeks. Only drive out when necessary
3	Can you walk me through a typical driving session, and how you interact with current vehicle technologies?	Usually uses google maps or waze for direction unless driving around frequent areas. Do not drive during peak hours because it's the worst and sometimes frustrating
4	Rank the level of importance to you: Distraction free, Easily navigable, Convenience	Convenient, easily navigable, distraction free
5	What problem do you face the most often while driving?	Usually to keep a lookout for other drivers. May be able to control how you drive but not others. Driving around unfamiliar areas is also an issue. For example, staying in west and gets lost easily while driving in the east

6	Have you heard of Autonomous Vehicles (AV)?	Yes
7	What are your main concerns about the safety of autonomous vehicles?	Might not be able to judge the situations on the road compared to human being
8	Do you think an AV can solve your problems? How?	Yes, driving in unfamiliar places or when too tired to drive
9	What makes you feel safe and unsafe when interacting with an AV as a driver. What are your main concerns about the safety of autonomous vehicles?	Safe: know that he will arrive at the location given. Unsafe: what if there were roadworks or an accident that happened, how can I be sure that the AV knows and deter away from it
10	How do you see autonomous vehicles influencing emergency response services such as fire trucks, ambulances, and law enforcement?	Can see that it may provide additional support to our emergency response services. They would not be able to focus much on the road to get from point A to point B
11	How do you handle system alerts or warnings when driving? How effective do you think these alerts are?	Sometimes it may be difficult to focus on the road and check for alerts. Unless you know what the beeps and alerts represent. It may be effective but it can be distracting as well.

Table 5: Interviewee 5 transcripts

S/N	Question	Answer
1	Can you roughly tell me your age?	23
2	Do you drive?	Yes
3	How often do you drive?	Usually, 5 times a week.
4	What is your commute like?	I drive to school, gym and nearby library to study.
5	Can you walk me through a typical driving session, and how you interact with current vehicle technologies?	I drive an EV. I start by turning off the power supply, then plug out the charger. After that, I will turn on engine. When I am inside, I will plug in my phone and use Apple CarPlay for GPS services. I will then check mirror before leaving carpark.
6	What problem do you face the most often while driving?	I faced problem in losing or inaccurate GPS location when I enter a tunnel and sometime I encounter inconsiderate driver on the road.

7	Have you heard of Autonomous Vehicles(AV)? Share with me what your understand about Autonomous Vehicles(AV)?	Yes, I have heard of it before. During my NS in Tengah air base, there is a driverless bus that fetch pilot to the air field but I did not board that bus before. It drive the vehicle without any driver.
8	What are your main concerns about the safety of autonomous vehicles?	The concerns I have is I am unsure of the technology on the safety of the control of the autonomous car. And what if the autonomous car malfunction, I don't think the car can handling it safe.
9	Do you think an AV can solve your problems? If yes, how does it solve your problems? If no, why does it not solve your problem?	It would ease my driving journey but what if it went to the tunnel and lost connection. I would feel it is a danger to use the car.
10	What kind of system alerts or warnings you need/preferred when transit from Autonomous mode to Manual mode when encounter emergency situation?	I need guideline on how to operate and inform on you on what to do when things goes wrong. I would prefer like a voice to tell me like there is danger in front and tell me what to do. It will be better to have some visual aid to indicate or alert me.

Table 6: Interviewee 6 transcripts

S/N	Question	Answer
1	May I roughly know your age?	24 years old
2	Do you drive? And how often do you drive? What is your commute like?	Yes, roughly once every two weeks. Only drive out when necessary
3	Can you walk me through a typical driving session, and how you interact with current vehicle technologies?	Usually uses google maps or waze for direction unless driving around frequent areas. Do not drive during peak hours because it's the worst and sometimes frustrating
4	Rank the level of importance to you: Distraction free, Easily navigable, Convenience	Convenient, easily navigable, distraction free
5	What problem do you face the most often while driving?	Usually to keep a lookout for other drivers. May be able to control how you drive but not others. Driving around unfamiliar areas is also an issue. For example, staying in west and gets lost easily while driving in the east

6	Have you heard of Autonomous Vehicles (AV)?	Yes
7	What are your main concerns about the safety of autonomous vehicles?	Might not be able to judge the situations on the road compared to human being
8	Do you think an AV can solve your problems? How?	Yes, driving in unfamiliar places or when too tired to drive
9	What makes you feel safe and unsafe when interacting with an AV as a driver. What are your main concerns about the safety of autonomous vehicles?	Safe: know that he will arrive at the location given. Unsafe: what if there were roadworks or an accident that happened, how can I be sure that the AV knows and deter away from it
10	How do you see autonomous vehicles influencing emergency response services such as fire trucks, ambulances, and law enforcement?	Can see that it may provide additional support to our emergency response services. They would not be able to focus much on the road to get from point A to point B
11	How do you handle system alerts or warnings when driving? How effective do you think these alerts are?	Sometimes it may be difficult to focus on the road and check for alerts. Unless you know what the beeps and alerts represent. It may be effective but it can be distracting as well.

Table 7: Interviewee 7 transcripts

S/N	Question	Answer
1	Can you roughly tell me your age?	24 years old
2	Do you own a vehicle?	Yes
3	Do you drive? If yes, how often do you drive? What is your commute like?	I drive maybe like 3 to 5 days a week on the plus side and some weeks I don't drive. Usually every other week I will drive.
4	What problem do you face the most when you're often driving?	Bad drivers, I guess not really like bad, impatient drivers are the main thing and people who got their licence super long ago and like the way they drive is very relaxed, so they don't signal and they drive like they own the road.
5	How do you feel when you encounter a pedestrian crossing the road?	My experience for most of Singapore is quite okay, I guess. Certain areas people tend to j-walk more recklessly. But overall quite okay.
6	Have you experienced an AV before?	Other than like an auto park, but no. I know there are buses in NP. I have not personally.

7	Do you think that AVs can solve your problems?	Yes and no, I think where we are in technology right now. AVs are probably for small areas where they can map the route, like a school compound like NP or NUS. Or like hospitals because I know some hospitals have terrible transport. On the main road as of now, I personally don't trust the AI to make the decisions enough.
8	What makes you feel safe and unsafe when interacting with an AV as a driver?	I don't know what priorities it has, obviously it has its parameters, it stays in its lane, and it detects cars. But what if someone is driving recklessly, I haven't really seen how they react to that. Train of thought of the AI.
9	Do you see autonomous vehicles influencing emergency response services?	Eventually yes.
10	Can you walk me through a typical driving session, and how you interact with current vehicle technologies?	You open the door and put the key in, and check mirrors because he shares the car with his parents. When you drive out you need to signal. Most of the time they park parallel, so they don't have to signal and just go out. Helps mom with job, going to areas his mom doesn't like driving to.
11	In what ways do you think an autopilot car can do better than humans?	Long drives, like road trips to KL or Malacca. I know a lot of people drive but some hate the drive itself sometimes when it gets past a certain amount of time. Some people also find it fun; it depends on person to person. From my experience the drives can be quite tiring, especially at night.
12	Do you think public transport should change their operators to autopilot systems?	I would say if they did, a lot of people would lose their jobs. You have to see how much unemployment there would be. There are quite a lot of bus and taxi drivers in Singapore. If they can somehow still have a backup driver, hybrid system, not fully automated.
13	What tasks do you find most challenging when operating semi-autonomous or fully autonomous systems?	When a vehicle is automated to some extent, you lose certain amount of controls that you have than being fully operated by a person.

		Like not having full control as in not making the decision he wants.
14	How do you handle system alerts or warnings when driving?	I do use them; I still follow the way I was taught both in the driving centre and the army. I use the mirrors but I do rely on the sensors a bit especially at certain angles. It's more of like a helping tool instead of a crutch. I try not to always rely on it. A lot of vehicles I have driven do not have these.
15	How comfortable are you with working alongside autonomous systems, such as adaptive cruise control or self-parking features?	I think they are fine as long as you can correct it in a scenario that it is wrong. Like in case it gets too close to the wall and you press the brake and the car stops. As long as you can do that I think it is fine. I haven't done it myself.
16	In an emergency situation, how do you think a human driver and an autonomous system should collaborate?	Yes, but the human should be able to override.
17	In an accident, how would you the driver feel if you were held responsible for an AI's mistake?	I would be pretty upset. It's a bit grey. The system is completely to blame. I think in that scenario the car manufacturer should be at fault. There should be cameras to get the evidence. The car manufacturer should deal with the damages.
18	Do you think autonomous vehicles should have ethical programming for life and death situations?	Not too sure, I feel there needs to be. I feel like the programming should keep whoever is in the car safe. It shouldn't just hit people.
19	Would you consider using an autonomous vehicle?	Yea, cruise control and stuff like semi-autonomous.
20	What features or capabilities do you envision having in an autonomous vehicle?	360 cameras, we had those in the expensive vehicles in the army. Quite useful.
21	What kind of features make you feel safe when interacting with AVs?	Warning system mainly, most AVs are more technologically advanced, camera and sensor wise. It's better when you're driving a vehicle that you are unfamiliar with.
22	What kind of feedback should autonomous vehicles provide in emergency situations?	It would be nice if it could alert you a second earlier. But that is hard. I think an alert before the e-brake cause as the driver, you're fine

		cause you know what is going to happen. A lot of people like your passengers are going to be shocked.
23	How do you feel about manually driven vehicles being slowly replaced by autonomous vehicles?	I would still like the choice to drive my own car, I wouldn't like a fully autonomous vehicle.

Table 8: Interviewee 8 transcripts

S/N	Question	Answer
1	Can you roughly tell me your age?	28 years old
2	Do you own a vehicle?	No, but my family does
3	Do you drive? If yes, how often do you drive? What is your commute like?	Yes, about twice a month, mostly short drives to local destinations
4	What problem do you face the most when you're often driving?	Encountering aggressive or distracted drivers
5	How do you feel when you encounter a pedestrian crossing the road?	I remain cautious and alert, always prepared to stop
6	Have you experienced an AV before?	No, I have not experienced an AV before
7	Do you think that AVs can solve your problems?	Partially, as AVs can reduce human error, but they might not handle all situations better than a skilled driver
8	What makes you feel safe and unsafe when interacting with an AV as a driver?	Safe: Advanced sensors and predictable behaviours; Unsafe: Potential technical failures and lack of human intuition
9	Do you see autonomous vehicles influencing emergency response services such as fire trucks, ambulances, and law enforcement?	AVs could streamline operations but may struggle in dynamic, unpredictable emergency scenarios
10	Can you walk me through a typical driving session, and how you interact with current vehicle technologies?	I start the car, check all systems via the dashboard, and use assisted driving features like lane keeping
11	In what ways do you think an autopilot car can do better than humans?	AVs can maintain consistent attention and adherence to traffic rules, potentially reducing accidents

12	Do you think public transport should change their operators to autopilot systems? Why or why not?	Adopting autopilot systems in public transport could increase precision and efficiency, reducing human error and potentially improving safety. However, the transition could lead to significant job losses and require substantial investment in technology and training. Public acceptance and trust in the technology would also need to be carefully managed.
13	What tasks do you find most challenging when operating semi-autonomous or fully autonomous systems?	Understanding when to take over control from the automated system, especially in unclear situations
14	How do you handle system alerts or warnings when driving? How effective do you think these alerts are?	I find them helpful, especially for maintaining safe distances and parking assistance
15	In what scenarios do you think autonomous vehicles might struggle compared to human drivers?	The human judgement of drivers, for example, like India where a lot of the drivers drive very close, the autonomous driving would not work in countries like that. That’s where they will struggle.
16	How comfortable are you with working alongside autonomous systems, such as adaptive cruise control or self-parking features?	Comfortable with non-critical functions like parking but wary of full driving automation
17	In an emergency situation, how do you think a human driver and an autonomous system should collaborate?	The system should assist but allow the human driver to take over in complex situations
18	In an accident, how would you the driver feel if you were held responsible for an AI’s mistake?	Frustrated, as the responsibility should ideally be shared with the manufacturer in case of a system fault
19	Do you think autonomous vehicles should have ethical programming for life and death situations? If yes, what kind of ethical rules should they follow?	Yes, they should prioritise minimising harm; decisions should be transparent and based on extensive ethical considerations
20	Would you consider using an autonomous vehicle?	Maybe in the future, once technology and regulations are more developed
21	What features or capabilities do you envision having in an autonomous vehicle?	Automated navigation and parking, integration with smart traffic systems

22	What kind of features make you feel safe when interacting with AVs?	Features that would enhance safety in AVs include real-time 360-degree surveillance, advanced obstacle detection, automatic braking systems, and robust cybersecurity measures to prevent hacking. Additionally, clear communication interfaces that inform the driver of the vehicle's actions and intentions would increase trust and comfort.
23	What kind of feedback should autonomous vehicles provide in emergency situations? Like e-braking	Pre-collision warnings and automatic emergency braking with human override capabilities
24	How do you feel about manually driven vehicles being slowly replaced by autonomous vehicles?	It's an inevitable progression, though I'd prefer options for manual control to be maintained

