# Glide

## Shared Control for a Comfortable Drive

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# INTRODUCTION

## Introduction

The rapid advancement of automated vehicle (AV) technology is reshaping the landscape of transportation, promising increased safety, efficiency, and accessibility [1] [2] [3]. However, as vehicles transition from being human-driven to being automated systems, challenges are introduced one of which is the need to design interfaces that empower all passengers and enhance their trust in AVs.

AVs can operate independently of a driver. They allow passengers to focus on non-driving related activities such as reading, watching movies, or working. To ensure passengers feel at ease and retain a sense of control over their journey, it is crucial to provide them with some level of influence over the driving experience.

In traditional vehicles, the driver holds complete authority over the vehicle's behaviour. On the other hand, in AVs, the vehicle is in control, hence, introducing the potential for new control distribution models where control is shared among all occupants.

This thesis investigates the role of tangible interfaces in providing an increased experienced control by all passengers, by offering a promising alternative to purely graphic or voice-based systems. Tangible interfaces have been shown to enhance situational awareness and engagement in a range of applications, especially in combination with haptic feedback [4].

Through extensive research, ideation, and prototyping, this thesis proposes and evaluates the novel interaction concept 'Glide'. This concept allows passengers to adjust the driving behaviour of AVs using a tangible interface, while maintaining a fair distribution of control. The outcome of this work contributes to the broader discourse on human-vehicle interaction by proposing a concept which can act as a steppingstone for further research into shared control between passengers of AVs.

## Design Goal

The goal of this project is to develop a concept that gives AV passengers a **sense of perceived control** over the vehicle's **driving behaviour**. The concept will culminate in a **graphic and tangible interactive interface** that allows passengers to **provide input** and therefore **enhance their comfort and trust** in the automated driving experience.

## Design Process

In this project, I followed a goal-driven, non-linear design methodology, stepping away from conventional linear frameworks like the Double Diamond or more structured phases of Design Thinking [5][6]. Although my process drew inspiration from Design Thinking principles - empathy, iteration, and user-centeredness - it was adapted to support the parallel development of three interconnected components. This allowed for iterative insights, informing and refining each other.

While my approach shares some similarities with Design Thinking it differs in structure. Design Thinking often follows a more step-by-step progression through stages. Instead, my process was more flexible, and elements were worked out in parallel. For instance, insights made while prototyping the tangible interface directly impacted the design of the digital interface, while technical limitations influenced the interaction possibilities for both. This adaptation was intentional, as it allowed me to respond dynamically to new insights and challenges, rather than adhering to a fixed, predetermined sequence of stages.

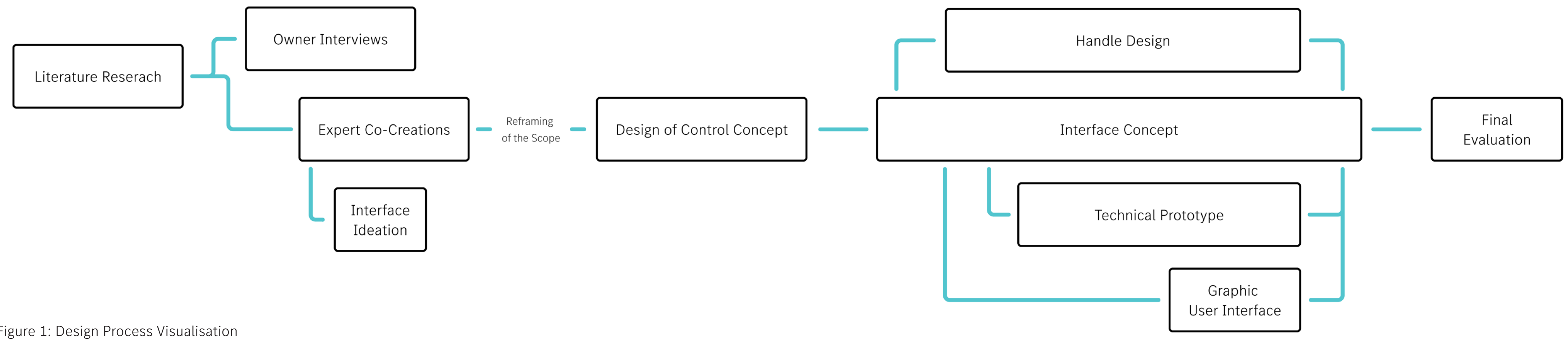


Figure 1: Design Process Visualisation




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# RELATED WORK

## Shared Control

An important aspect of this master thesis is shared control. Specifically, regarding a fair division of control over the AV between the passengers. Whilst researching shared control in the automotive domain, it became apparent that research on this subject mainly focuses on shared control between the driver and the AV, and not on shared control between the different passengers.

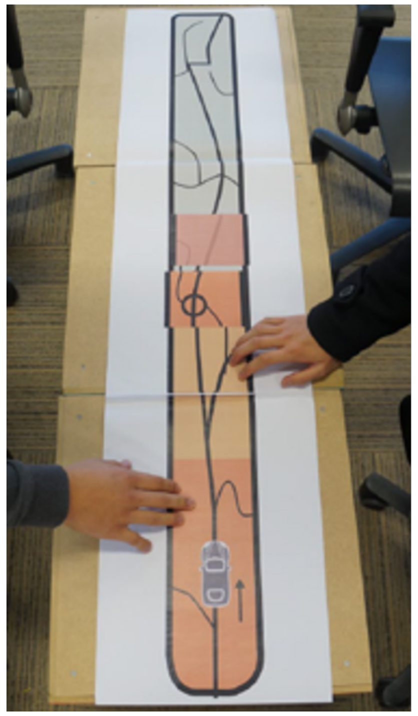
The 'H-metaphor', proposed by Damböck et al. [7], is inspired by the idea of cooperative driving where the automated system and the driver work together. It is designed to keep the driver in the loop but also allow the driver to communicate their wishes to the vehicle. In this metaphor, the vehicle is compared to a horse which has the ability to make choices itself. This type of cooperation will still be necessary even if the passengers share control, as they will likely only influence global settings such as the driving style. However, especially in higher levels of automation where even the driver has the possibility of engaging in non-driving related tasks, it is equally important to consider shared control between each of the passengers in the vehicle.

A research-through-design project conducted by Zoelen et al. [8] considered exactly this 'democratization' of driving. In their paper they present two concepts which explore ways of control division between the passengers. They conclude the paper with four design implications: 1. The AV should have "a personal user interface for every passenger that allows them to indicate desired changes". 2. "a communal interface which shows a combination of the indicated desired changes". 3. "a vehicle interface where the AV displays its current behaviour". And lastly, "a visualization for the occurrence of a desire for change in behaviour". Whilst their project was not evaluated with users, it can serve as a starting point for my design.

Shared control is also an important aspect in other domains, which can be used to inform a concept about shared control in the automotive domain. In her PHD, Berger [9] explores shared control in collaborative, interactive media systems in various environments, as well as the automotive domain. Whilst her research focused on shared control between passengers of AVs, it specialised on the entertainment system inside of the vehicle. Her proposed control modes can still act as inspiration or starting point for a new control distribution concept. The five control modes are briefly summarized in figure 4.







Figures 2 & 3: Concepts proposed by van Zoelen et al. (2019)

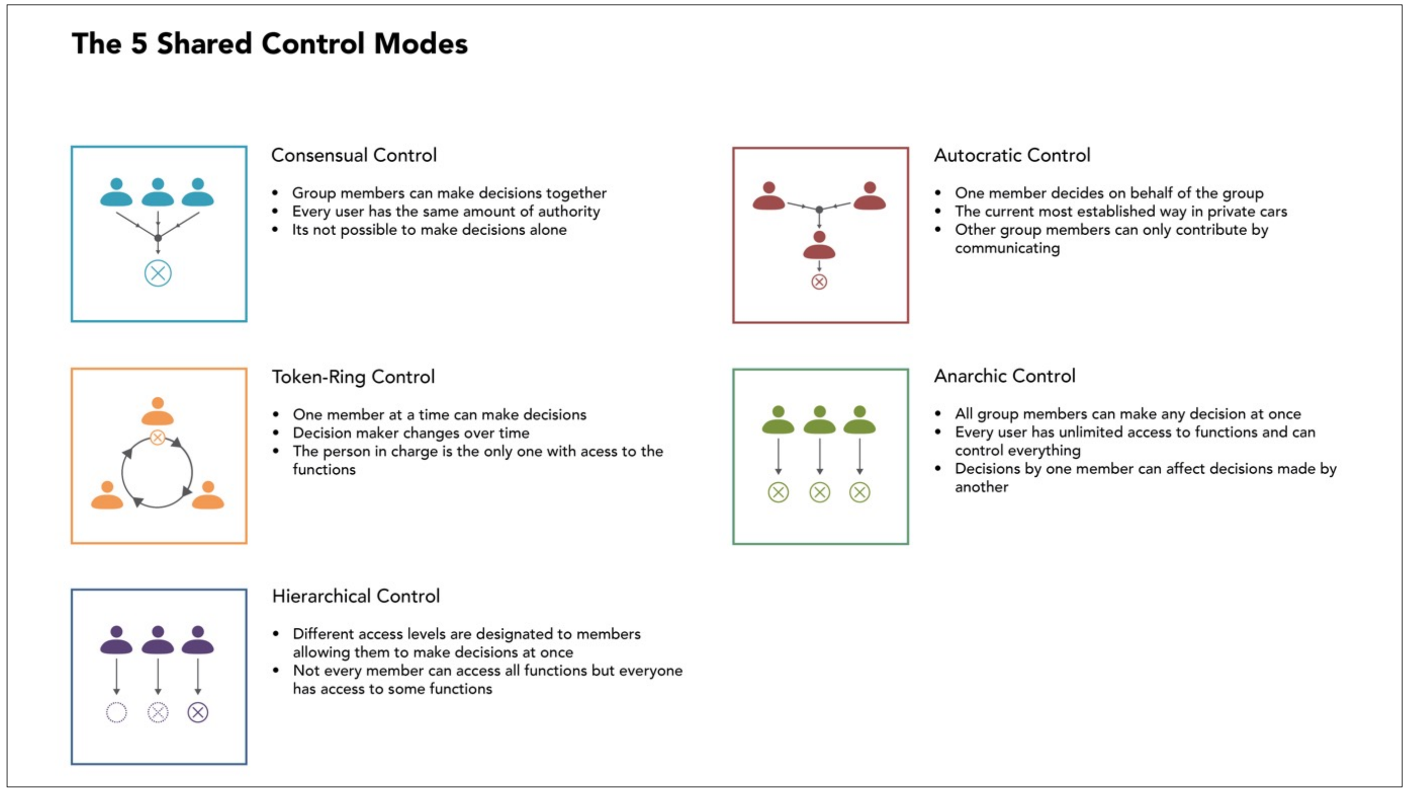



Figure 4: Control Modes developed by Melanie Berger [9]

## Tangible Interfaces for Automated Vehicles

In the automotive community a significant amount of research has focused on the development of tangible interfaces for AVs. This has been done to allow for more natural and less distractive interaction compared to traditional screen or voice-based interfaces. [10] Whilst tangible interfaces might not improve the overall performance of tasks, they have the ability to offer a better experience for the user when interacting with AVs [11].

If we take a look at the current in-vehicle infotainment systems, we see that the general trend is to remove as many physical interaction elements and increase the screen size as much as possible [12]. Whilst the use of touch interfaces can reduce the number of parts and materials needed, therefore reducing manufacturing costs, it also impacts the usability and user experience as interfaces become more complicated [13]. This was also shown in a study conducted by Čegovnik et al. [14] who found that although users rated touchpads and free-hand interfaces as more attractive and novel, physical buttons were considered more efficient and dependable.

Considering the various benefits of tangible interfaces, there are design projects that focus on these interfaces specifically for AVs. One example is 'Stewart' an AV interface which was designed to be tangible and contain haptic feedback meant to enable the driver to sense and influence the behaviour of the vehicle [10] [15]. One of its goals was to counteract the loss of physical connection between the vehicle and user, which screen and voice interfaces have introduced. A second example is the interface designed by Ghani et. al., [16] which presented a concept that aims to 'improve engagement and emotional connection' between the passengers and the vehicles, using a tactile interface. Through haptic feedback 'the driver and the vehicle become companions who support each other' which can be beneficial to make the users more comfortable and trusting of the AV [10].

Another benefit of introducing tangible interfaces in the automotive context is their ability to enhance the situational awareness of the users when using haptic feedback. If it is used as in 'Stewart' and 'Scribble', (Figures 5 & 6), two tangible interfaces designed by Felix Ross [17] [10], it has the ability to provide information to the user about the vehicle's surroundings. Especially when visual or auditory channels are overloaded or impaired through other tasks using haptic feedback can enhance situational awareness, outperforming even visual-audio cues [4]. Passengers of AVs will likely be engaged in non-driving related tasks that may overload these specific channels. Therefore, providing them with the ability to quickly and easily gain situational awareness through haptic feedback could be very beneficial [18].