Appendix D: Prototype

Figure 1: When user is in the car

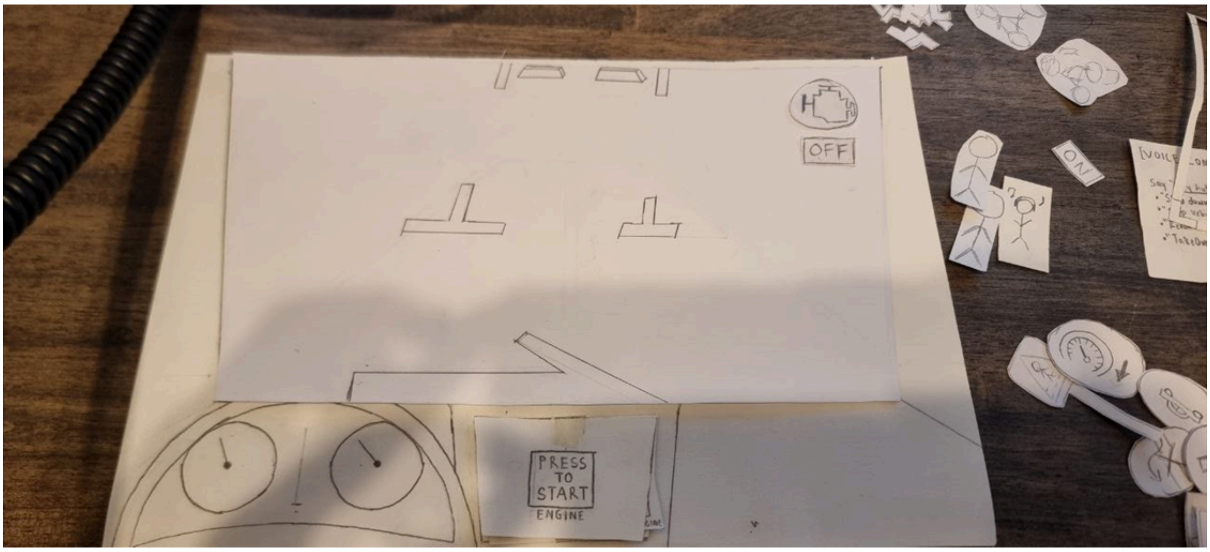


Figure 2: Starting engine

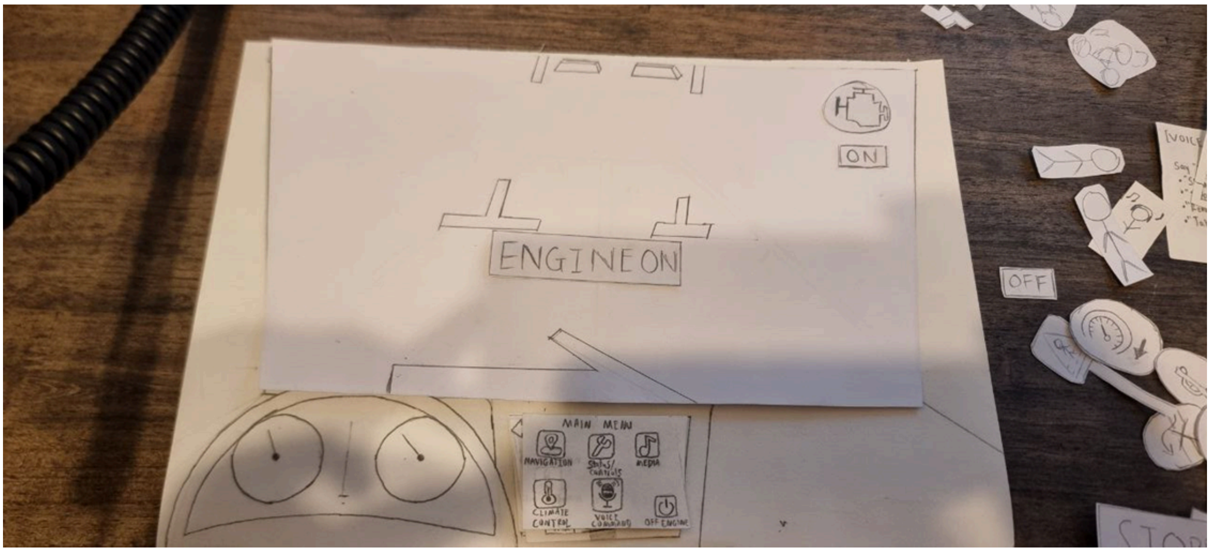


Figure 3: User input destination

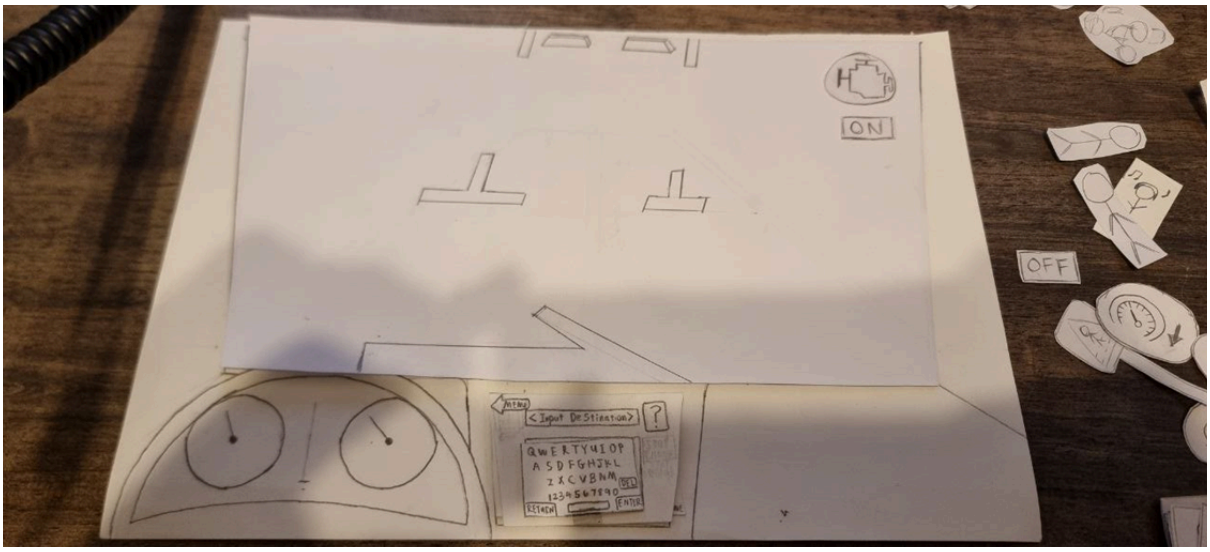


Figure 4: Starting journey

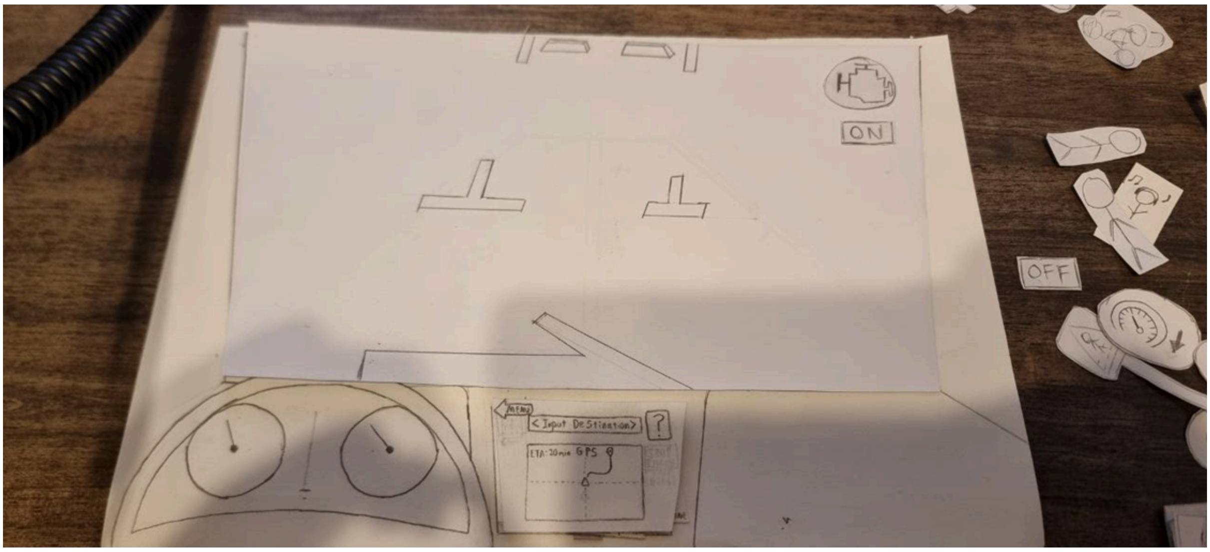


Figure 5: List of voice commands

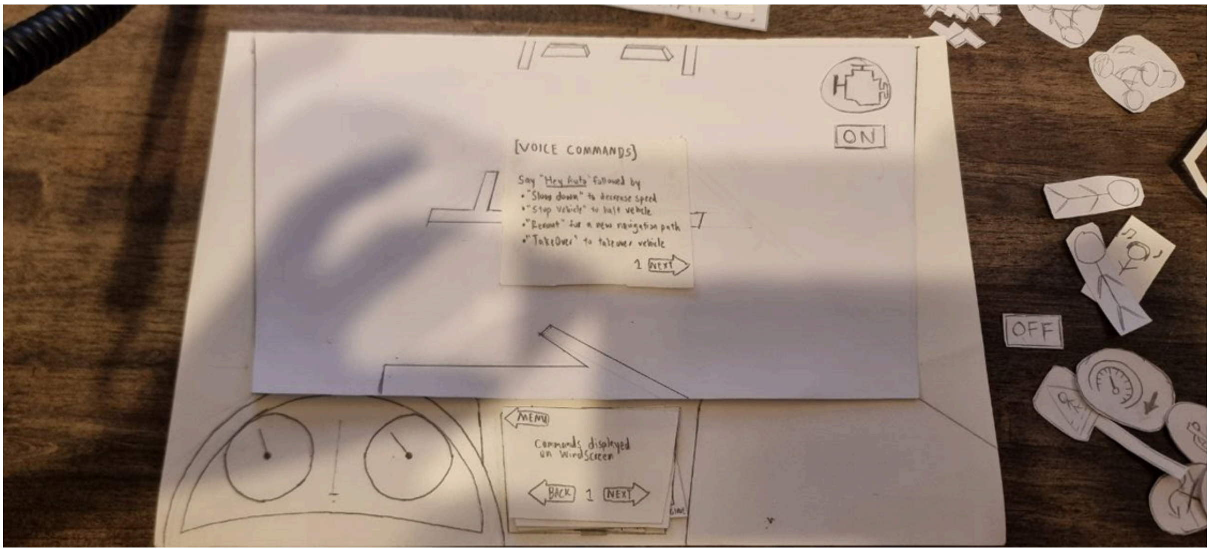


Figure 6: User use wrong voice command

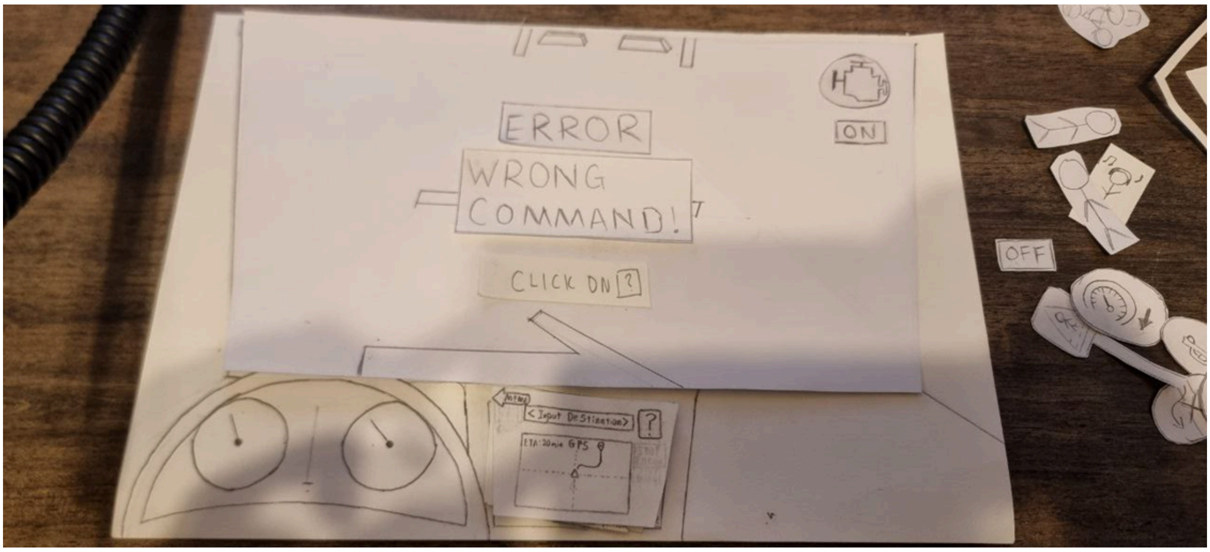


Figure 7: Detecting truck

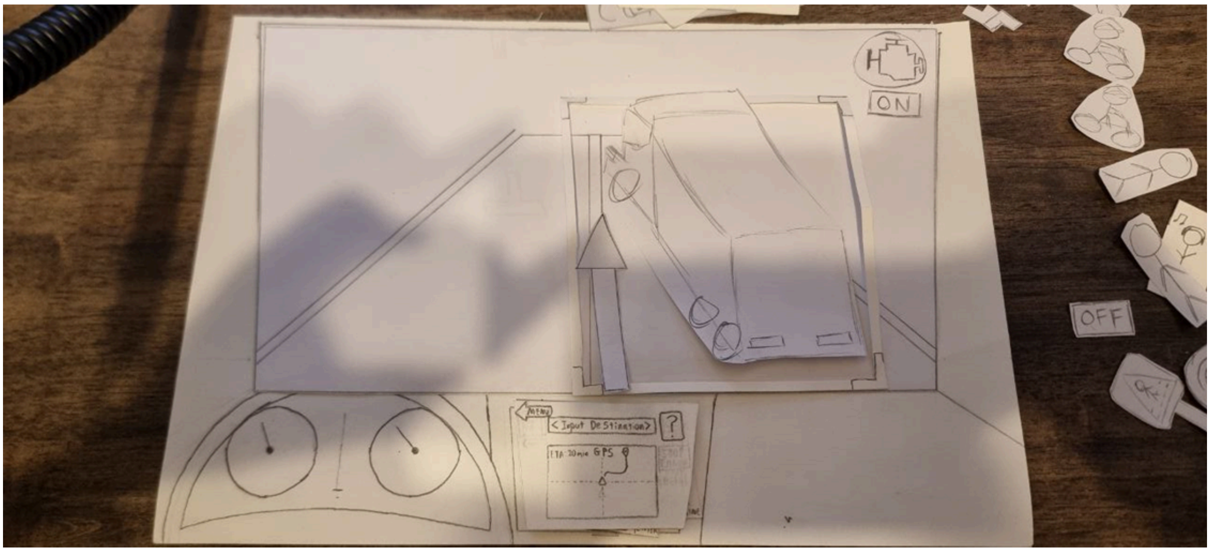


Figure 8: Detecting car

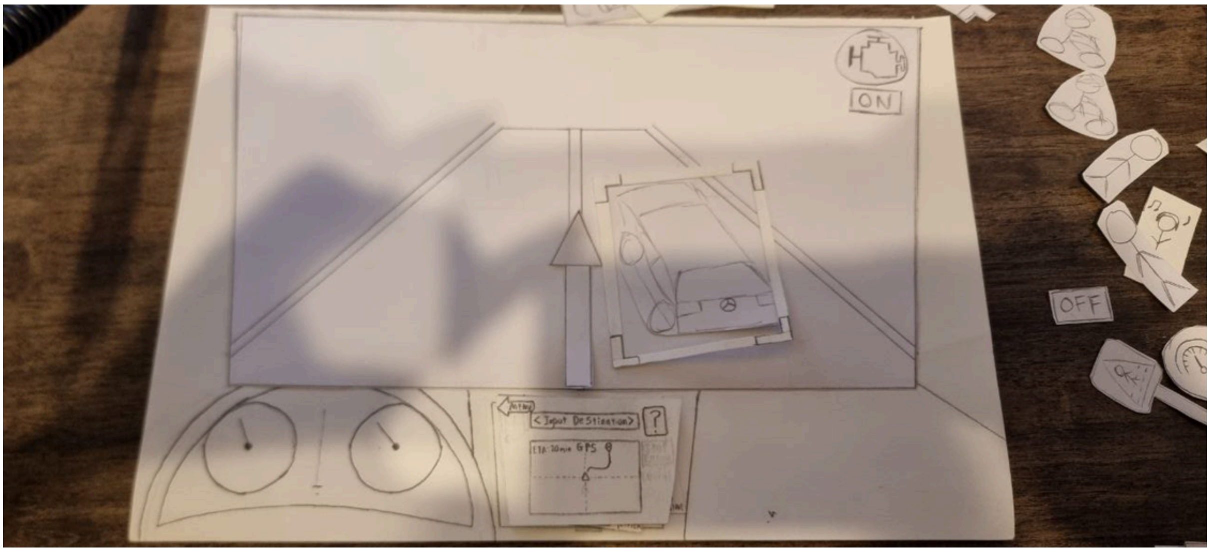


Figure 9: Detecting pedestrian and cyclist and automated car is slowing down

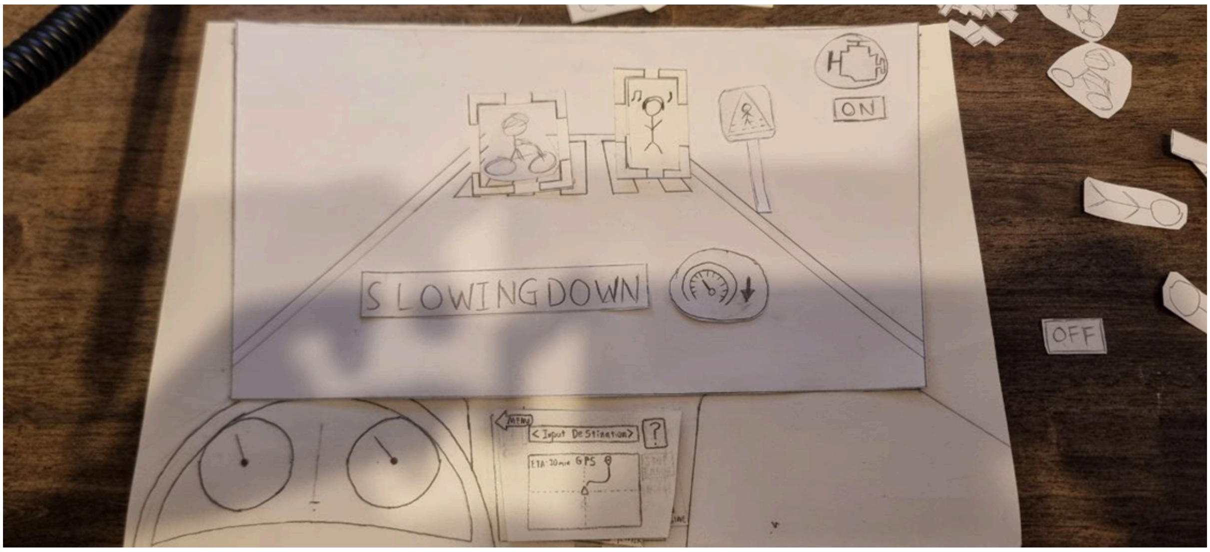


Figure 10: Detected accident

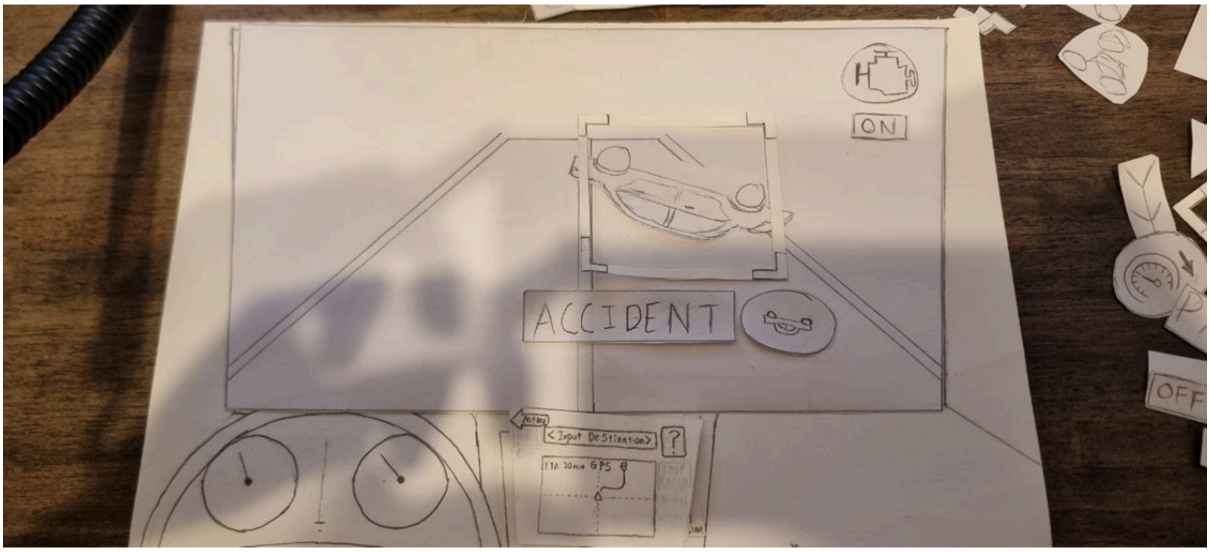


Figure 11: Given user options when detected accident

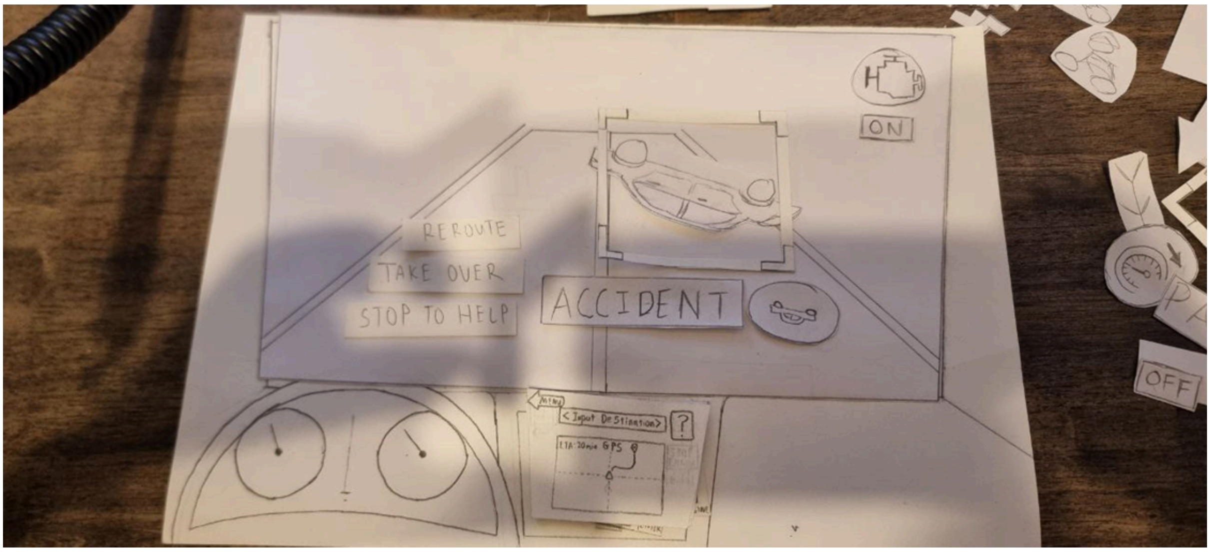


Figure 12: Rerouting options when detected accident

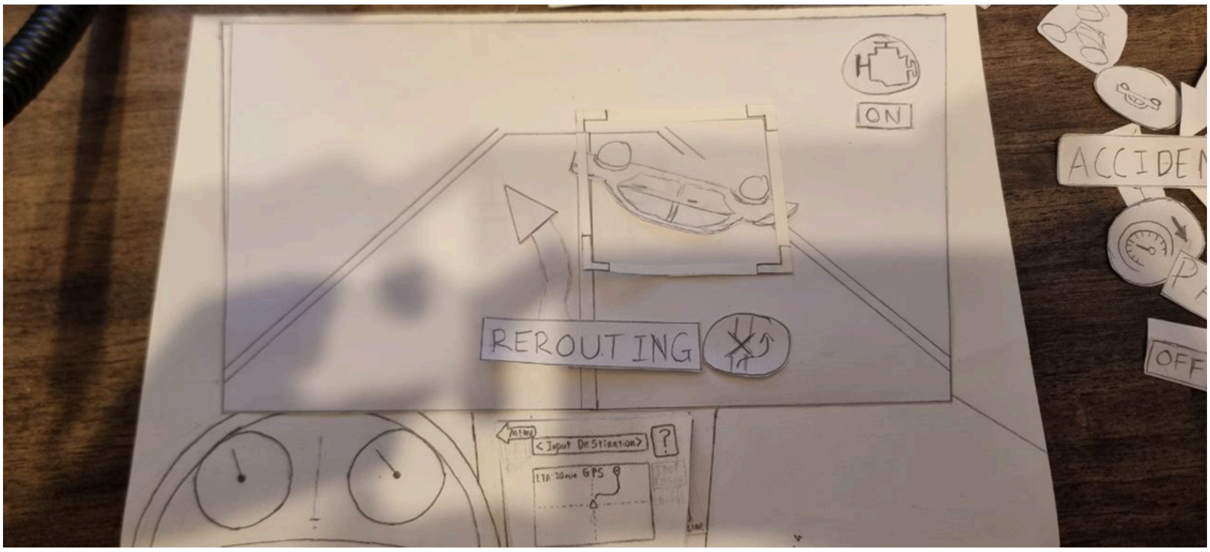