Figure 5: 'Scribble'

Figure 6: 'Stewart

## Tangible Interactions

Tangible interactions have also been used in many other domains besides the automotive one. They have various benefits, that are highly relevant to this thesis. Firstly, tangible interactions can improve the user engagement and their satisfaction by providing a more immersive and user-friendly experience. Angelini et al. [19] have investigated introducing more tangible interactions in the IoT sector. Similarly to the current automotive domain, the IoT sector largely focuses on touch interactions. In their paper they argue that reintroducing tangible interactions would free up cognitive resources and support peripheral interactions – both very valuable aspects in the automotive domain especially in AVs.

Another benefit of tangible interactions is their ability to exploit the previous knowledge of users and their affordances to create more intuitive interactions. However, they also have the ability to aid the understanding of systems by enabling reflection through engagement with them. This is explored by Hornecker [20] who argues that designers do not have the ability to control or design specific affordances, as physical objects have a wide range of potential affordances which may not align with the designers' intentions. Additionally, he states that it might be more important to focus on 'seamful' instead of seamless integration of tangible interactions as this supports reflection by enabling users to consciously observe the system.





## Driving Characteristics and Passenger Discomfort

Passenger discomfort in vehicles is a multifaceted issue which is influenced by various driving characteristics that can be categorized in physical or psychological factors. In order to create a more comfortable experience for passengers it is therefore important to understand which of these factors are relevant and which ones could be adjusted.

### Physical Factors

Literature highlights four principal driving characteristics that affect discomfort, and each of these are linked to the acceleration of the vehicle.

The first is 'longitudinal acceleration' which occurs during maneuvers such as starting and stopping [21] [22]. As the human body is sensitive to changes in velocity, rapid acceleration or breaking create discomforting forces.

The second factor 'Jerk', which describes abrupt changes in acceleration, is an even more critical aspect. When the vehicle accelerates or breaks unevenly or unpredictably the body has less time to adapt to these changes, leading to an uncomfortable experience, especially at higher vehicle speeds [23] [24].

The third factor 'lateral acceleration' can be felt during cornering or lane changes. High lateral acceleration creates a feeling of being pushed sideways which can also be particularly uncomfortable at high speeds or when it occurs unexpectedly [23] [24].

Lastly, 'vertical acceleration' is the least influential factor. However, it still impacts the user experience. Bumps, dips or an uneven road surface can have a negative effect, especially when these movements are frequent or strong [23].

### Psychological Factors

There are also important psychological factors that affect the driving experience. 'Headway Distance', also described as the distance to the vehicle in front, can lead to anxiety when passengers feel as though the distance is too short. This is amplified when the vehicle ahead performs unexpected movements [24].

Another factor is 'Mode confusion'. In the context of AVs, it is crucial that passengers understand the vehicle's level of control confidence. A lack of clarity can lead to confusion in the passengers and therefore potentially dangerous situations [25].

Lastly, 'lack of control', which is related to a loss in autonomy in the driver, is a factor which can be quite unsettling. Whilst giving away control is part of the AV experience; it will remain important to give passengers the ability to adjust certain aspects of the ride [26][27].

## Automation Level

The Society of Automotive Engineers (SAE) has established a framework comprising six levels of driving automation (Figure 7) [28]. This classification outlines the various degrees of automation, listing the functions performed either by the driver or the vehicle. At levels 4 or 5, the system can manage all driving tasks. Hence, only these were considered for this project because they allow for complete driver disengagement. The important distinction between the two levels is that level 4 is only available in designated areas, meaning a human driver is responsible for parts of the drive, whilst level 5 would be available anywhere.

Currently, Mercedes-Benz has achieved certification for level 3 automation systems with such vehicles already authorized for road use as of 2023 [29]. Waymo have also been conducting trials with level 4 AVs since 2022 [30]. These advancements suggest that level 4 technology will be making it into private vehicles in the coming decade [31]. Therefore, this master's thesis will be focusing on SAE level 4 AVs.

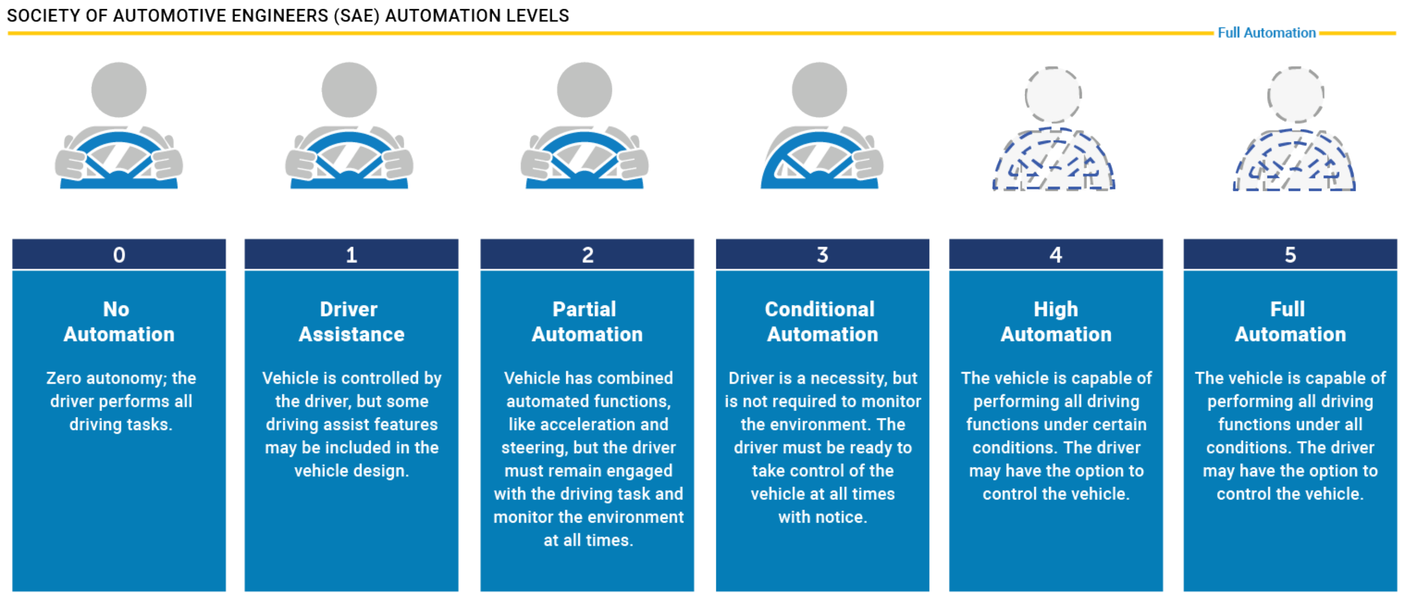



Figure 7: Automation Levels [32]



## Previous Work

Before starting my thesis, I conducted a survey with 143 participants regarding passenger discomfort. This offered valuable insights in addition to the secondary data collected during the literature research. The goal of the survey was to get a better understanding of the various factors affecting passenger discomfort in current driving situations where a human driver is still the standard.

Only 11% of the participants stated that they had never felt uncomfortable as a passenger in a vehicle before. – The other 89% stated their reasons for discomfort:
- 'Risky Overtaking' and 'Insecure Driving Style' (73 participants).
- 'Distracted Driver' (64 participants).
- 'Fast Driving' (62 participants).

65% of participants said they communicate their discomfort to the driver at most half of the time, usually less.
- However, 114 participants expressed the wish for a way to communicate their discomfort to the driver.

Reasons for not communicating discomfort:
- Most answered was that passengers were afraid of the driver's reaction.
- Second most answered was that passengers did not know the driver since it was a service such as a Taxi or Uber.

The insights from this questionnaire painted a clear picture about the evident desire to communicate driving style preferences and provided me with additional factors which affect passenger comfort, other than the above-mentioned factors found in literature. As this is a recap of my previous work, this section has been derived from my FMP proposal from June 2024.

## Chapter Summary

This chapter reviewed different aspects of design research relevant to the development of tangible interfaces and shared control (in AVs), aiming to enhance user experience and passenger comfort. The review covers four key areas: tangible interfaces, tangible interactions, shared control, and driving characteristics affecting passenger discomfort.

By reviewing this literature, I was able to learn about the benefits of tangible interfaces such as enhancing situational awareness. In the context of shared control the research highlighted the need for personal and communal interfaces to manage control preferences effectively. Learning about the physical and psychological factors which influence passenger discomfort was also crucial to understand how to design a more comfortable experience.

These learnings laid the foundation for the design project presented in the following sections.

# REFINING THE SCOPE

## Expert Co-Creation

Mercedes-Benz considers four user groups as their core buyers: ‘Aspiring Young People’, ‘Mobile Professionals’, ‘High Income Families’, and lastly ‘Luxury Seekers’. Two of these are visualised in figures 8 & 9.

Due to the broad project scope at the start of the semester, it was unclear whether a single universal interface could fit the needs of each user group. Therefore, I planned to conduct expert co-creation sessions and interviews with Mercedes-Benz owners. These were meant to kickstart the ideation phase and narrow down the scope.

The following chapter will explain these studies and how the outcomes influenced a restructuring of the planning.

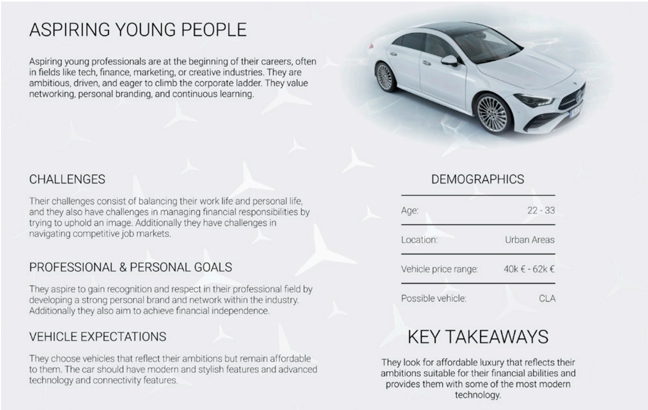



Figure 8: Visual overview of User Group


Figure 9: Visual overview of User Group

### Methodology

Co-creation is described as “a wide range of participatory practices for design and decision making with stakeholders and users” [33]. I decided to embrace the opportunity of working in a team with experienced automotive UX designers to start the ideation process together with them. The scenarios included the above-mentioned user groups, but also discomfort factors such as the distance to the vehicle in front, etc. The scenarios aimed to create a common frame of reference with the experts, and they were meant to make narratives involving AVs more relatable.

Next to the scenarios, I also introduced the shared control concepts previously presented. These control concepts were meant to encourage creativity by offering alternatives to the current autocratic control mode or a possible consensual control distribution.

Considering that the expert co-creation sessions were conducted in the Mercedes-Benz design department, notes were only taken using pen and paper due to the restriction on photo, video and audio recordings.

### Participants

A total of four co-creation sessions were conducted. The experts chosen for this session were part of the Advanced UX design team of Mercedes-Benz, where each of the experts has a strong background in user-centred design. Considering the focus of the advanced design team it meant they have worked on AV related concepts before and were therefore accustomed to such speculative design.



To ensure privacy, the names of the experts will not be stated in this report. If their credibility needs to be verified, please contact me directly at l.g.w.licht.pradillo@student.tue.nl

### Procedure

The co-creation sessions lasted for one hour and were conducted with one expert at a time. Each session was divided into four parts:

**1: Short Introduction into the Project**
The experts were introduced to the goal of creating an interface for the passengers of AVs and the focus on lvl.4 autonomous vehicles. The description of the project goal was intentionally kept vague as to avoid bias.

**2: Initial Questions**
The experts were asked questions regarding their own predictions for the automotive domain in the coming 10 to 15 years. This was done to project an image of how far they expect the automotive market to develop.

**3: Introduction to the control modes by Berger [9]**
The participants were then introduced to the control modes. A visual summary was handed to them which they could also later refer to. After ensuring the different control modes were clear, the final part of the session started.

**4: Scenarios**
The participants were read a short scenario that contained a potential user group and a discomfort factor that had to be adjusted.

The experts were then asked whether they think each passenger would have to agree with an adjustment of the parameter. Hereafter, they were given 3 minutes to brainstorm ideas on how the parameter could be adjusted by the passengers. They were told to think-aloud in order to understand their thinking process. ‘Think-Aloud’ is a technique used to get participants to vocalize their thoughts, which provides insights into their immediate thoughts and reactions [34]. Additionally, they were asked to consider and use the five control modes as inspiration. This was repeated for a total of five scenarios with the same procedure.

After going through the five scenarios, the experts were asked to explain their ideas, which lead to an open discussion.

### Analysis and Discussion

Each expert’s notes were reviewed, and two key themes emerged: ‘Automation Levels Available in the Next 10–15 Years’ and ‘Chosen Control Modes.’