Figure 13: Stopping options when detected accident

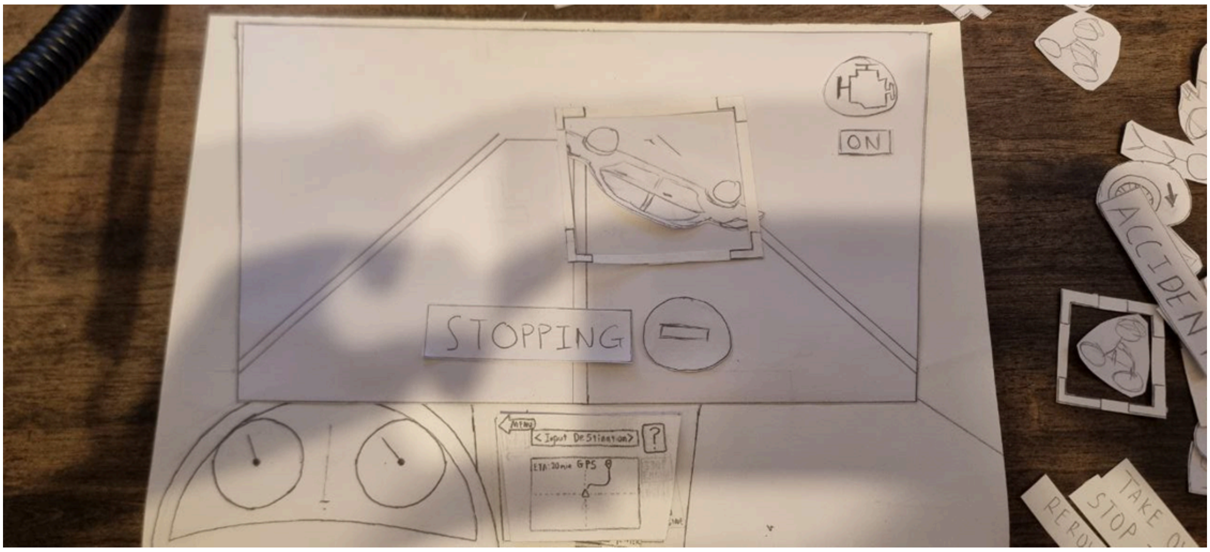


Figure 14: Does not detect pedestrian

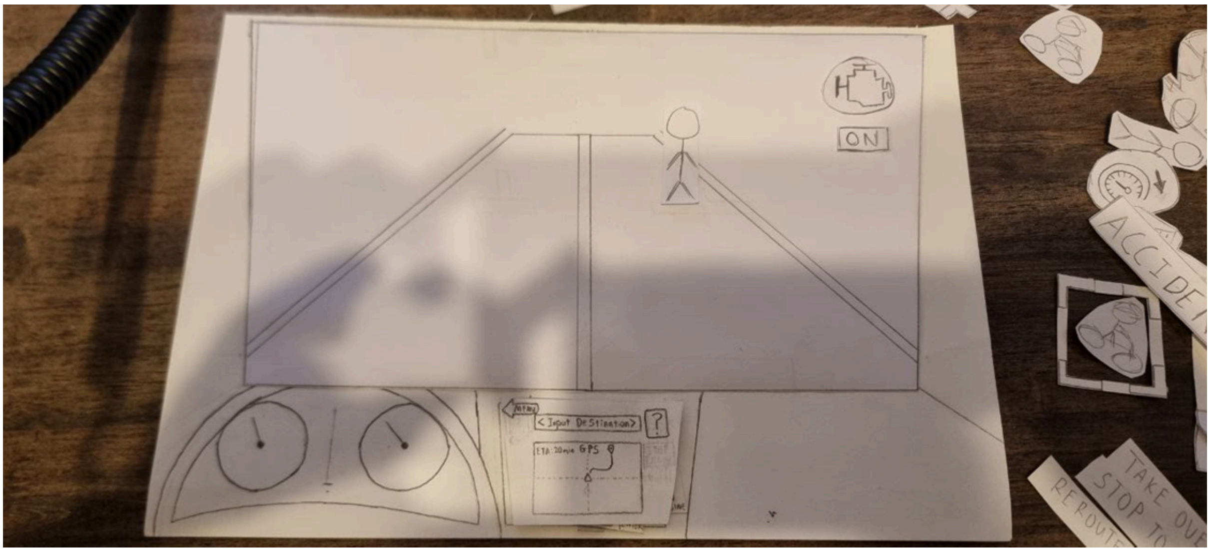


Figure 15: Given command to stop car when pedestrian is not detected

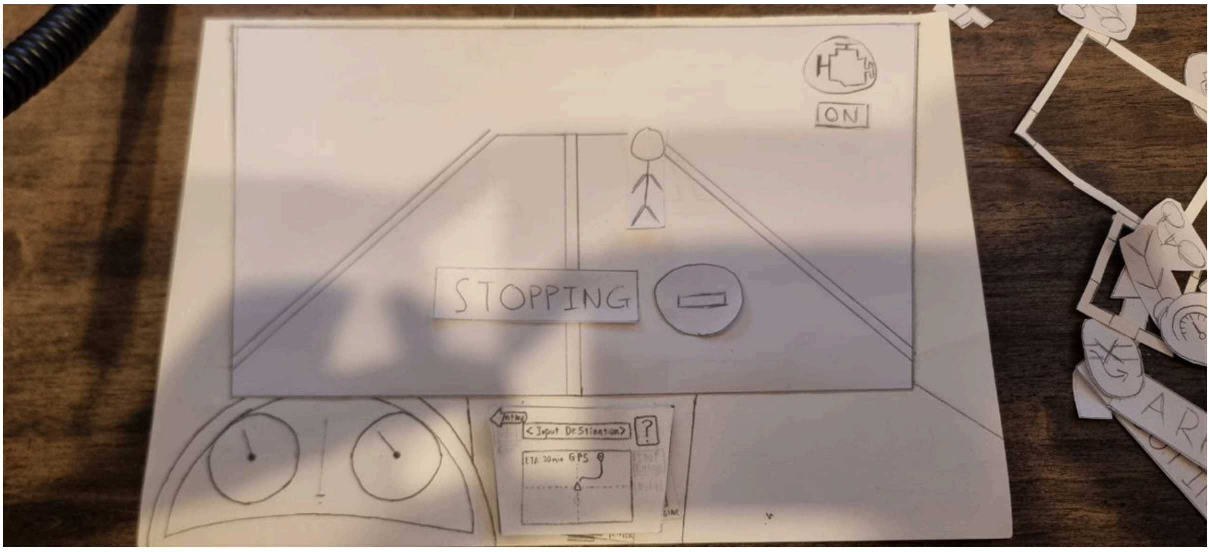


Figure 16: Car is parking

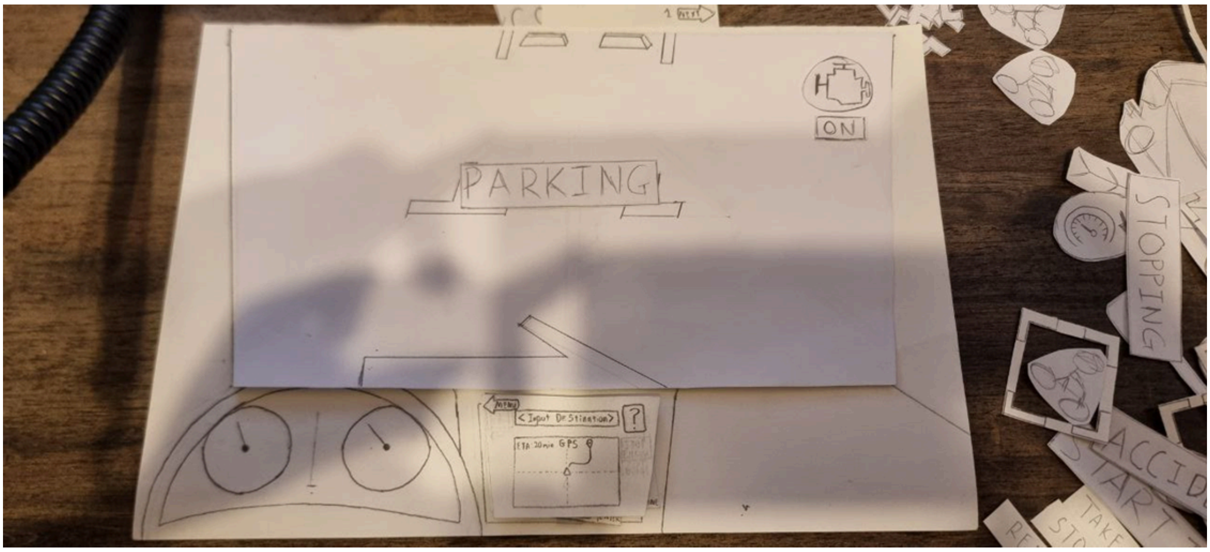


Figure 17: Car is parked

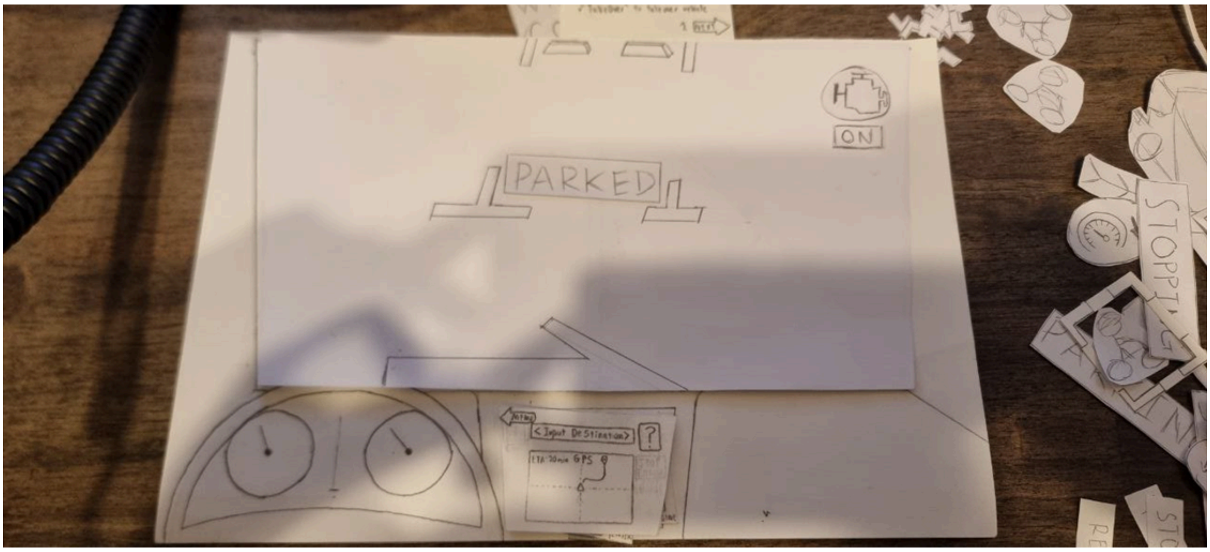
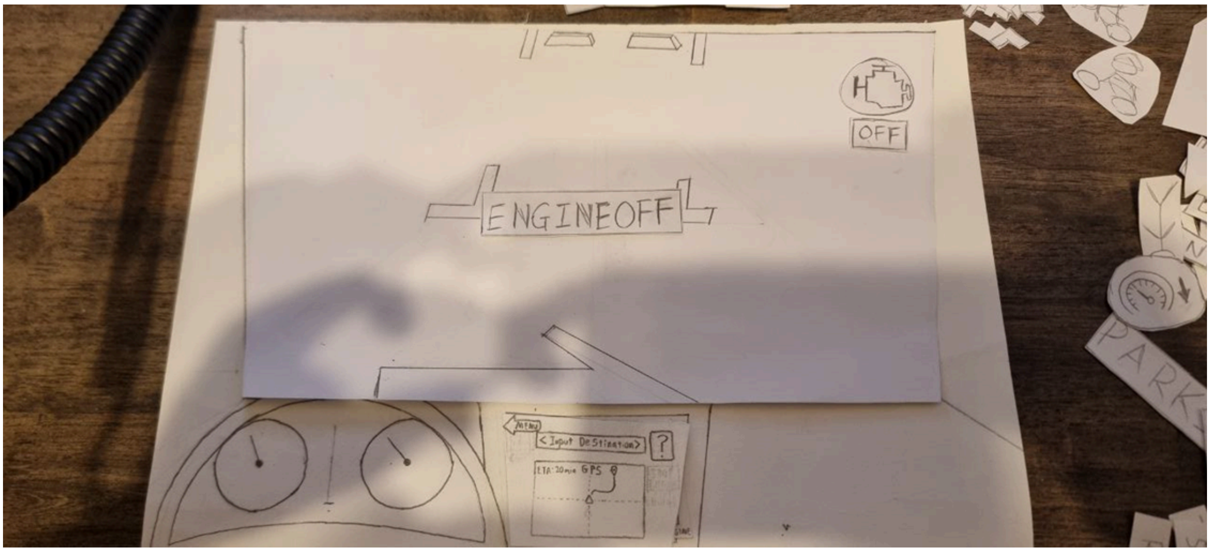