**1. What level of automation will be available to the public in 10-15 years?**
All four experts agreed that Level 4 automation would see significant development within the next 10-15 years. Expert 4 believes that while Level 3 automation will be widely available in most new vehicles, Level 4 will primarily be accessible in the higher-end automotive market. He also suggested the possibility that Level 4 automation might be limited to the right lane of highways. All experts concurred that Level 5 automation would not yet be available for private vehicles as they are often used for travel to remote locations. However, it could be feasible for public transportation, given their fixed routes. Lastly Expert 2 noted that automation

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technology will likely not be advanced enough to navigate to secluded areas, which is why he expects private vehicles to retain a steering wheel for the foreseeable future.

**2. Which control-modes were chosen for each scenario?**

Before brainstorming interaction possibilities for each scenario, the experts were asked which control modes they believed best suited each situation. This revealed a critical misunderstanding in the original project scope.

Each expert highlighted the role of ownership in shaping passengers' comfort to provide feedback to the AV. Contrary to my initial assumption, they emphasized that ownership and the 'drivers' role remain relevant even when the AV assumes all driving tasks. All four experts agreed it would be socially unacceptable for any passenger to alter the driving style unless they are the 'driver' or the vehicle's owner.

Given their perspectives on control, when the AV takes over, it is unsurprising that most experts favoured the autocratic control mode. In scenarios involving children (Scenarios 1-3), the experts agreed that children would only be able to voice their opinions without having decision-making power. Interestingly, Experts 1, 2, and 3 noted that if their partner was present, they would discuss changes with them, allowing for some degree of consensus, although the final decision would still rest with the 'driver' maintaining autocratic control.

**3. Ideas Proposed during the brainstorming**

Even though the experts were asked to focus on tangible interfaces during their ideation a few ideas were still focused on voice or gesture commands. When discussing these, Expert 4 argued that voice commands will become more advanced in the future. However, he also agreed that these could not always be useful in AVs depending on the passengers' activities. Three of the four experts also thought of a single interface that could adjust multiple vehicle parameters at once.

An interesting perspective introduced and discussed with Experts 1 and 2 concerned the transparency of passenger input. While Van Zoelen et al. [8] emphasize the need for visibility in passenger choices to achieve shared, democratized control, the experts noted that full transparency with consensual control could instead lead to conflict as passengers may have differing views on authority.

These discussions highlighted the need for hierarchy to avoid misunderstandings about control dynamics. Figures 10, 11 & 12 show a few of the ideas that were created during the brainstorming of the co-creation.

## Discussion

Whilst the experts have previously worked on speculative projects involving AVs, a lot of their work revolves around current vehicles which is why their focus may still be on the current 'autocratic' control division. However, their views on autocratic control still hold some value

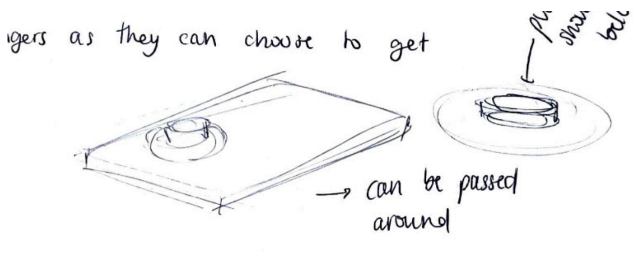


Figure 10: Idea of an Expert





because they reflect other vehicle users feel. Looking at the previously mentioned survey the results showed that passengers don't speak up about their discomfort, with the highest reason being fear of the driver becoming upset. Therefore, even if given an option to provide feedback, they will not automatically feel comfortable using it. And more importantly, a consensual system does not take the autonomy of the driver into account, which would be considerably reduced.

Given these reasons, the feedback from the experts should be considered carefully and not just be adopted, as this would result in another autocratic system.

## Refinement of the Scope

Initially, I assumed that passengers should have equal control once the automated driving is activated. However, the co-creation sessions revealed that the experts strongly disagreed. This means that control distribution is a far more complex aspect which I did not consider in the planning of the project.

Since the analysis revealed that there is not just a single control mode offering a fair control distribution, a potential combination would be necessary. Consequently, I chose to revise the project scope and instead of advancing directly to interface ideation, I prioritized defining a framework for a fair control distribution between passengers.

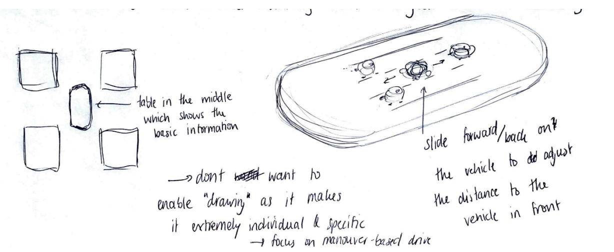

Figure 11: Idea of an Expert

## Owner Interviews

Initially, I planned to conduct semi-structured interviews with Mercedes-Benz owners belonging to the previously identified user groups. These interviews aimed to explore how owners currently use their vehicles and how they imagine interactions with these AVs would look. The goal was to potentially reveal specific needs and values owners have, which could then be integrated in the interface.

Two interviews were conducted: one with a participant from the 'aspiring young people' group and another participant from the 'high-income families' group. Whilst these interviews provided interesting insights into the use of their vehicles and purchasing motivations, it became clear that both participants struggled to contextualize automated vehicles (AVs), as they had no prior experience or reference point.

Therefore, when the opportunity for working with actual experts in the field became apparent, I decided to no longer continue with the owner interviews as it would be much more beneficial for the process to prepare co-creation sessions with individuals who could better understand and situate themselves in the AV context.

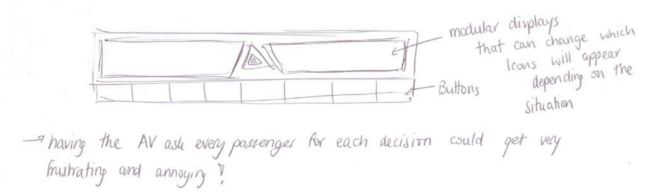


Figure 12: Idea of an Expert

# CONTROL CONCEPT DESIGN

## Brainstorming

Once it was clear I first needed to investigate the control distribution, I initiated a brainstorming session to explore various ways control could be allocated among passengers. One interesting idea that emerged was the 'Hybrid System' which combines a static control distribution, where the 'driver' receives a larger amount of control, with dynamic elements to divide the remaining control among passengers. In this idea emotions could serve as a basis, allowing passengers to communicate their emotional state to the vehicle, which could then allocate control dynamically.

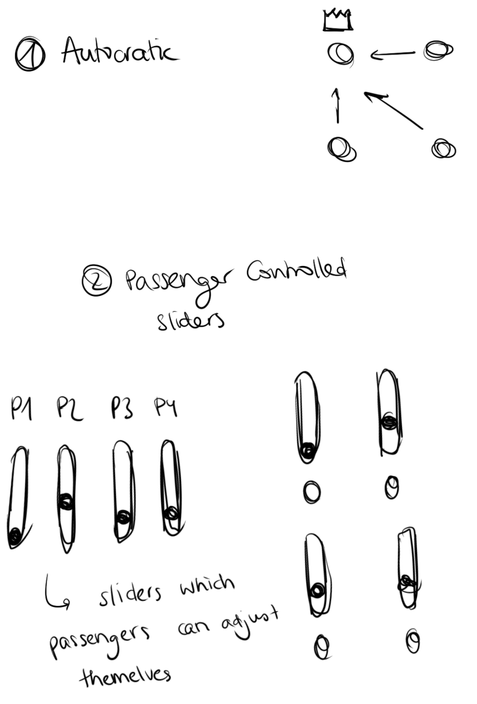
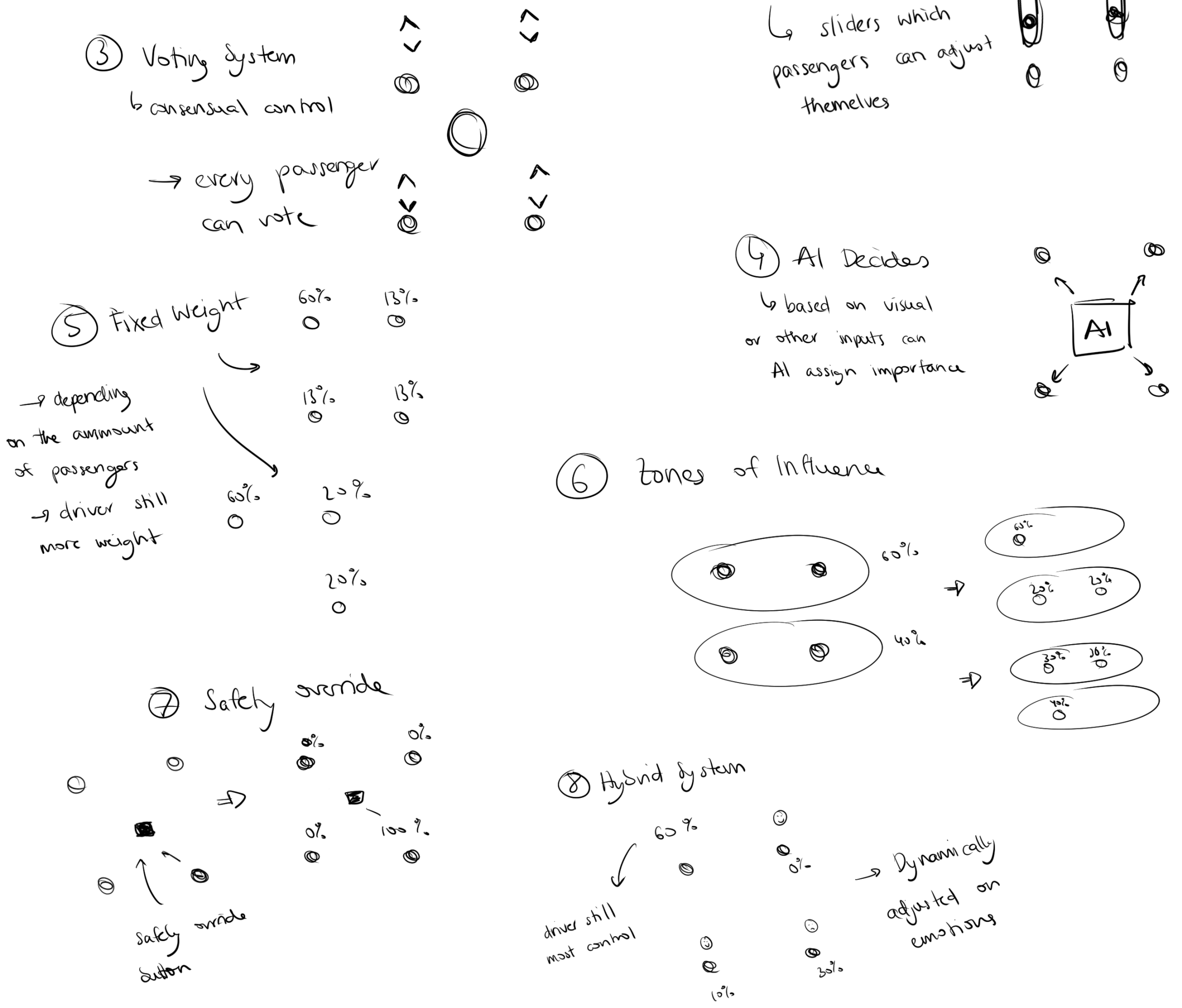


Figure 13: Ideas from Brainstorming about Control Allocation between Passengers



## Emotions as Control Division Decider

This idea led to an exploration of how passengers' emotional states might be conveyed to the vehicle. Technological methods to measure emotions such as facial tracking or Electroencephalography were not considered during this exploration following the design decision to create a tangible interface. Instead, various self-assessment tools were considered such as the 'PANAS', 'Self-Assessment Manikin (SAM)', 'Geneva Emotion Wheel', etc.

Most of these tools require the participants to assess a large range of emotions. This would be difficult to do rapidly and intuitively, a critical aspect, as passengers' emotional response to a driving situation might change at a moment's notice. Therefore, the most applicable tool appeared to be the SAM (Figure 14).

SAM uses a non-verbal, pictorial approach to measure the pleasure, arousal, and dominance "associated with a person's affective reaction to a wide variety of stimuli." [35]. This simplicity would allow passengers to quickly indicate their emotions, and it would be easier to create an interface with low cognitive load, facilitating low-effort feedback.

I therefore attempted to map valence and arousal to potential driving behaviours of AVs, however this proved challenging (Figure 15). Exploratory discussions were consequently conducted with the author previously mentioned control modes, and a Mercedes-Benz employee focused on Multimodal UX. After discussing the concept, both informed me that, whilst it would be an interesting and novel approach, it would be very difficult to ensure emotions are communicated accurately. Therefore, I decided to step back from this approach and revisit earlier brainstorming ideas to identify more feasible solutions for dynamic control distribution.

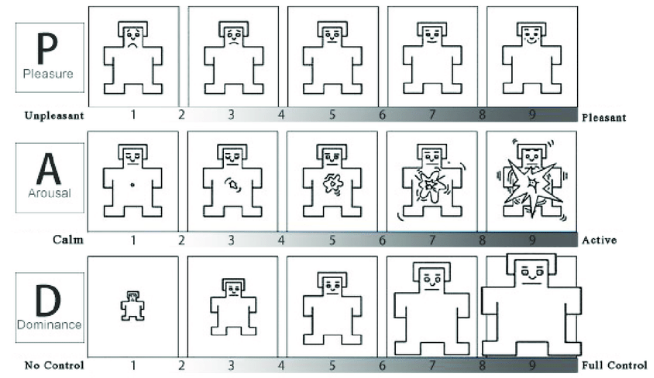


Figure 14: Self-Assessment Manikin Form

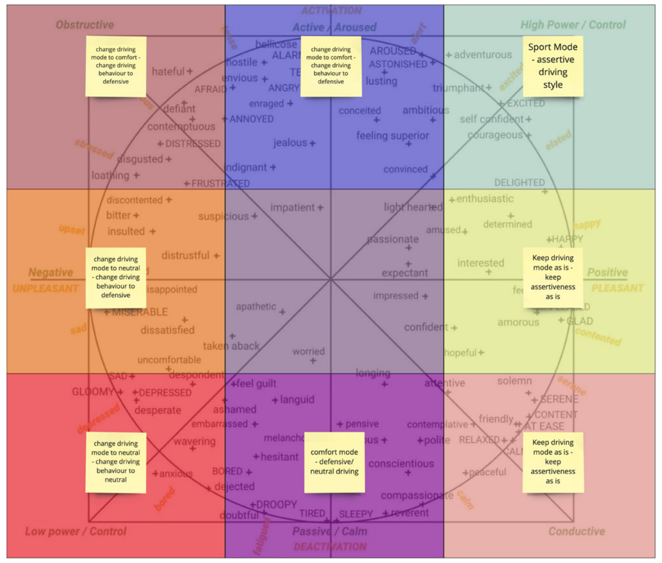

Figure 15: Attempted mapping of driving behaviour to Arousal/Valence




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# 'Driver sets a Range' Concept

Following the exploratory talks, another idea which stood out as an innovative approach was the 'Fixed Weight' distribution system where the driver retains a higher percentage of control while passengers share equal control over the remaining allocation. This system has three key benefits:

- It ensures the driver's autonomy is preserved and cannot be overridden by passengers.
- It allows passengers to make meaningful adjustments to driving behaviour rather than just recommendations.
- It provides equality among passengers as each one has the same amount of control.

The idea of the 'Fixed Weight' distribution was further worked out and the following control distribution concept emerged:

The driver holds primary control by selecting one of three predefined driving modes: Comfort, Balanced, or Sport, which dictate the vehicle's general driving dynamics. The driver can either select one of these predefined driving modes or enter a more detailed menu to customize specific system parameters individually. These parameters include the distance to the vehicle ahead, the smoothness of acceleration/breaking, the vehicle's relative speed, and assertiveness. Each parameter is adjustable on a scale divided into three zones: Comfort, Balanced, and Sport. Importantly, when the driver selects a mode like Comfort, they can only make adjustments within that zone, maintaining the overall feel of the selected driving style.

Passengers also have the ability to adjust the vehicle's behaviour, but their adjustments are confined to the range of the driver's selected mode. For example, if the driver selects Comfort mode, a passenger can influence the dynamics to drive closer to the Balanced mode but cannot transition fully into Balanced or Sport. In this case, the vehicle will take both the driver's and the passenger's preferences into account, finding an average within the Comfort zone to accommodate their wishes.

This system allows the driver to set the general tone of the drive while giving passengers the ability to fine-tune the driving experience, all without overriding the driver's authority.

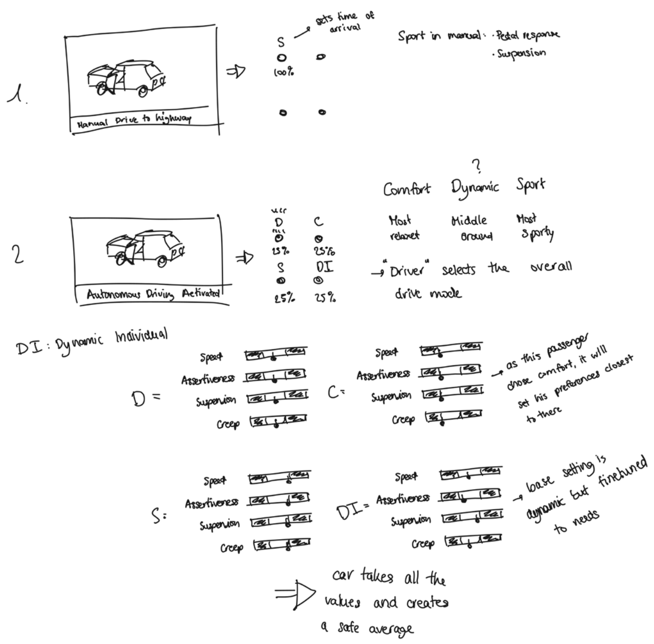

Figure 16: First Sketch of the Control Concept



# Development of an Interactive Interface

To illustrate how adjustments to the vehicle drive dynamics would affect the overall driving style, I developed an interactive prototype using Figma. The prototype allowed me to showcase how the drive mode selected by the driver affects the general drive mode, and the effect passengers have on the system.

## Iteration 1

The initial iteration (Figures 17 - 19) of the interactive prototype focused on functionality rather than aesthetics. Its primary goal was to illustrate passenger interaction dynamics, not to finalize the interface's visual design.

It was exploratively presented to a colleague from the design team to identify potential gaps in its ability to communicate the concept. The discussion showed that it should be evaluated further with a higher fidelity version to properly test the concept with other designers from the team.

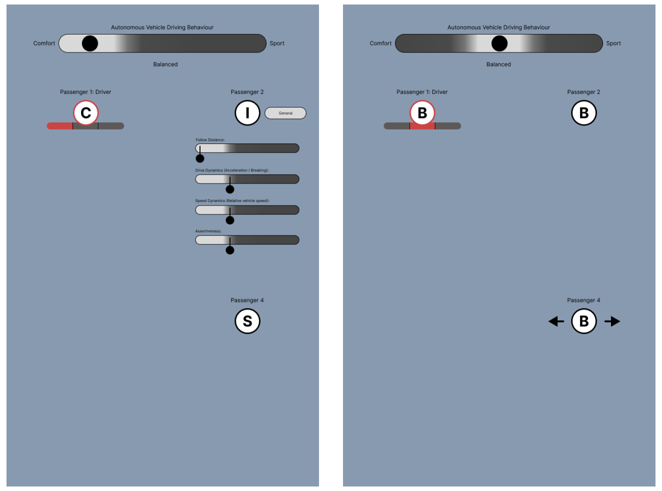

Figure 17 & 18: Different Control Concept States

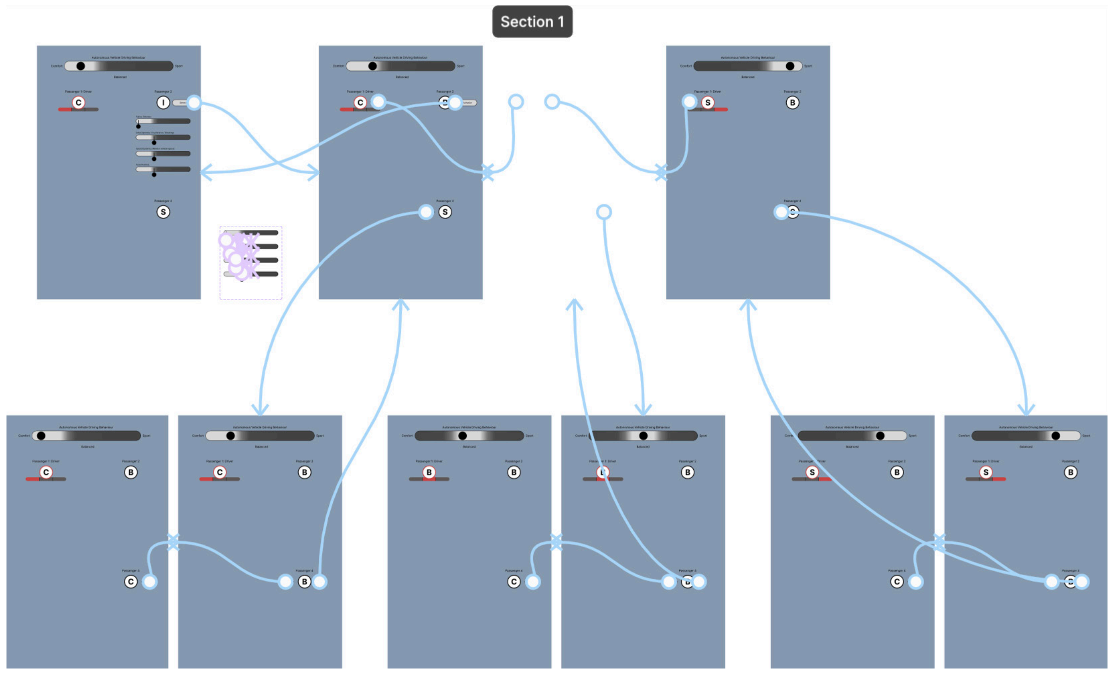


Figure 19: Flow Diagram of Iteration 1



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## Iteration 2

Figures 20 - 22 show the second iteration of the Figma interface. This interface maintained the functionality of the first iteration but focused on making it more aesthetic and intuitive. An important change was the simplification from having three driving modes to only Comfort and Sport. Additionally, by using an abstract representation of a vehicle on the road, a visual link was drawn between the control distribution and an automotive environment and colours were used to communicate the different driving modes. The chosen modes were also reflected inside of the vehicle's representation.

The following section will present how this interface was evaluated with design professionals and potential users.

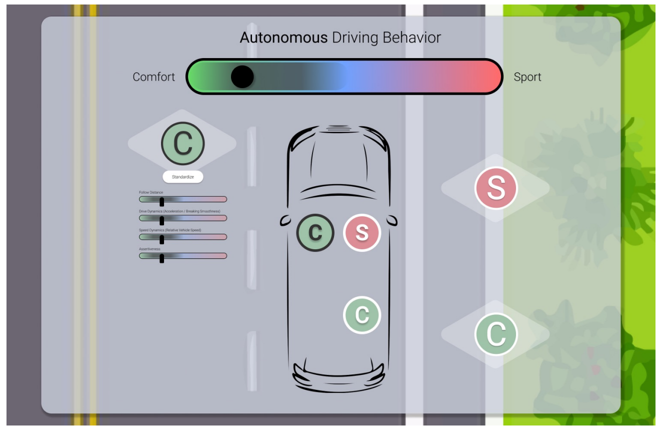


Figure 20: Screen of the Second Iteration

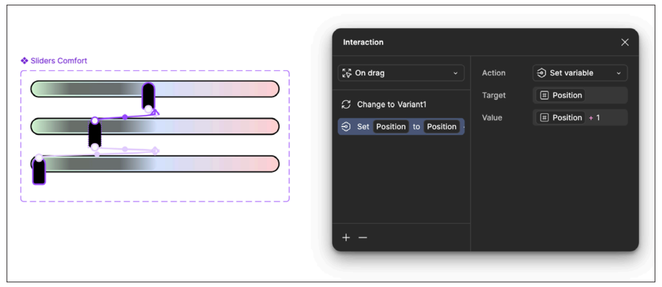


Figure 21: Variables for the sliders that affect the slider position

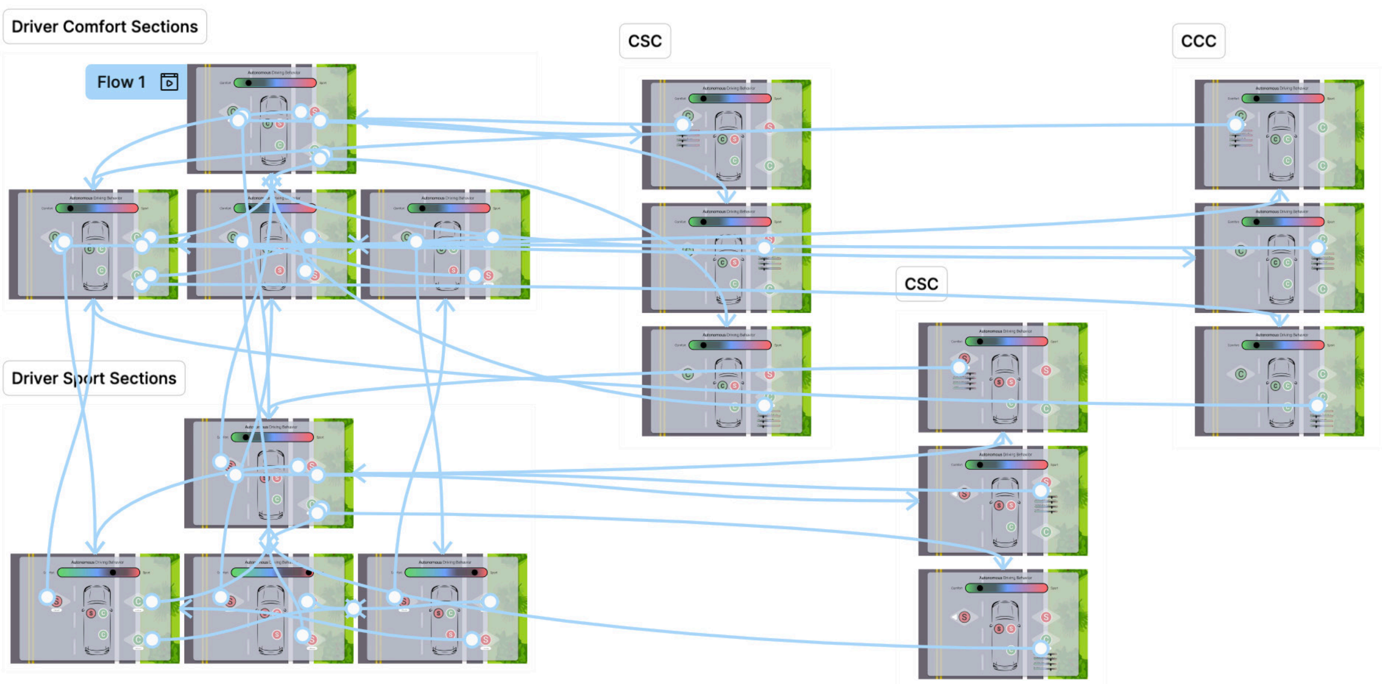


Figure 22: Flow Diagram of Iteration 2



# Evaluating the Control Distribution Concept

To assess whether this control distribution would be accepted, an evaluation was conducted using the semi-structured interview method. This is a widely used qualitative research method that combines structured questions with the flexibility to explore new topics as they arise during the interview [36] [37].