Figure 18: Engine off



Appendix E: Heuristics Evaluation

Table 1: UI experts 1 from Team 30

S/N	Heuristics	Severity Rating	Description
1	Visibility of system status	0	System shows the route and whereabout of the vehicle and marks nearby obstacles
2	Match between system and the real world	0	There are use of icons that perfectly represent the functionalities
3	User control and freedom	0	I can return to the main menu after accessing the functions and there is voice commands for me to give instructions to the vehicle
4	Consistency and standards	0	The system follows a consistent design of the services that can be accessed from the menu
5	Error prevention	1	System marks a pedestrian or a nearby vehicle and performs actions based on the specific situation. If it fails to mark, the user can take over.
6	Recognition rather than recall	0	Main system is on the dashboard of the car and includes a question mark icon on every panel to indicate it is a help guide.
7	Flexibility and efficiency of use	0	User can use voice commands to give instructions to the car
8	Aesthetic & minimalist design	0	Information on the system isn't cluttered and there are ample space to avoid overloading of information
9	Help users recognize, diagnose, & recover from errors	2	Users will be prompted by an error message of using the wrong command at a given situation but not detail.
10	Help & documentation	3	System has command list of voice commands to use but does not have has a instruction manual on how to operate the car

Table 2: UI experts 2 from Team 30

S/N	Heuristics	Severity Rating	Description
1	Visibility of system status	1	The system effectively displays the vehicle's route and location, highlighting nearby obstacles.
2	Match between system	0	The icons used in the interface accurately

	and the real world		represent their respective functionalities, making them easy to understand.
3	User control and freedom	1	Users can easily return to the main menu after accessing different functions, and voice commands are available for providing instructions to the vehicle.
4	Consistency and standards	0	The system maintains a consistent design across the services accessible from the menu, enhancing user familiarity.
5	Error prevention	2	The system identifies pedestrians and nearby vehicles, taking appropriate actions based on the context. If the system fails to detect these objects, the user has the option to intervene.
6	Recognition rather than recall	0	The main system interface is conveniently located on the car's dashboard and features a question mark icon on each panel, providing easy access to help guides.
7	Flexibility and efficiency of use	0	Users have the option to issue voice commands to control the vehicle, enhancing usability and efficiency.
8	Aesthetic & minimalist design	0	The system's information is presented clearly and without clutter, allowing users to absorb the content without feeling overwhelmed.
9	Help users recognize, diagnose, & recover from errors	1	Users receive prompts through error messages if they issue incorrect commands in specific situations, assisting them in correcting mistakes.
10	Help & documentation	0	The system is equipped with an instruction manual and a comprehensive list of voice commands for user reference.

Table 3: UI experts 3 from Team 30

S/N	Heuristics	Severity Rating	Description
1	Visibility of system status	1	Visible system statuses via a HUD on the dashboard and windscreen of vehicle
2	Match between system and the real world	0	The icons used in the interface match their respective functionalities.
3	User control and freedom	2	System has a good level of control via voice inputs but, would prefer more than 1 option for a use case

4	Consistency and standards	3	Navigation of dashboard and voice controls are consistent, but limited.
5	Error prevention	1	Faulty inputs are properly validated by the system
6	Recognition rather than recall	3	Experienced some difficulty understanding what kinds of commands to user for various use cases
7	Flexibility and efficiency of use	3	Efficient for certain cases, but the system is inflexible to other types of use.
8	Aesthetic & minimalist design	0	Clean and rather accessible layout of dashboard/HUD
9	Help users recognize, diagnose, & recover from errors	2	Do not recall much assistance for errors in the system. Just error messages given for invalid inputs.
10	Help & documentation	2	Some documentation provided for types of voice command.

Table 4: UI experts 4 from Team 30

S/N	Heuristics	Severity Rating	Description
1	Visibility of system status	1	Status of the system is displayed properly eg. Engine on/off, Parking, etc. However, there should be an indicator for when the user needs to make a decision.
2	Match between system and the real world	0	Words with matching icons so there's no ambiguity.
3	User control and freedom	0	UI provides many options and controls for the user.
4	Consistency and standards	0	Consistent design across the interfaces.
5	Error prevention	2	When prompting user to make decisions using exclusively voice control based on certain events that occur on the road, the pop ups on the windscreen UI does not indicate use of voice control (hidden affordance), user may try to choose an option via the dashboard instead.
6	Recognition rather than recall	0	Most options are intuitive especially with a help icon to indicate a tutorial/guide for the UI
7	Flexibility and efficiency	0	Options on the dashboard are only one page

	of use		each with a convenient button to return straight to the menu
8	Aesthetic & minimalist design	2	Simple design but UI on the windscreen can get too cluttered. The Dashboard UI for the prototype is too small.
9	Help users recognize, diagnose, & recover from errors	0	Error messages will display and options are provided for the user to remedy the issue.
10	Help & documentation	0	Tutorial for voice command is provided at the start to show what commands are available.

Table 5: UI experts 5 from Team 30

S/N	Heuristics	Severity Rating	Description
1	Visibility of system status	0	The prototype displayed standard feedback to users that included real-time object detection capability. For instance, “Truck Detected’, “Engine On/Off”.
2	Match between system and the real world	0	The prototype fully embraced the real world aspects as though it was a regular automobile except with autonomous capability.
3	User control and freedom	1	There was a manual takeover but unclear whether there are any undo or modify options.
4	Consistency and standards	3	There were overlaps between verbal commands and physical commands like touching the screen.
5	Error prevention	3	To a certain extent there were error preventions however, in an autonomous vehicle I expected that there was no need for me to execute many commands however the prototype still relies on the user extensively.
6	Recognition rather than recall	3	There were command lists for different commands that can be executed but it was not exactly user friendly to find the command list.
7	Flexibility and efficiency of use	4	To a great extent, but I feel that efficiency can be improved by streamlining certain actions such as using voice commands for common actions like starting the vehicle.
8	Aesthetic & minimalist design	3	Main screen was filled with different functions which was confusing for me at the first glance.
9	Help users recognize, diagnose, & recover from errors	0	The prototype was able to identify and recognize accidents ahead and alert me ahead of time.
10	Help & documentation	3	The “?” could be misleading as I did not expect to see the command list under the icon

			initially.

Table 6: UI experts 6 from Team 30

S/N	Heuristics	Severity Rating	Description
1	Visibility of system status	3	There were visible system status at every stage. It was not clear what the boxes meant, but I can infer that it's from
2	Match between system and the real world	0	It felt like I was in the driver seat of the car
3	User control and freedom	0	There's some pre-built options to suggest to the user. Able to take over the vehicle if wanted to.
4	Consistency and standards	2	Some stuff are voice activated while some stuff are operated via the control panel.
5	Error prevention	3	There are some error mitigations, but I had to tell the vehicle to slow down and reroute when it approached an accident. I missed the cue for that.
6	Recognition rather than recall	3	I could not remember the voice commands when I needed them. They were only flashed for a brief amount of time
7	Flexibility and efficiency of use	0	Voice commands made everything easy to use
8	Aesthetic & minimalist design	0	Control panel was not cluttered. I did not like labels popping up on my windscreen and blocking my sight of the traffic condition
9	Help users recognize, diagnose, & recover from errors	0	Car has built in systems to help reroute and accommodate for a fair amount of scenarios
10	Help & documentation	4	Clicking on voice commands brings up what I can do with voice commands. But I don't see any external operator help in case the built-in voice command in the car cannot handle the situation.

Appendix F: Think Aloud Video

Team 43 Think Aloud. (n.d.). https://youtu.be/GijoIBWNdGA

Appendix G: Think Aloud Usability Script

Table 1: Usability Script

Introduction
Welcome, and thank you for participating in this usability test. Today, you'll be testing an autonomous vehicle (AV) system, and we'll be guiding you through a series of interactions with the vehicle. The goal is to evaluate the user experience as well as the system's responses to your commands and external events.
Objective
During this test, you will: 1. Start the AV. 2. Input and confirm a destination. 3. Use commands to interact with the AV. 4. Observe the AV's reactions to obstacles, pedestrians, and road incidents. 5. Successfully reach your destination and park. Please note that for safety, this is a simulation, and no real driving will occur.
Test Instructions
❖ Starting the Car ➢ Prompt: Begin by issuing the command, "Start the car." ➢ Expected Response: The AV should acknowledge with, "Car is starting." ➢ Observer Note: Ensure the user notices the confirmation message. ❖ Inputting Destination ➢ Prompt: You will now input your destination. ➢ Action: Type or say the desired destination. ➢ Expected Response: The AV will confirm by asking, "Confirm input destination." ➢ User Action: Confirm the destination by selecting "Yes" or verbally confirming. ➢ Observer Note: Record if the confirmation process is intuitive and clear. ❖ Beginning Movement ➢ Prompt: Once the destination is confirmed, the AV will start moving. ➢ Expected Response: The vehicle begins moving towards the destination.

- Viewing Available Commands
    - Prompt: Ask the AV to display a list of available commands. You may do this by saying, “Display commands” or by selecting a “Commands” option on the interface.
    - Expected Response: The AV will display a list of commands that you can issue while in transit (e.g., “Slow down,” “Stop,” “Change lane”).
    - Observer Note: Make sure the user finds the command list easy to access and interpret.
- Detecting Nearby Vehicles
    - Prompt: Observe as the AV detects moving cars in front. The AV should adjust speed as needed.
    - Expected Response: The AV shows awareness of nearby vehicles, adjusting speed and maintaining a safe distance.
    - Observer Note: Note the user’s response to the AV’s actions and whether they feel comfortable with the AV’s proximity handling.
- Slowing Down for Obstacles
    - Scenario: The AV detects an obstacle ahead.
    - Expected Response: The AV slows down to avoid the obstacle.
    - Observer Note: Observe if the user feels confident that the AV has detected and responded to the obstacle in time.
- Handling Pedestrian Crossings
    - Scenario: The AV detects a zebra crossing with a pedestrian.
    - Expected Response: The AV should automatically slow down and stop to allow the pedestrian to cross.
    - Observer Note: Ask the user if they felt the AV responded appropriately. Check for any signs of hesitation or discomfort.
- Resuming Travel
    - Prompt: After the pedestrian has crossed, the AV should continue moving towards the destination.
    - Expected Response: The AV resumes travel smoothly.
    - Observer Note: Note if the user feels the transition from stopping to resuming travel is smooth and natural.
- Reacting to a Road Accident
    - Scenario: The AV detects an incoming road accident ahead.
    - Expected Response: A message should appear on the windscreen, stating, “Road Accident detected.” The AV slows down and manoeuvres to safely continue the journey.
    - Observer Note: Observe the user’s reaction to the warning message. Ask if they feel reassured by the AV’s response to the incident.
- Arriving at Destination
    - Prompt: The AV announces that it has reached the destination.
    - Expected Response: The AV stops and asks for the next action.
- Parking the Car
    - Prompt: Command the AV to park in an available slot. You can say, “Park the car” or select the parking option.
    - Expected Response: The AV parks itself in a nearby available slot.

➢ Observer Note: Note the user's response to the parking process. Ask if they felt the AV parked smoothly and in a timely manner.

Appendix H: Think Aloud Task List

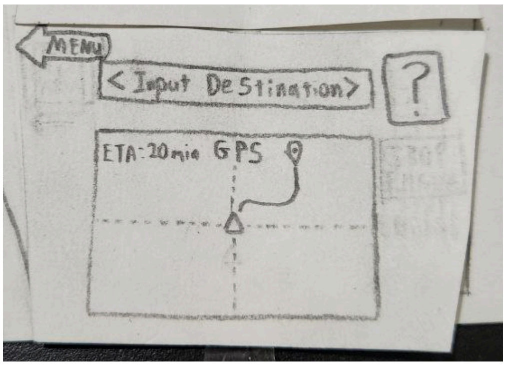
Table 1: Task List

Task List
1. Start the car/engine
2. Input destination
3. Viewing available voice commands on the windscreen
4. Response to AV not detecting obstacles (Pedestrians)
5. Respond to traffic accidents (Possible actions to choose from is labelled on the WindScreen)
6. Parking the Car
7. Turn off engine

Appendix I: Prototype Changes

Figure 1: Change Question Mark symbol to "Microphone" symbol

Before *After*



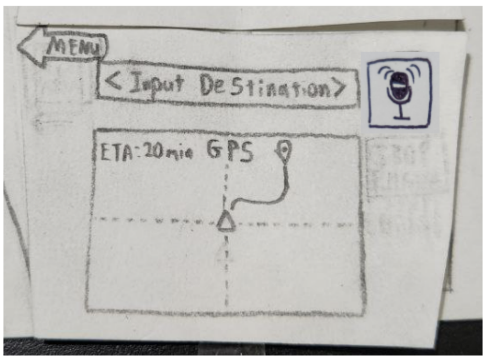


Figure 2: State clearly at the bottom of the command List "Click back to Menu to close Command List"

Before *After*

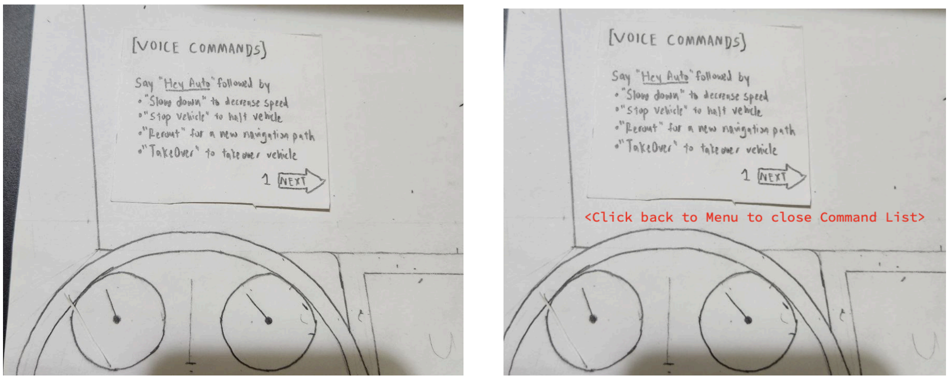


Figure 3: Instructions on the windscreen to choose Action via voice command

Before *After*

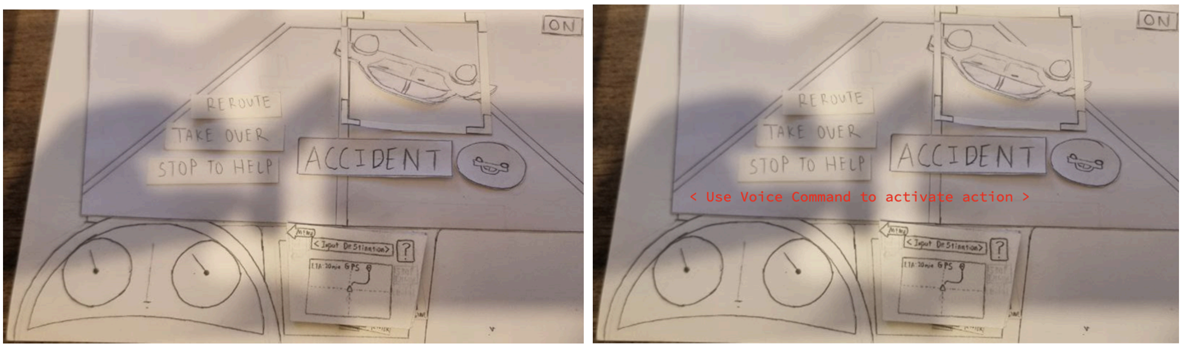


Figure 4: Prompted on the windscreen to use voice command to initiate parking

Before *After*

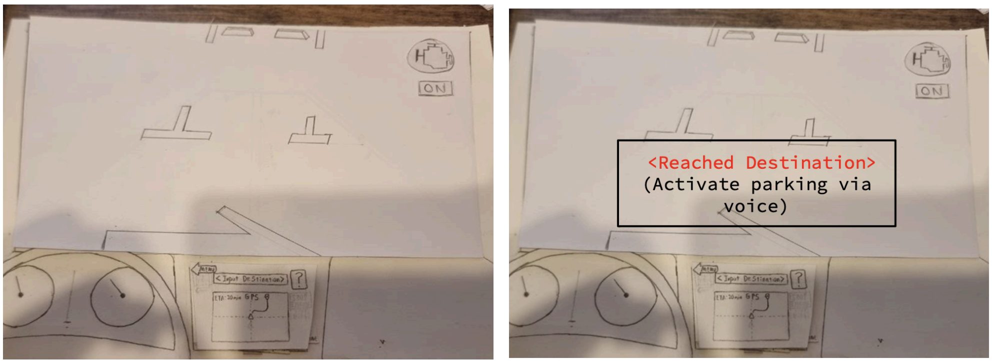
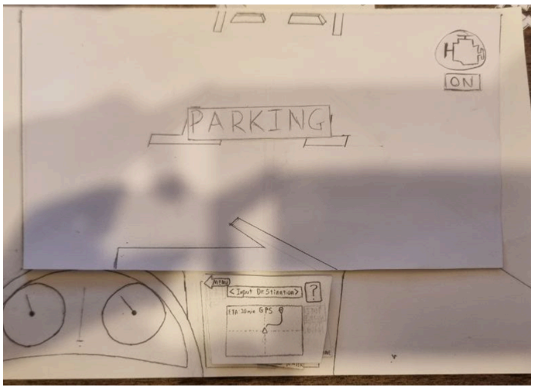


Figure 5: Engine control can only be done in the main menu

Before *After*



Appendix J: Implementation

Figure 1: Experiment ‘A’ and ‘B’ start

Figure 2: Experiment ‘A’ dashboard ‘Engine Off’

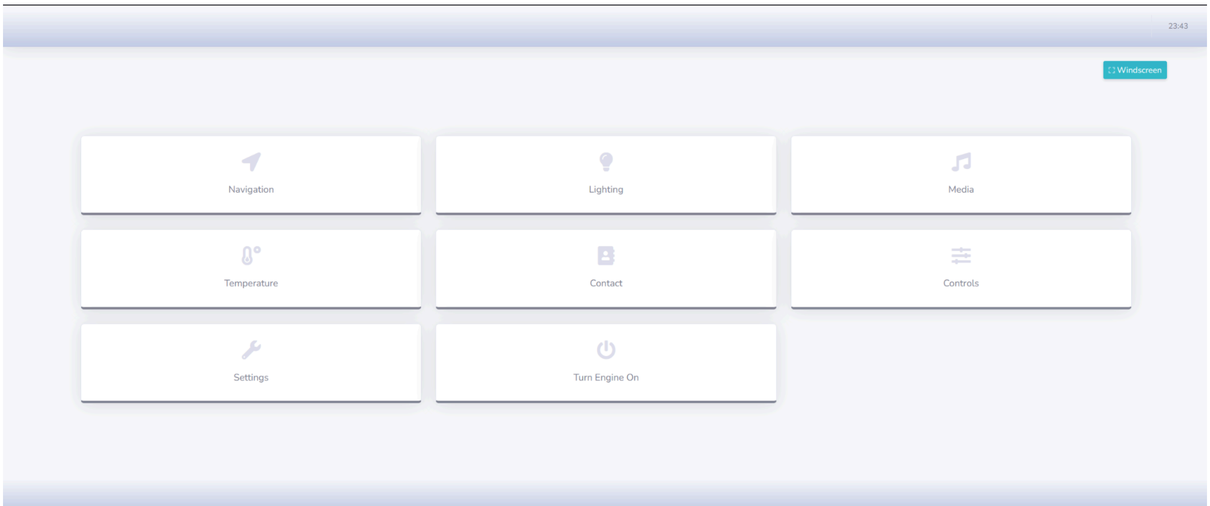


Figure 3: Experiment 'A' & 'B' Starting Engine

Figure 4: Experiment 'A' & 'B' Navigation 1

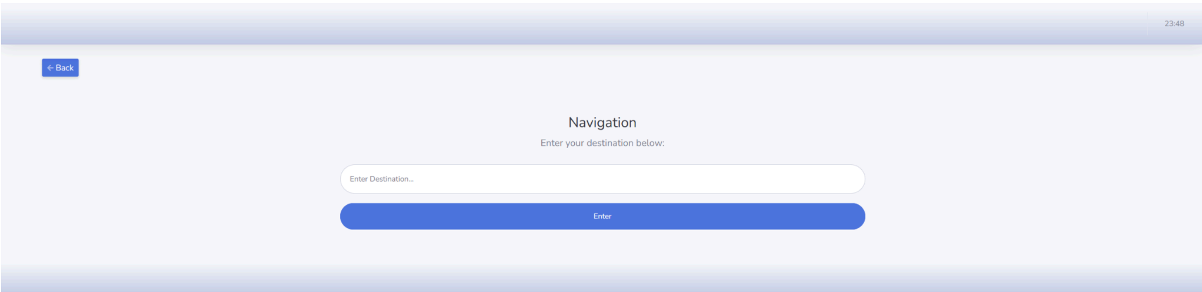


Figure 5: Experiment 'A' & 'B' Navigation 2

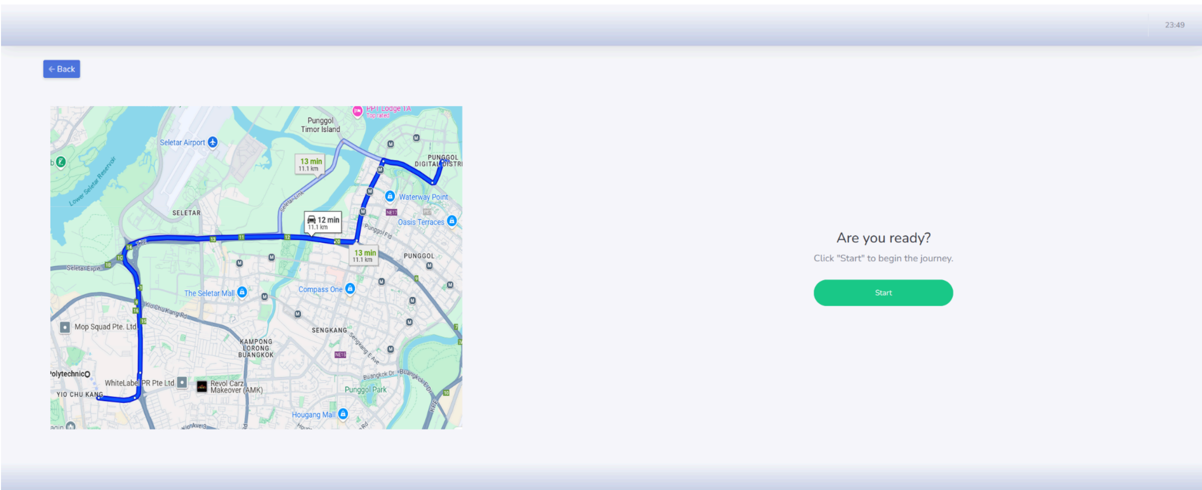


Figure 6: Experiment 'A' & 'B' Navigation 3

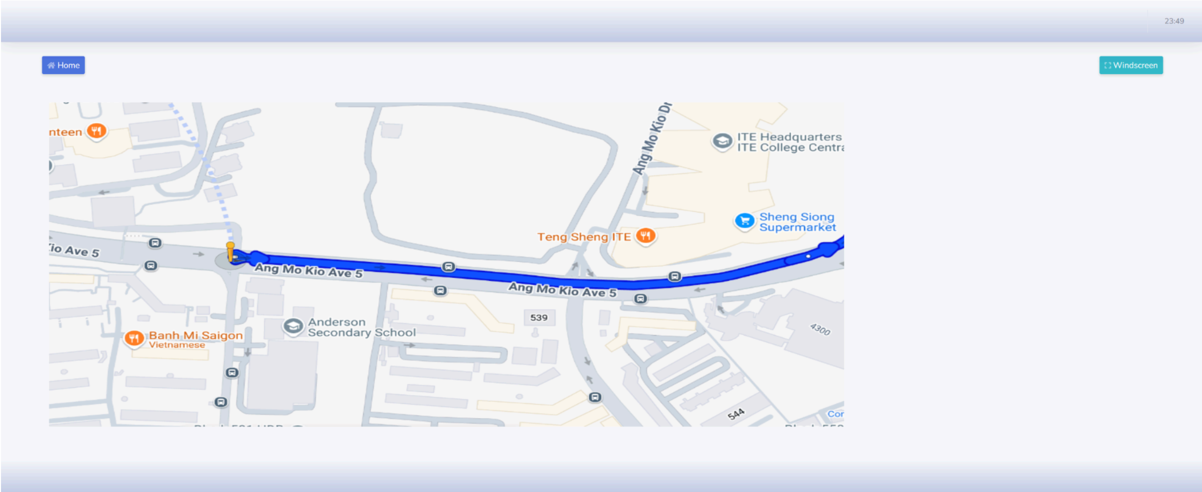


Figure 7: Experiment 'A' Detecting

Figure 8: Experiment 'A' Detecting Accident

Figure 9: Experiment 'A' Car Parking

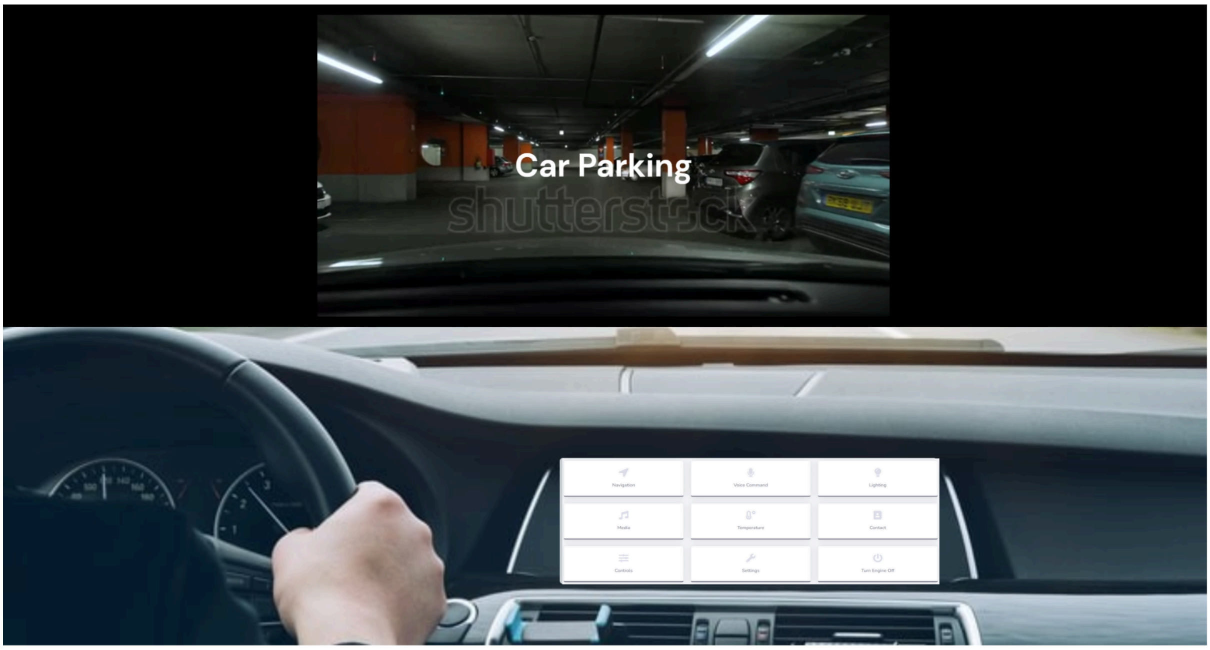


Figure 10: Experiment 'A' Car Parked

Figure 11: Experiment 'B' Detecting

Figure 12: Experiment 'B' Detecting Accident

Figure 13: Experiment 'B' Car Parking

Figure 14: Experiment 'B' Car Parked

Figure 15: Experiment 'A' & 'B' Engine Off

Appendix K: Implementation Demo

HCI Team 43 Demo. (n.d.). https://www.youtube.com/watch?v=jtfR3XbrflI

Appendix L: Experimentation Consent Form

Figure 1: Consent form

PARTICIPANT CONSENT FORM

The consent form is to participate in the INF2002 Human Computer Interaction project conducted by second year undergraduate students in the Singapore Institute of Technology, as a part of their project coursework.