## Methodology

A total of five potential users and four designers, participated in the evaluation which lasted around 20 - 30 minutes each. The designers each have a strong background in UX design and currently work in the automotive domain. The participants were convenience-sampled, with criteria including age (20+), a valid driver's license, and prior driving experience.

The interview focused on three areas: 1. Does the control distribution provide sufficient autonomy for passengers? 2. Do the sliders to adjust system parameters benefit the UX? 3. The comfort of passengers to make changes.

## Analysis, Findings and Discussion

The answers were thematically analysed. After reading the transcription or notes, codes were generated which I then grouped into the following five themes [38].

**Does the control distribution concept offer sufficient autonomy to passengers?**
Eight out of the nine participants agreed that this concept provides passengers with enough autonomy to adjust the driving style of AVs. Importantly, Designer 3 agreed that the concept provides sufficient autonomy, however, only if the adjustments made by passengers are perceptible during the ride.

Designer 1 argued that they would not feel they had enough autonomy because they couldn't fully adjust the driving style from "sport" to "comfort" if desired. Contradictory, they believed every occupant should have equal control. Even though in a fully democratic system individual adjustments still require the agreement of others, just as in this concept.

**Should the driver have more control than the passengers?**
Three Users believed that once the automated driving is activated, control should be equally distributed. Designers 1 and 4 supported this view, while Designers 2 and 3 believed the driver should retain greater control which was in line with the majority of Users. A result which aligns with the co-creation outcomes.

Another interesting aspect mentioned by User 2 is that the driver should always retain more control unless they are asleep. A point also discussed during the exploratory testing of the initial Figma prototype.

**Is there a difference between different passenger types?**
Five participants suggested limiting control for certain passenger types, particularly children and rear-seat passengers. User 4 argued that since rear passengers are often children, their control should always be restricted.

User 3, along with Designers 1 and 4, proposed that only children should have limited control, which could be implemented using features such as a child lock. They reasoned that children lack the critical thinking necessary to make rational decisions, particularly regarding safety aspects.

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Whilst AVs will only allow a safe driving style, adjustments made by children will never result in dangerous situations. However, they could consider the interface a toy and make adjustments for fun without understanding the consequences.

**Are the customizable system parameters understandable?**
Participants unanimously agreed that the ability to adjust system parameters is beneficial and understandable. However, opinions diverged on the number of adjustable parameters. Designer 1 felt that the system included all the key parameters, while Designers 2, 3, and 4 suggested that the parameters might be too specific and recommended reducing their number, an opinion also voiced by User 4. On the other hand, User 3 considered the number appropriate with User 2 in contrast, expecting more parameters. A key insight voiced by User 5 was the importance of experiencing noticeable effects on the driving experience when adjusting parameters, as passengers would otherwise quickly stop using them. Lastly, Designer 4 recommended replacing text with visuals to enhance user comprehension of the parameters.

**Would passengers feel comfortable making adjustments to the driving style?**
All participants indicated that they would feel comfortable making adjustments to the driving style using this control distribution concept. Even though most participants believe the driver should retain most control, they would still feel comfortable making adjustments to the driving style using this system. Designer 2 explained that, since the driver sets the initial driving mode and therefore the adjustment range, they had no concerns about making smaller changes to fine-tune the driving style to their own preference, given that the driver made the first choice.

Figure 23: Evaluation Setup (Similar setup used for the Experts)

Figure 24: Evaluation Setup



## Design Implications of the Evaluation

This evaluation allowed me to verify that the developed control distribution could work as it appears to offer an adequate amount of control to passengers without overruling the driver's autonomy. However, feedback suggested I reconsider the number and specificity of adjustable parameters which were deemed understandable but too specific.

Concerning the overall project structure, the focus was now set on creating a physicalisation of the control division concept, as this would allow for a better evaluation of its ability to improve passenger comfort and trust.

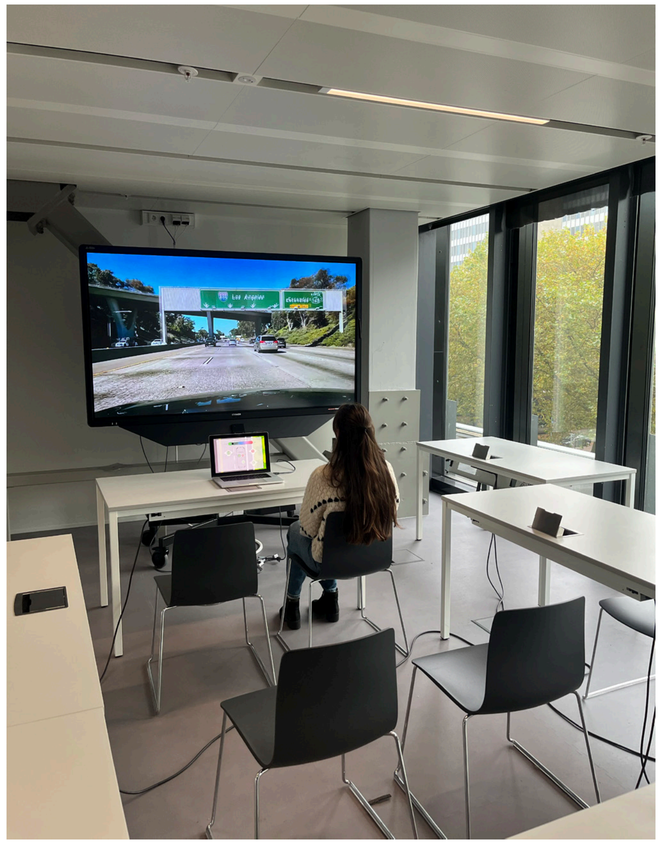

Figure 25: Evaluation Setup

# INTERFACE DESIGN

With the control distribution concept established, the design of the in-car interface could finally commence. This design phase was divided into two components: the design of the tangible interface that passengers would directly interact with, and a central graphic user interface (GUI) which would visually showcase the changes that are made by the passengers.

## Physical Interface

### Brainstorming

The process started with a brainstorming session to explore potential interaction methods. This brainstorming created a range of different ideas focused on the aspects of adjusting the interface parameters and switching drive modes. Before starting, I reviewed the possible parameters and decided to drop the speed dynamics as assertiveness already incorporated this parameter. After the brainstorming these ideas were discussed with my supervisor at Mercedes-Benz.

During this discussion, one idea emerged as a favourite, and I chose to explore its interaction possibilities further. Due to a personal goal I set before the semester, I chose to immediately build a Lo-Fi prototype instead of refining it further on paper first.

Figure 26: Overview of Brainstorming Ideas

# Lo-Fi Prototyping

## Paper-Protoyping

To quickly test the interaction of the previously selected idea, I built a simple prototype. Whilst interacting with the interface, I also considered the mapping of the three system parameters and, after some experimenting, decided on a lifting movement for assertiveness, a forward movement to close the distance to the vehicle ahead, and a tilting movement for acceleration. (Figures 27 – 34)

Ideally, a short study should have been conducted at this stage to assess whether the chosen movements were intuitive. However, to not interrupt the design phase again, I decided to work with my assumptions and discuss these with fellow designers. Instead, the intuitiveness of the selected movements was assessed at the end of the project.

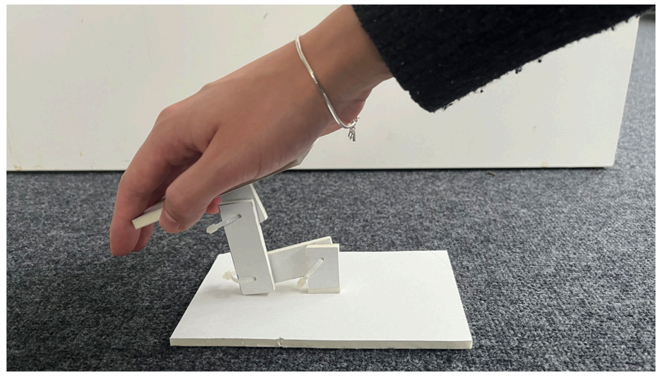

Figure 27: Paper Prototype

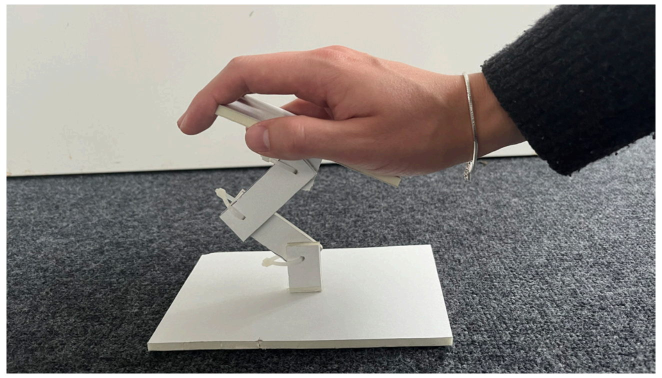

Figure 28: Paper Prototype

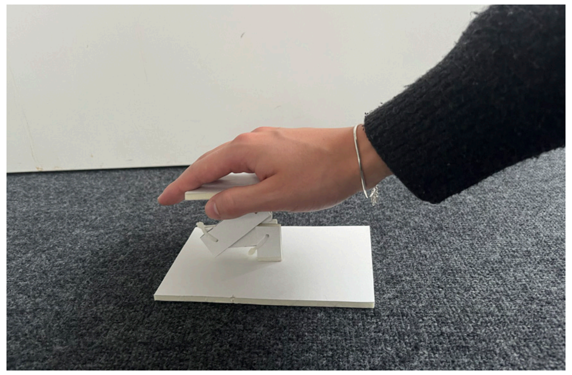

Figure 29: Paper Prototype

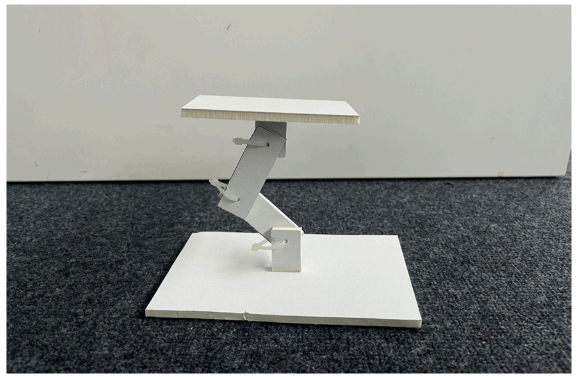

Figure 30: Paper Prototype

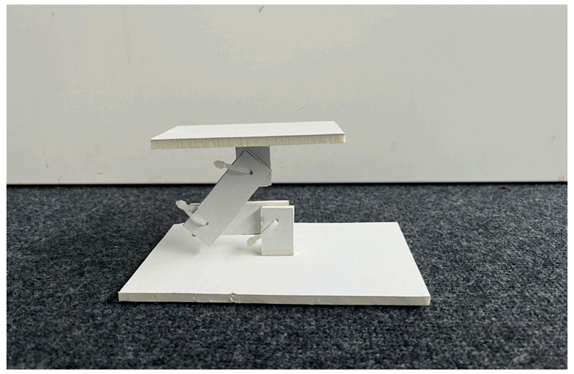

Figure 31: Paper Prototype

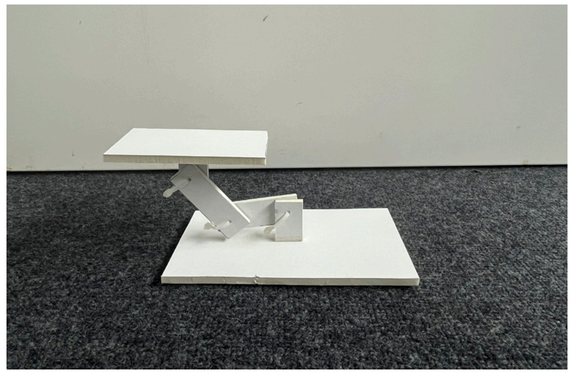

Figure 32: Paper Prototype



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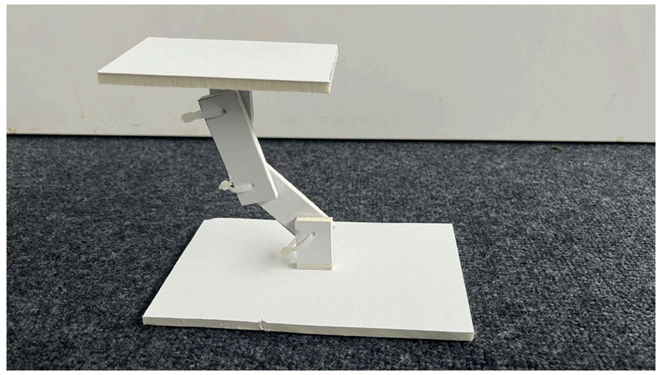