The objective of the project is to: Conduct an experiment on Autonomous Vehicle user interface.

- Augmented Reality windscreen display
- In-vehicle display

The implementation of the above application is complete and the team is at the stage of evaluating the final software product.

Participants are required to go through a series of tasks on how to operate the Autonomous Vehicle in 2 different versions. At the end of the experiment, they will complete a short survey to indicate which version they prefer.
Please note that it is the web application/functionality we are evaluating and not your technical skills.

DATA PRIVACY

(Please change accordingly to suit your evaluation)

- All the personal information (i.e. the email address), and the uploaded content (images and videos) will be stored in a secure server in the Singapore Institute of Technology, with the access restricted to only the people involved in this project. This data will not be shared with any third-party or used for commercial purposes.

- Your answers to the questionnaires will be made anonymous and held in strict confidence, and stored in a password protected computer in the Singapore Institute of Technology. The access will be restricted to only the people involved in this project. This data will not be shared with any third-party or used for commercial purposes. All the paper data (including notes) will be also kept secured.

- Personal information will not be recorded, except your email id and demographic information (i.e. gender). The email id will be used to contact you, during the duration of the evaluation and participation in the future research projects. The anonymous demographic information will be used for the purpose of evaluation only. The aforementioned information will not be shared with any third-party or used for commercial purposes.

You may withdraw from the experiment at any time without prejudice, and any data already recorded will be both discarded and deleted. If you have any further questions please send an email to: 2300874@sit.singaporetech.edu.sg

Figure 2: Participate 1 consent form

Full Name of the participant: Joel Koh

Contact Email: -

Signature: Joel

Date:

Figure 3: Participate 2 consent form

Full Name of the participant: Boon Yew

Contact Email: -

Signature:

Date: 22/11/2024

Figure 4: Participate 3 consent form

Full Name of the participant: Khoo Jun Ye

Contact Email: -

Signature:

Date: 22/11/2024

Figure 5: Participate 4 consent form

Full Name of the participant: Stephen Seah

Contact Email: -

Signature:

Date: 22/11/2024

Figure 6: Participate 5 consent form

Full Name of the participant: Shifa

Contact Email: -

Signature: *Shifa*

Date: 22/11/2024

Figure 7: Participate 6 consent form

Full Name of the participant: Deva

Contact Email: -

Signature: *Kumar*

Date: 22/11/2024

Figure 8: Participate 7 consent form

Full Name of the participant: Daniel Lip

Contact Email: -

Signature: *Daniel*

Date: 22/11/2024

Figure 9: Participate 8 consent form

Full Name of the participant: Tan Yong Sheng

Contact Email: -

Signature: *Sheng*

Date: 22/11/2024

Figure 10: Participate 9 consent form

Full Name of the participant: Lim Kuan Yong

Contact Email: -

Signature: *Kuanyong*

Date: 22/11/2024

Figure 11: Participate 10 consent form

Full Name of the participant: Darren Ho

Contact Email: -

Signature:

Date: 22/11/2024

Appendix M: Experimentation Task Information

Table 1: Task Information Sheet

Task information sheet
Evaluating the interface: In this stage, you need to complete the following tasks, either Experiment A or Experiment B depending on the one you chose:
Task 1: Choose the choice of the experiment
Task 2: Starting the AV
Task 3: Choosing or inputting the destination you want
Task 4: Observing the AV's reactions to obstacles, pedestrians and road incidents
Task 5: Parking the AV
Exit survey: In this stage, you will be answering a short questionnaire. The questionnaire will document your feedback regarding to the user interface of the AV. This may take around 2-5 minutes. The questionnaire will be used for the purpose of research. ***Please note that it is the user interface of the AV we are evaluating and not your driving skills.***

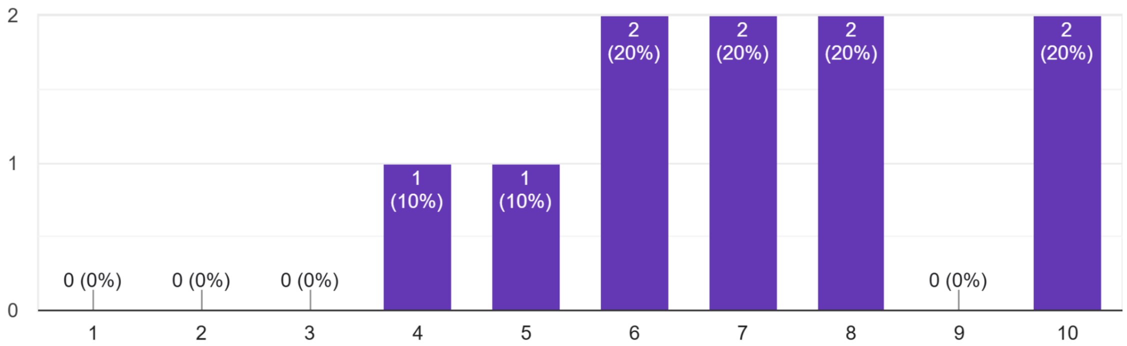
Appendix N: Experimentation Survey Result

Figure 1: Survey result on participate satisfaction level

In-vehicle display

On a scale of 1 to 10, how satisfied were you with the in-vehicle display?

10 responses



Augmented reality display

On a scale of 1 to 10, how satisfied were you with the augmented reality display?

10 responses

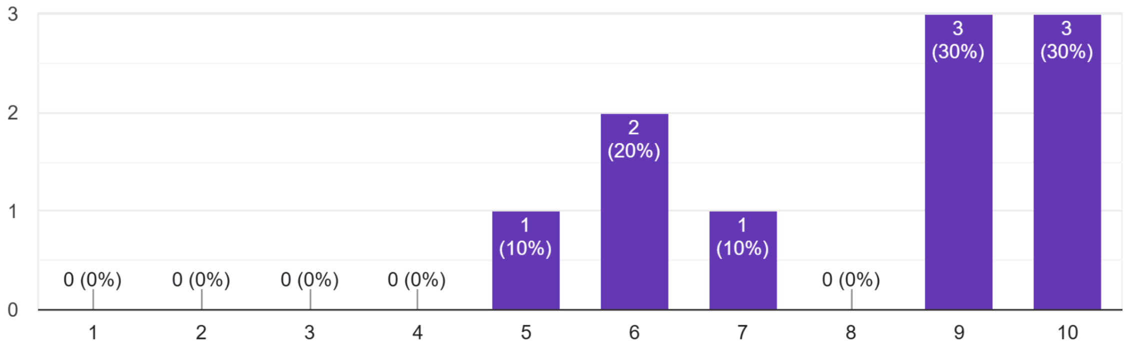
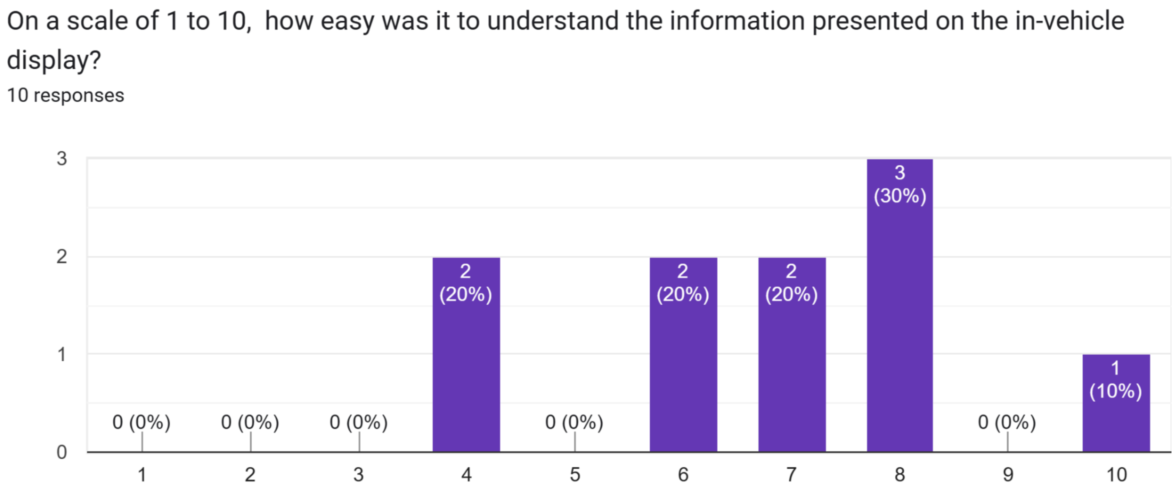


Figure 2: Survey result on understanding the information presented

In-vehicle display



Augmented reality display

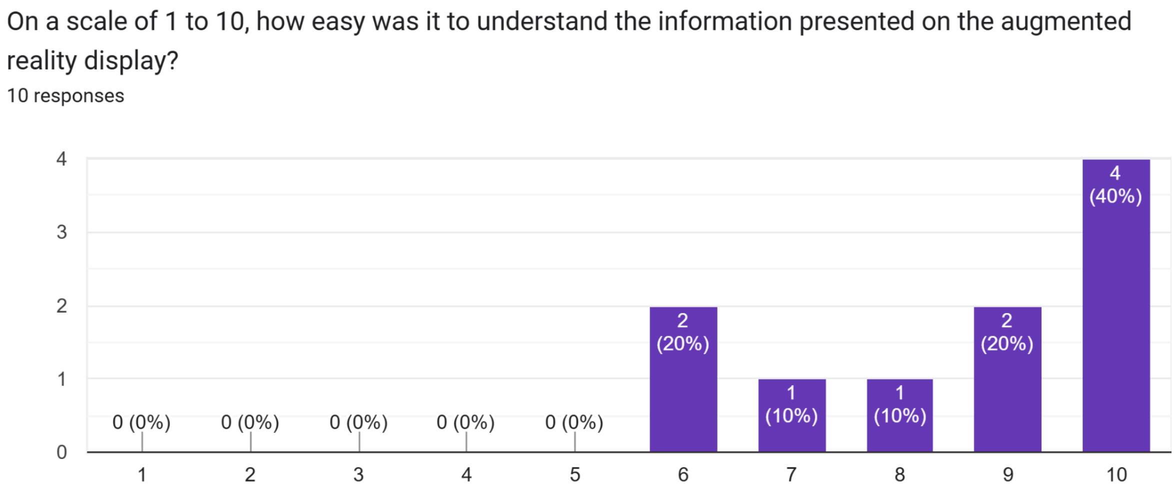
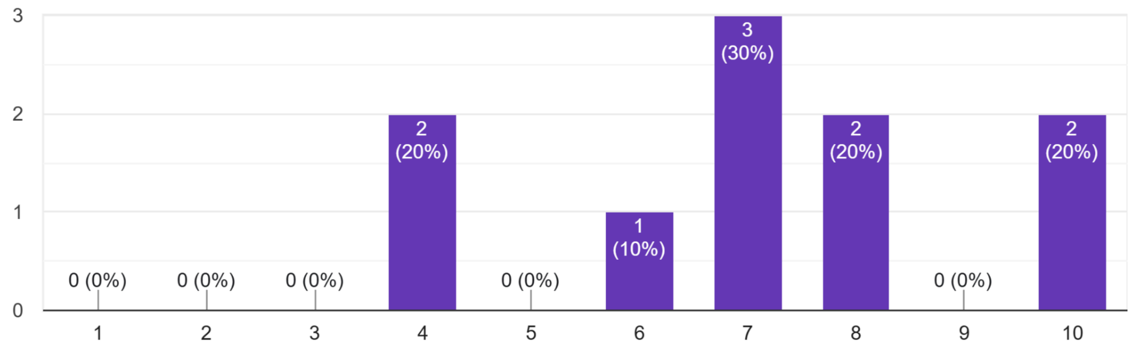