Figure 33: Paper Prototype

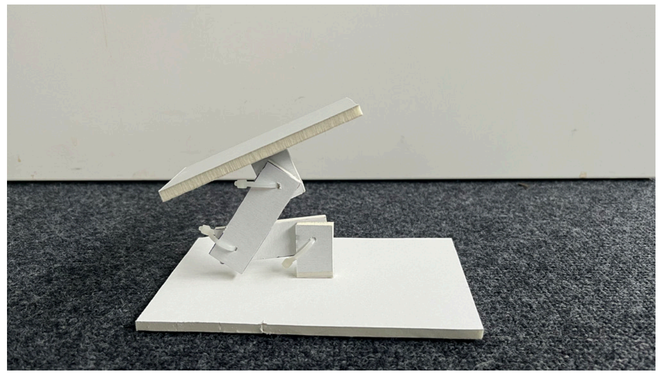
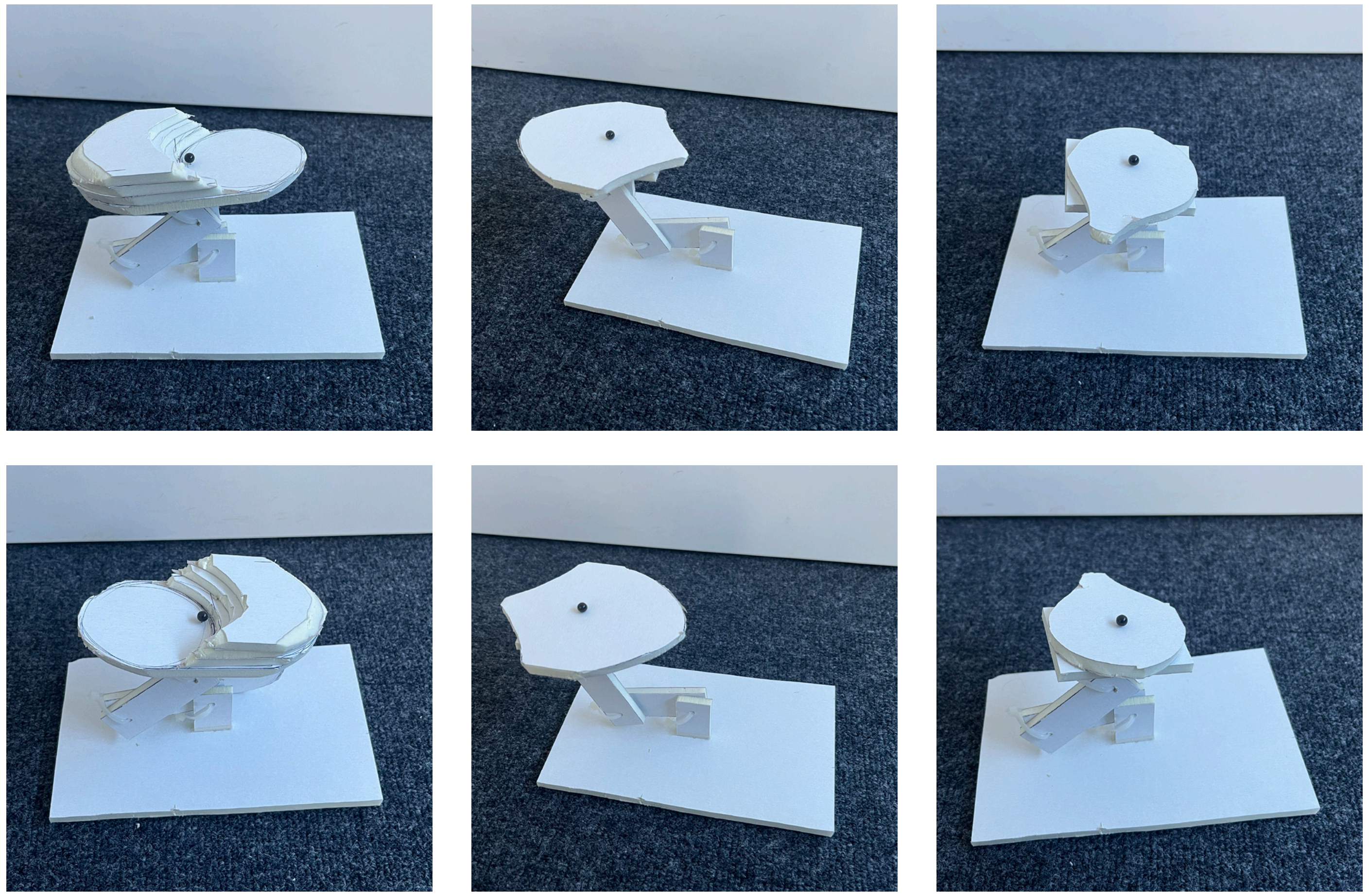


Figure 34: Paper Prototype

While this basic interaction was useful, it lacked an essential element from the Figma interface: the ability to switch global driving modes. Therefore, I created additionally attachable elements which complied with its functionality of being used 'blindly'. (Figures 35 - 40)



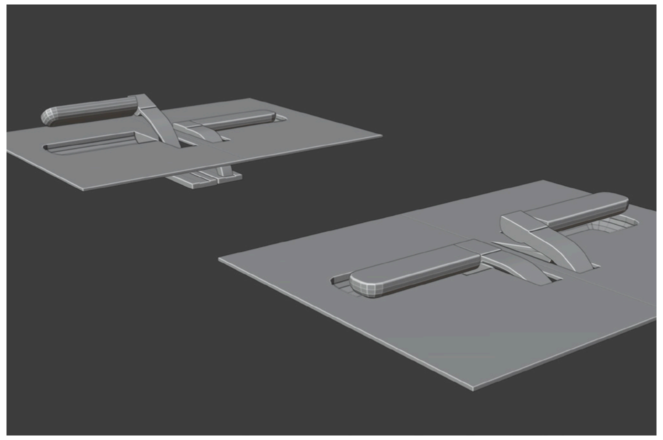
Figures 35 - 40: Attachable Elements

## Laser-cut Prototypes

Following a discussion with my coach, I realized that the tangible interface does not need to match the Figma interface one-to-one, if its functionalities remain. For example: the control concept enabled passengers to switch between comfort and sport by pressing one button. Its core benefit being that it allowed quick adjustments. In its simplest form, the tangible interface already allowed this without attachments.

Mercedes-Benz also suggested I continue with the chosen design; however, I was encouraged to revise the design to align it with their brand by making it sleeker and more elegant. Therefore, I developed an adapted design in the 3D modelling software Blender which retained the original movements. (Figure 41)

To physically explore the interaction with this new design, a first version was laser cut. The handle was initially encased in foamboard and subsequently, two additional iterations were laser cut, each exploring variations in handle shape and size. (Figures 42 -45 & 47 – 51)



Figures 41: Viewport Render of Redesign

Figures 42 - 45: 1st Laser cut Prototype





Interacting with these prototypes revealed a critical issue in the design and the chosen system parameters. Until now, the chosen parameters were the distance to the vehicle ahead, assertiveness and acceleration behaviour. These were based on the literature research and the survey conducted before the start of this thesis. However, a 'dead-zone' emerged due to conflicting inputs between the system parameters. (Figure 46)

After reviewing the parameters and their relationships between them, it became apparent that assertiveness was the only one which was not purely a system parameter. Instead it combined different parameters into one. I realized that a combination between speed, distance, and acceleration would essentially affect the overall assertiveness, so assertiveness was replaced with speed.

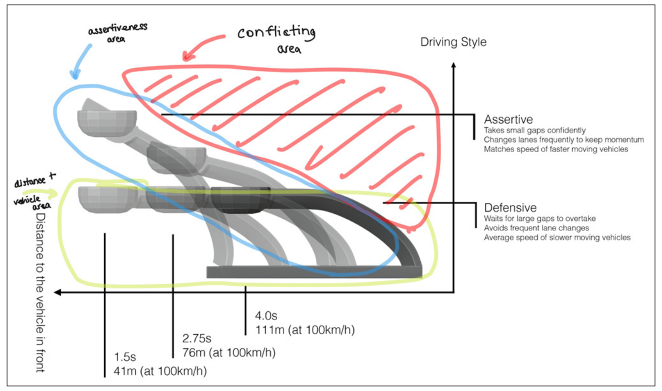



Figure 46: Illustration of 'Dead Zone'

Figure 47: 1st and 2nd Laser cut Prototypes

Figures 48 - 51: 1st and 2nd prototype in a vehicle to explore the placement

# Initial Concept

Building on the insights from early prototypes, the concept was worked out. Each passenger receives a physical device allowing them to adjust the vehicle's driving style through three key parameters: distance to the vehicle ahead, relative speed, and acceleration behaviour.

Each interface has integrated haptic feedback to facilitate subtle communication between passengers. Using force feedback, it is possible to inform passengers of others' chosen settings and therefore aid their situational awareness [18]. Next to this, the experience of the passengers is improved by addressing each occupant's need for popularity as the subtle awareness promotes cooperative behaviour such as opting for a more comfortable driving style after noticing that others prefer this [39]. When a passenger adjusts the interface, the haptics could mimic the positions of other active interfaces in the vehicle, providing a tangible sense of the vehicles' driving style and making adjustments feel more impactful. Next to the tangible interface, passengers would also see the effect their inputs have in a graphic user interface (GUI), integrated in the central infotainment screen. This would further increase their understanding of the influence of their actions [8].

To make this concept experienceable, I set out to build a technical prototype capable of simulating the haptic feedback and a GUI. The following section will outline the development of the technical prototype and the simultaneous development of the handle and GUI.

The physical interface was integrated into a current Mercedes-Benz vehicle—the EQE SUV variant. (Figures 52 - 54). This decision ensured the project remained free from NDA restrictions while aligning with realistic automotive standards for the next 10–15 years. As suggested by the experts, it will be unlikely that vehicles with rotating chairs will become the norm by then. Therefore, to keep the interface universal for multiple vehicle platforms, I chose to focus on the current standard.

Figure 52: Render of Handles in Middle Console

Figure 53: Render of Handles in Middle Console

Figure 54: Render of Handle in Rear Door





# Technical Prototype & Handle Design

## Technical Prototype

Each passenger's interface was equipped with two ALPS RSAON11M9 motorfaders positioned side by side. By working in tandem, these faders provided force feedback along the X and Y axes. Based on the project timeline, achieving force feedback in the rotational axis was not realistic, and therefore I opted for vibration feedback, which would ensure a perceptible haptic experience. The motorfaders were controlled by a L298N motor controller connected to an ESP32 whose Wi-Fi capability was an important aspect enabling multiple prototypes to communicate in real time with one another and with the GUI.