Figure 3: Survey result on clarity of information presented

In-vehicle display

On a scale of 1 to 10, how clear was the information displayed on the in-vehicle display screen?
10 responses



Augmented reality display

On a scale of 1 to 10, how clear was the information displayed on the augmented reality screen?
10 responses

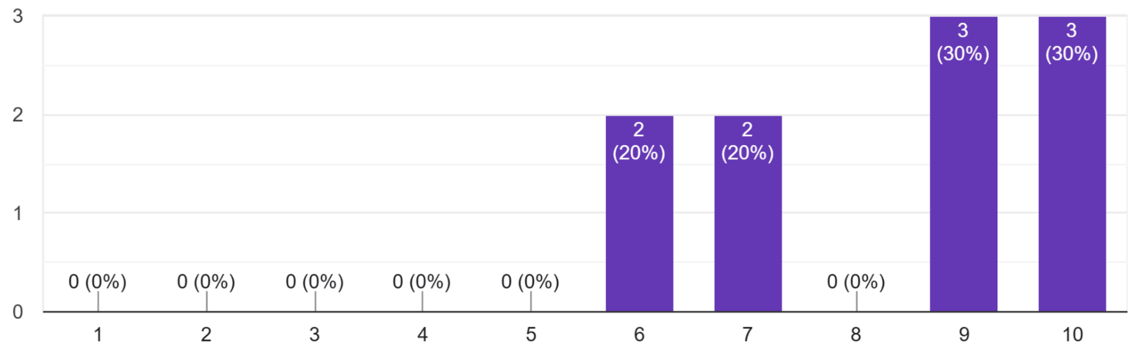
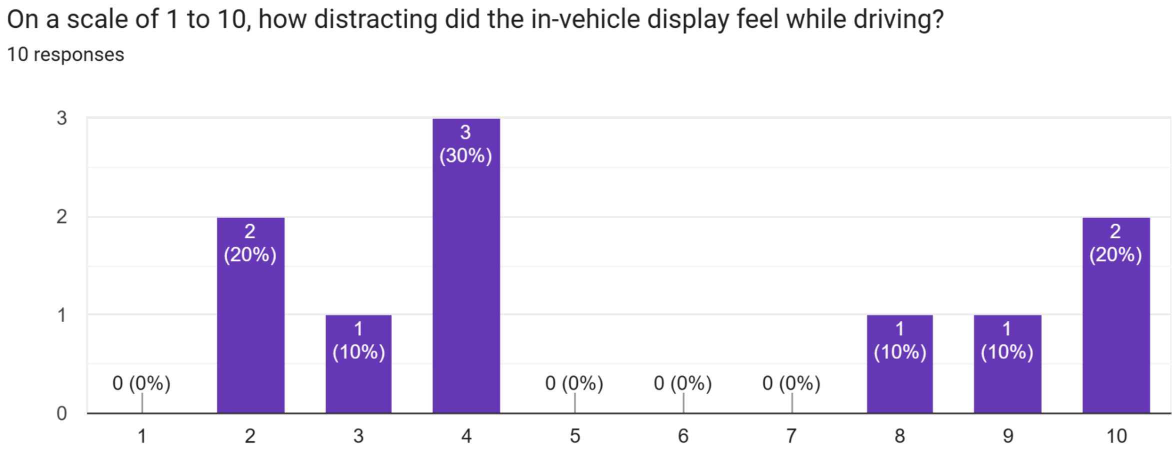


Figure 4: Survey result on distraction while driving

In-vehicle display



<u>Augmented reality display</u>

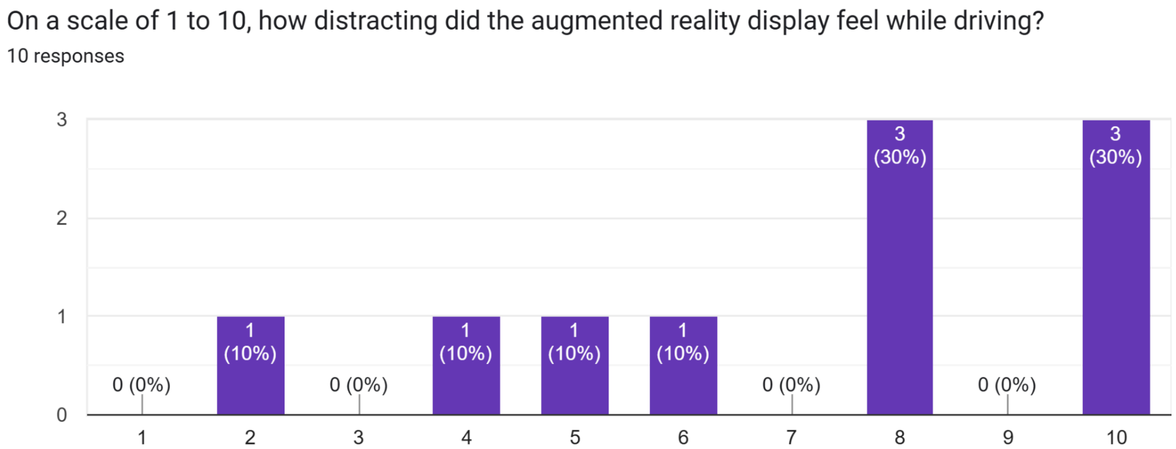
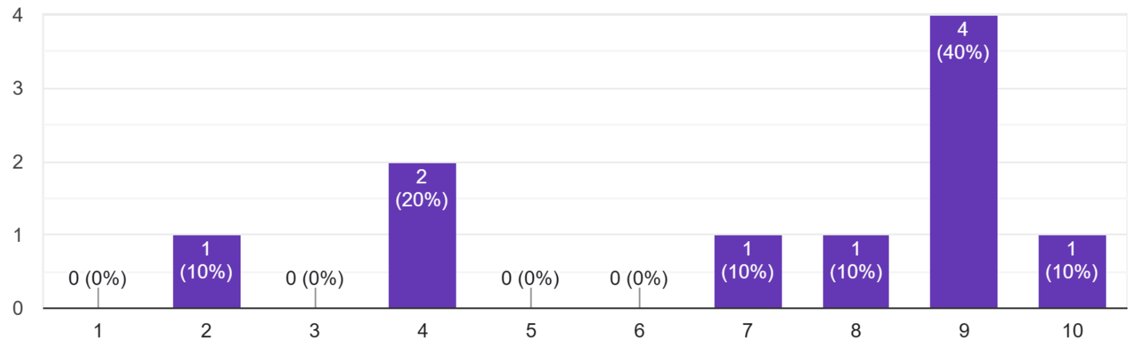


Figure 5: Survey result on maintaining focus on the road

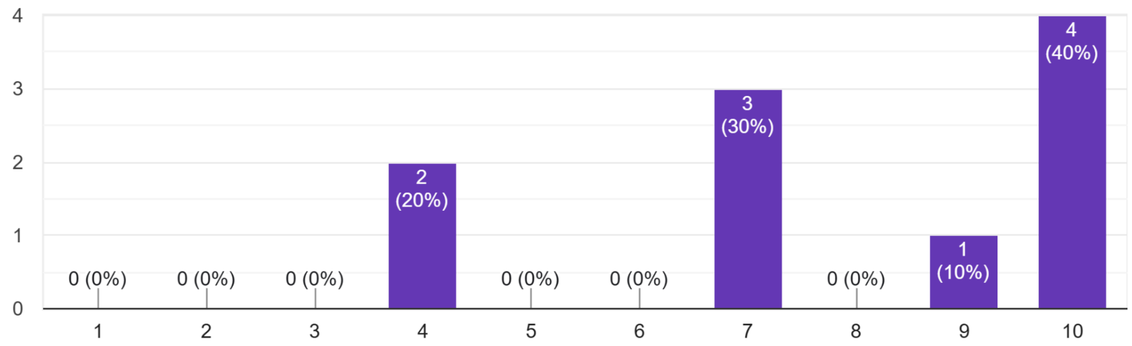
<u>In-vehicle display</u>

On a scale of 1 to 10, how easy was it to maintain focus on the road while using the in-vehicle display?
10 responses



<u>Augmented reality display</u>

On a scale of 1 to 10, how easy was it to maintain focus on the road while using the augmented reality display?
10 responses



Appendix O: Experimentation Result

Figure 1: Calculation of Z and p-value

$$W = \mathrm{Min}(W-, W+)$$

$$W = \mathrm{Min}(8.5, 27.5) = 8.5$$

$$\mu = \frac{n(n+1)}{4} = \frac{8(8+1)}{4} = 18$$

$$\sigma^2 = \frac{n(n+1)(2n+1)}{24} = \frac{8(8+1)(2*8+1)}{24} = 7.1063^2$$

The normal approximation is: $W \sim N(18, 7.1063^2)$

$$Z = \frac{27.5 - 18 - 0.5}{7.1063} = 1.2665$$

$$p = p(x \leq 1.2665) = 0.8973$$

$$\text{p-value} = 2 * \mathrm{Min}(p, 1 - p) = 2 * \mathrm{Min}(0.8973, 0.1027) = 0.2053$$

Figure 2: Calculation of effect size

The variable 'n' represents the number of pairs with a non-zero difference (some people use 'n' as the total number of observations, which is double the number of pairs).

$$r = \frac{Z}{\sqrt{n}}$$

$$r = \frac{1.2665}{\sqrt{8}} = 0.4478$$

$$f = \frac{2W}{n(n+1)}$$

$$f = \frac{2*8.5}{8(8+1)} = 0.2361$$

Figure 3: W statistics

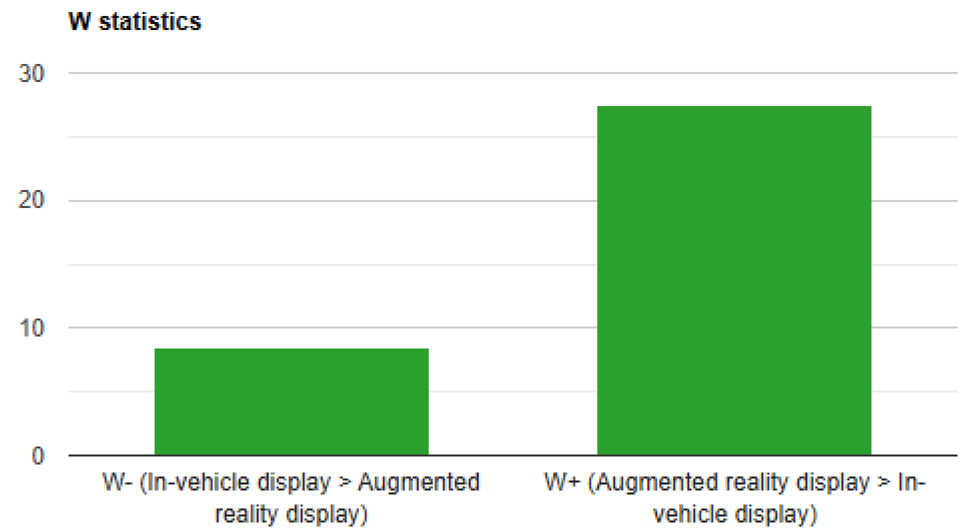
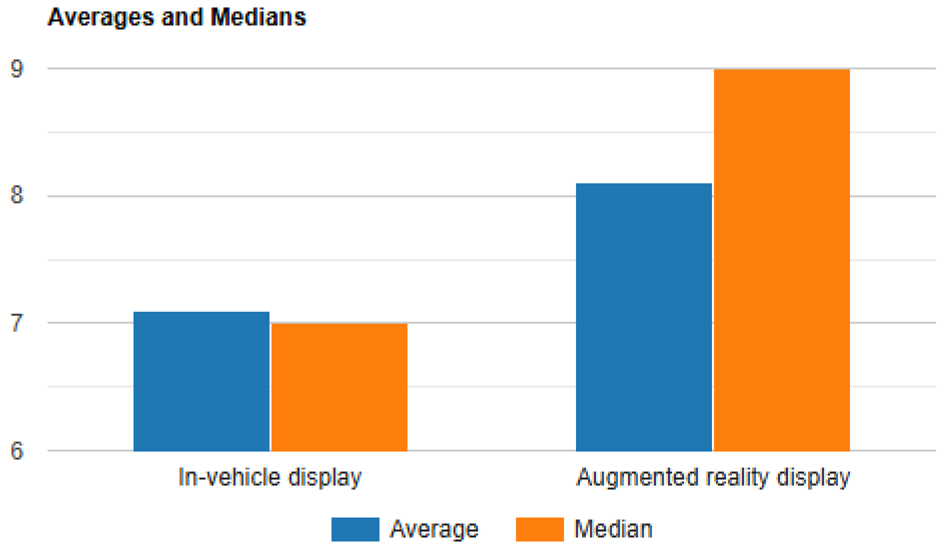


Figure 4: Averages and Medians


Averages and Medians
9
8
7
6
In-vehicle display
Augmented reality display
Average
Median