### Iteration 1: Initial Functionality

The primary focus of the first iteration was establishing technical functionality. The components were connected preliminarily, allowing the development and testing of communication between the motor faders and their positioning. (Figures 55 - 57)

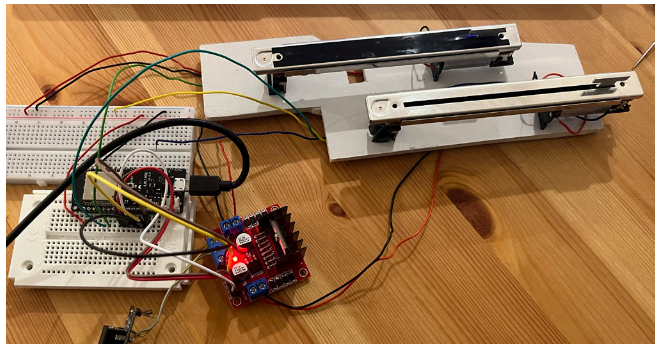


Figure 55: Provisionally Connected Motorfaders

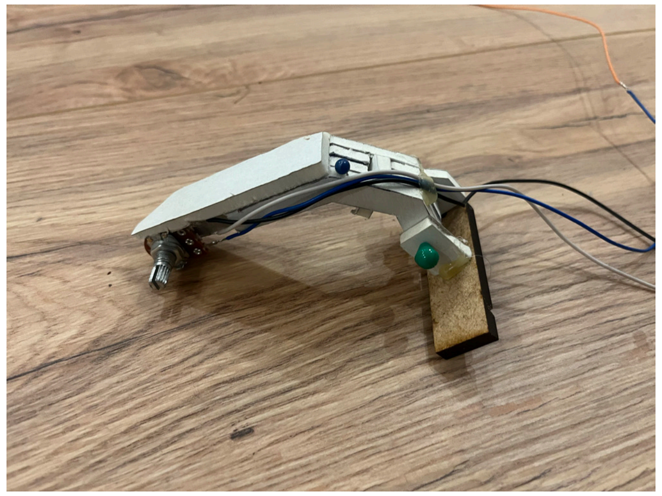


Figure 56: First handle with integrated potmeter

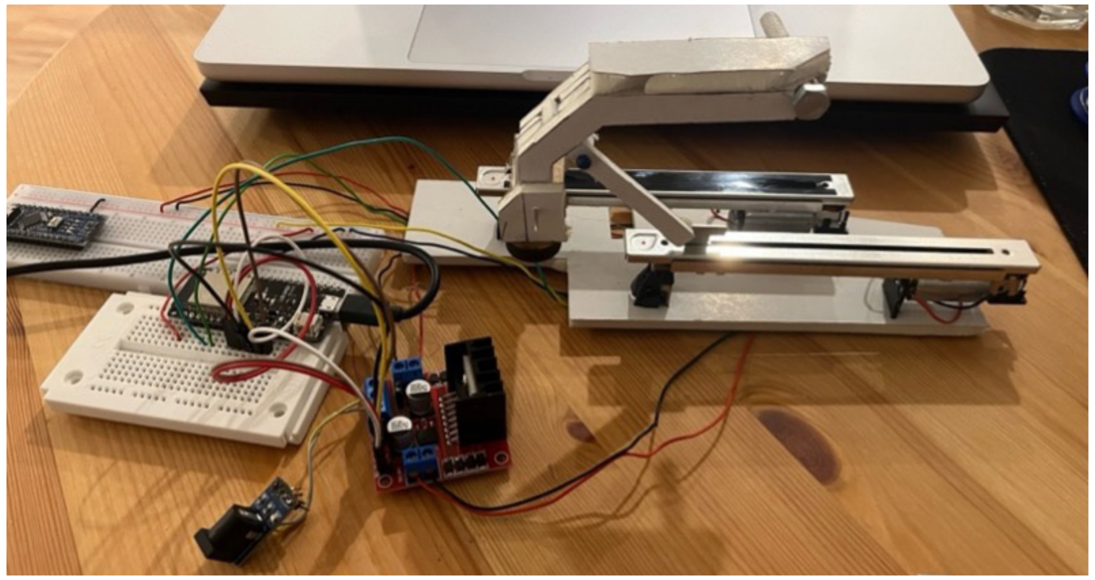


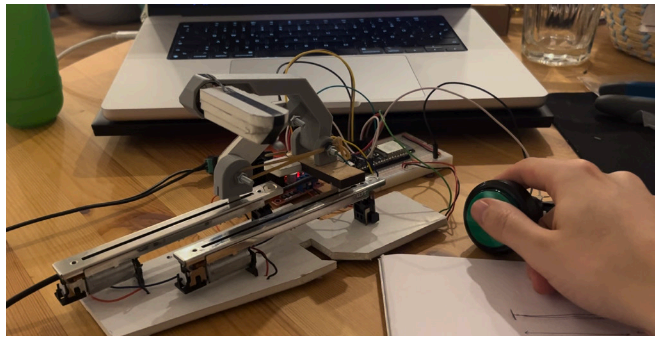
Figure 57: Handle Mounted on the Motorfaders

### Iteration 2: Structural Integration

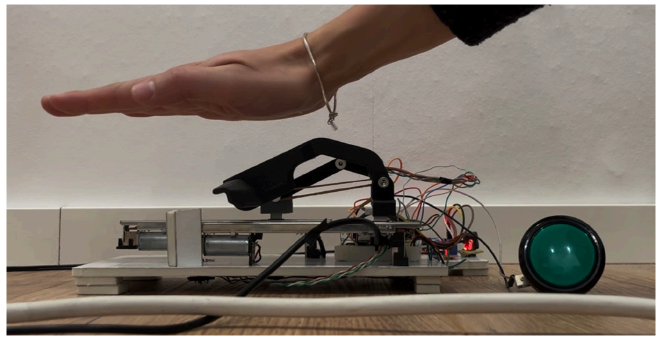
After many incremental steps the technical prototype was housed in a 3D printed structure which safely and compactly held the various components together. At this point the connections were also securely soldered and elements such as an IR sensor were included in the prototype to enable a new functionality of 'waking' the interface. (Videos 1 & 2) (Figures: 58 - 60)

Video 1: [https://youtu.be/JUfflXeiKh8](https://youtu.be/JUfflXeiKh8)

Video 2: [https://youtu.be/67X1FR5MDdc](https://youtu.be/67X1FR5MDdc)



Video 1: Motorfaders working in Tandem



Video 2: IR logic to activate the interface

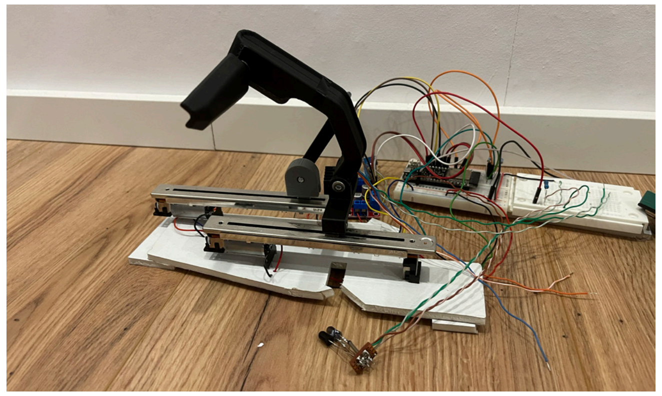


Figure 58: Handle with Grip mounted on the Motorfaders

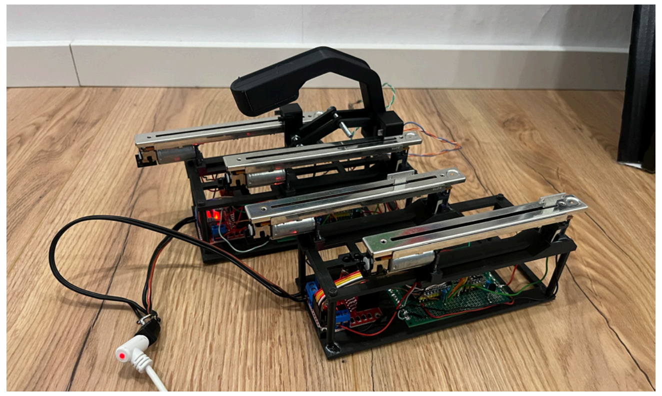


Figure 59: Handle in new 3D printed structure

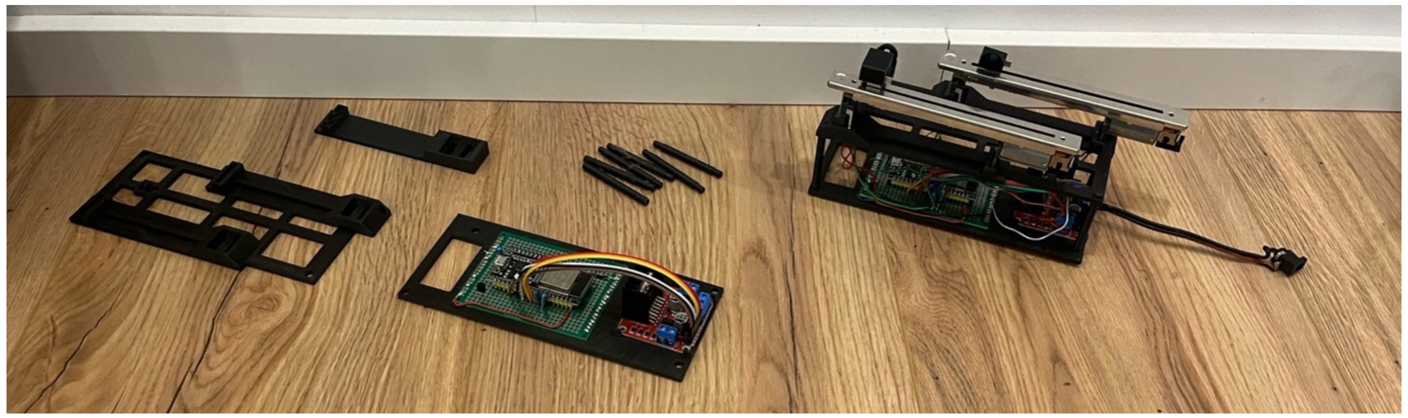


Figure 60: Development of the 3D printed Structure - test fit prints to final structure



### Iteration 3: Final Refinements Demonstrator

The final iteration improved the structural stability of the housing and added a rail system which ensured a more stable interaction with the prototype. (Figures 61 - 64) Additionally, an enclosure was constructed meant to visualize the placement of the front two handles inside of the EQE SUV. (Figures 65 - 71)

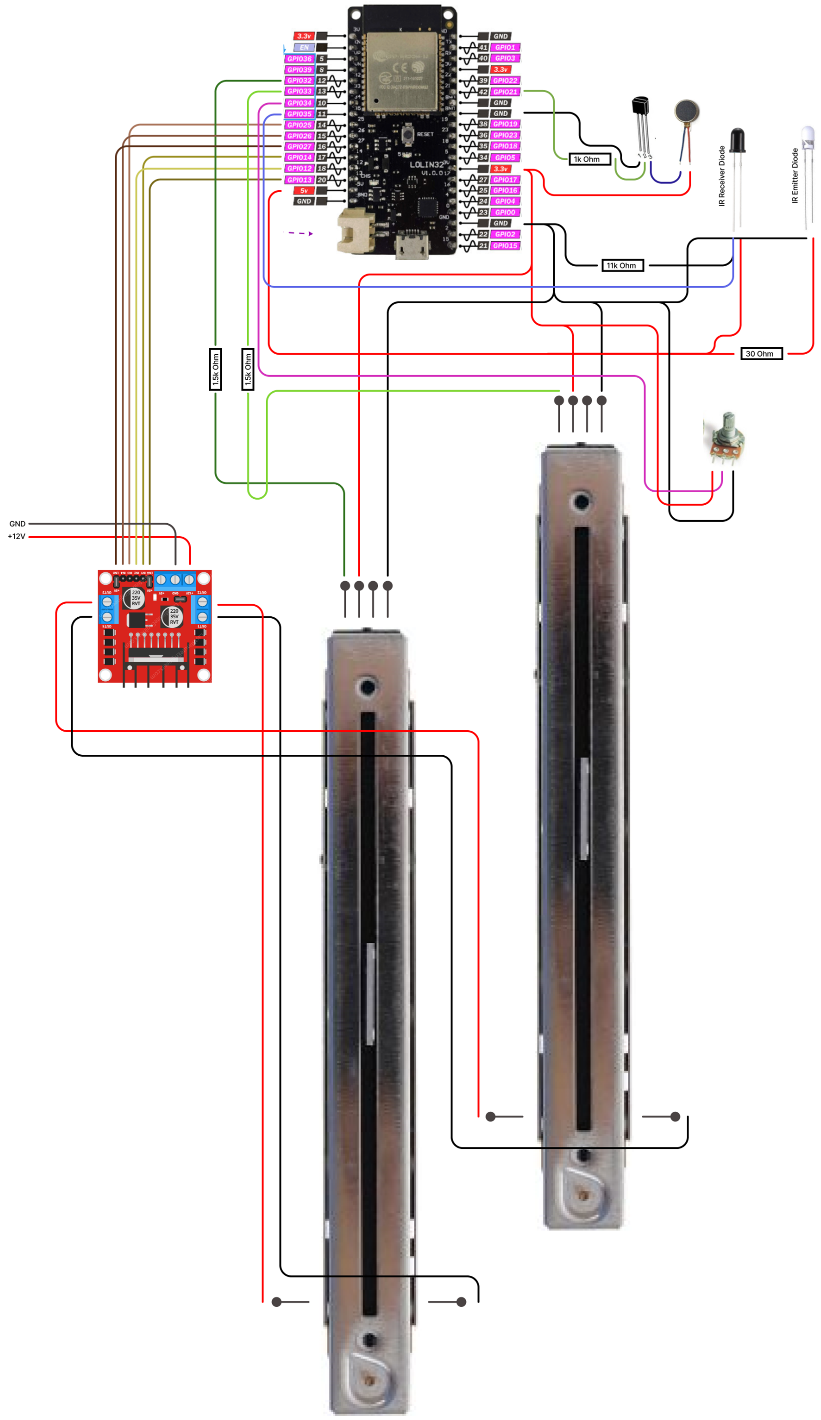


Figure 61: Wire Diagram of the Final Prototypes

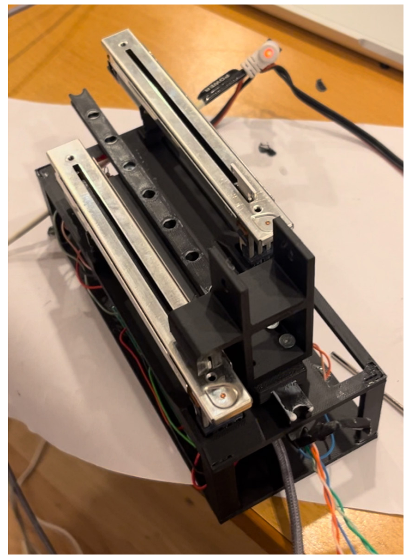


Figure 62: Rear handle holder on the Rail

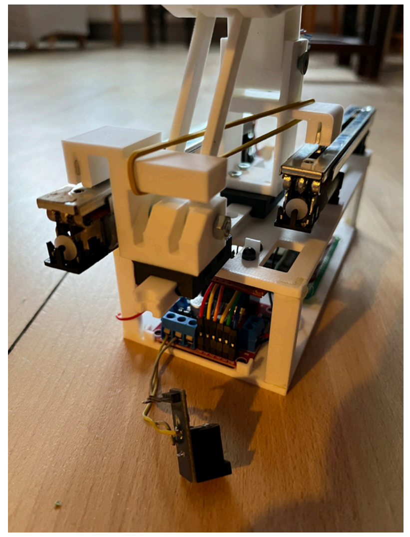


Figure 63: Handle mounted on Rail System

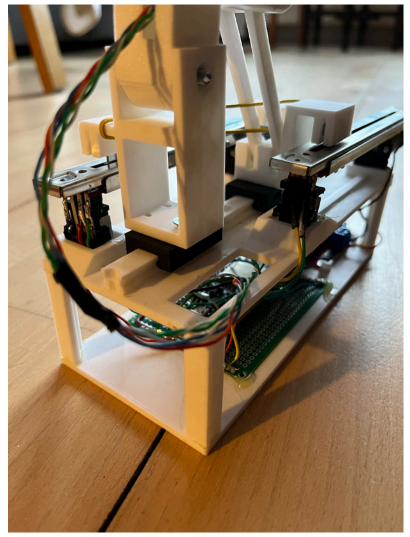


Figure 64: Handle mounted on Rail System



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Figure 65: Failed Print

Figure 66: 3D prints with filler and sanded

Figure 67: Spray painted enclosure with Silver Star

Figure 68: Test fit of the painted handles

Figure 69: Laser-cut monitor housing/hyperscreen holder attached to interface enclosure

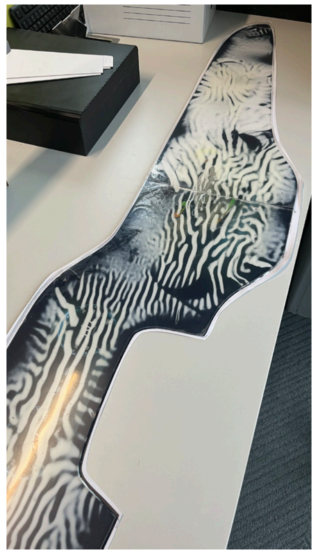

Figure 70: 'Hyperscreen' print attempt

Figure 71: (Almost) complete demonstrator



## Code:

The code was constantly being improved and iterated upon as well to match the increasing complexity of the setup. It was an incremental development, however, two important advancements were:

The addition of two prototypes meant the code was updated to manage communications between them. The code had to include unique identifiers and verify whether the other devices were sending values.

The second important development was the integration of 'Protopie Connect' a software tool that allowed seamless communication between the prototypes and the GUI.

Figure 72 visualises the data flow between the different components. A much more detailed version also showing the ESP32 code logic, and 'Protopie Studio' logic can be found in "Appendix 1- Data Flow Visualisation".

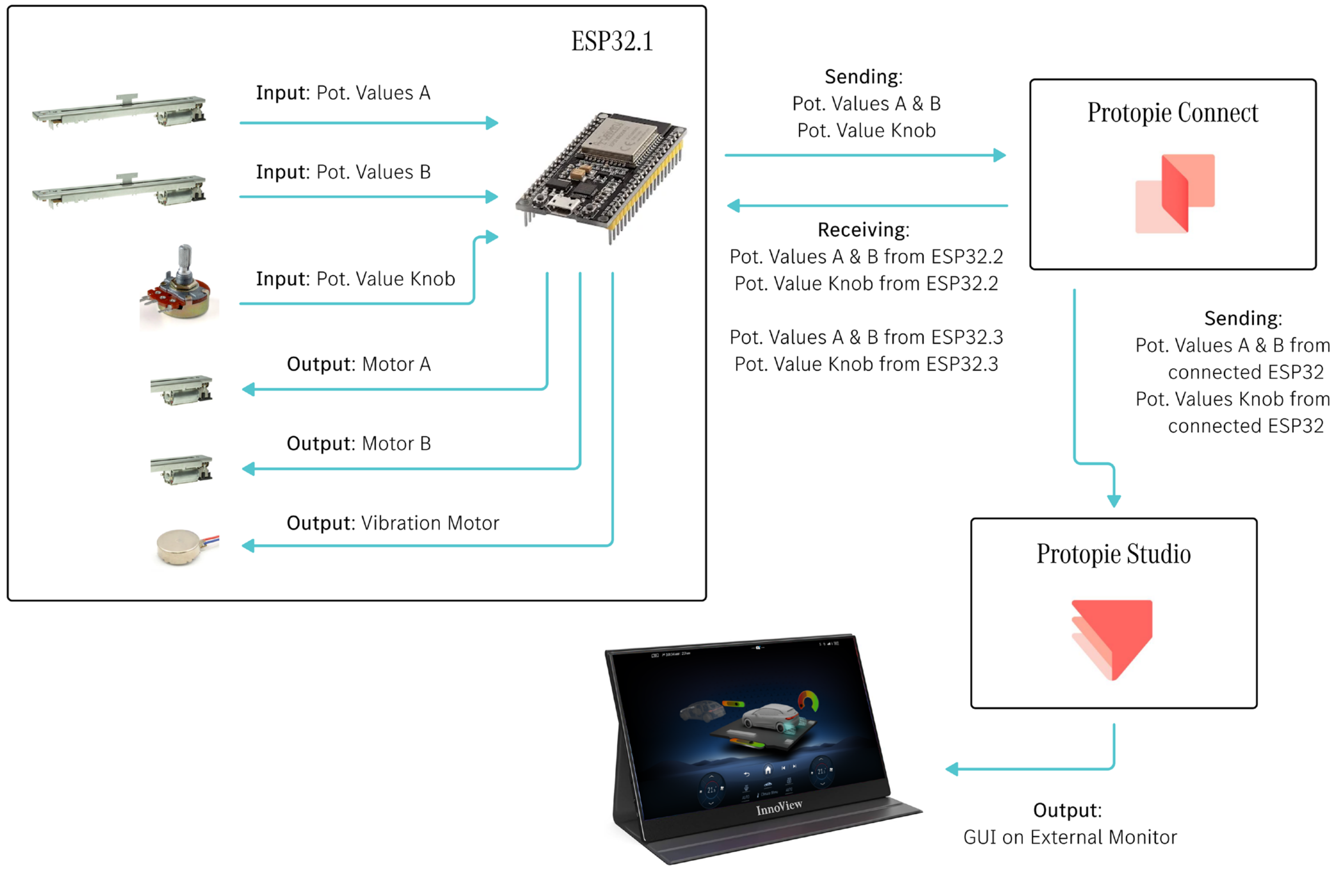


Figure 72: Simplified Diagram showing the Component Data Flow

## Handle Design - Pt.1

The handle design was another aspect that was developed in tandem to the technical prototype. I privately purchased a 3D printer to rapidly print, implement and test new versions. The accompanying illustration highlights changes in the design, and their respective benefits and drawbacks. The illustration shows two major shifts:

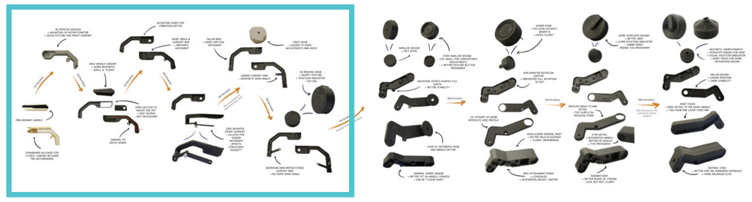

Figure 73: Entire handle process - pt.1

### 1. Transition from Elongated Grip to Knob

The initial concept included an elongated grip which could be rotated. While effective in the early laser-cut prototypes, this design introduced instability when moving the handle and required a larger footprint in the vehicle. At this point in the project, I was offered to present the current design to the Mercedes-Benz team.

As several designers suggested replacing the grip with a knob, I therefore created a foamboard version of this idea which confirmed improved usability and a reduced footprint, leading to the adoption of the knob design.

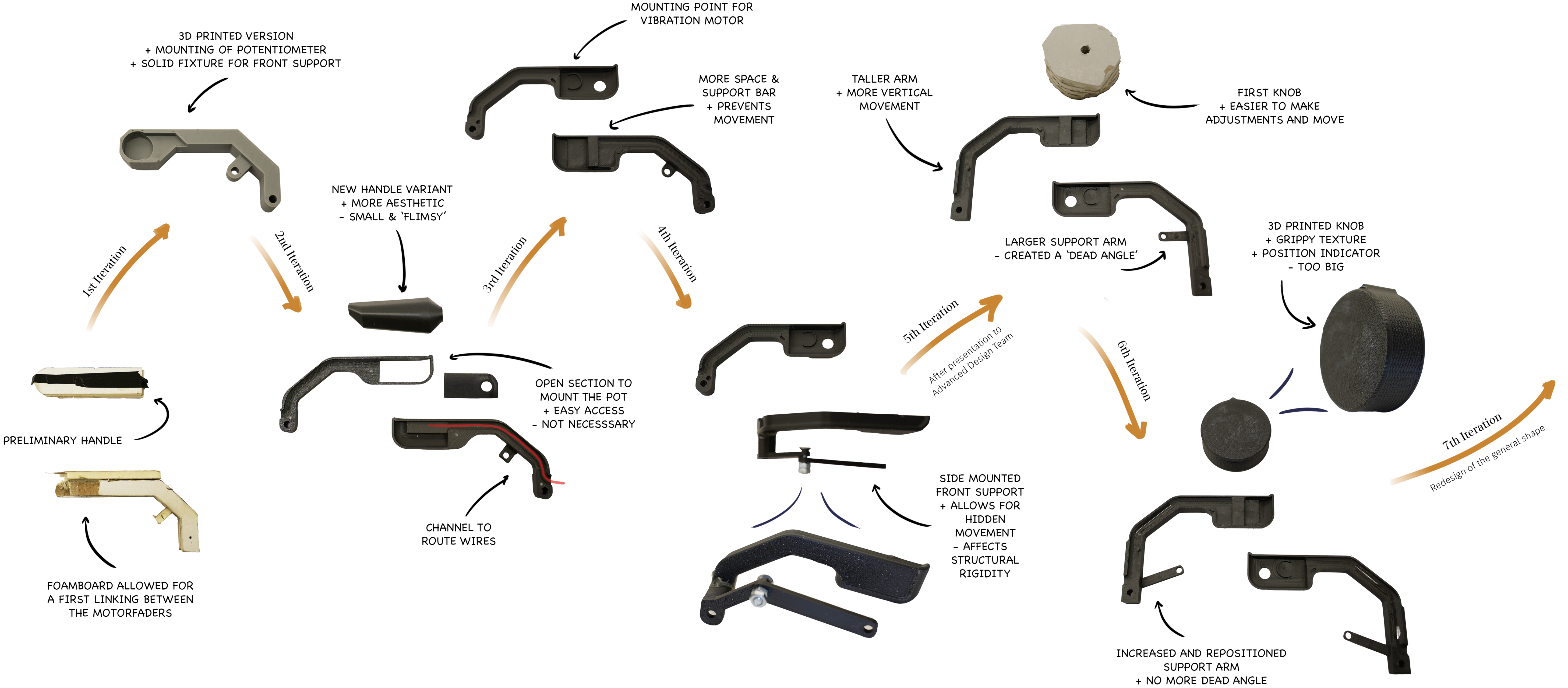


Figure 74: Handle process - pt.1





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Figure 74: Entire handle process - pt.2

## Handle Design - Pt.2

### 2. Change in Arch Direction

The original design incorporated an upwards arch. With further advancements in the technical prototype, I started considering the implementation in the vehicle. Whilst elegant, the design looked frail and did not feel as though handle and knob were one element.

To rectify this a mood board and a brainstorming session inspired a new design which created a more cohesive appearance and a better integration in the vehicle interior.

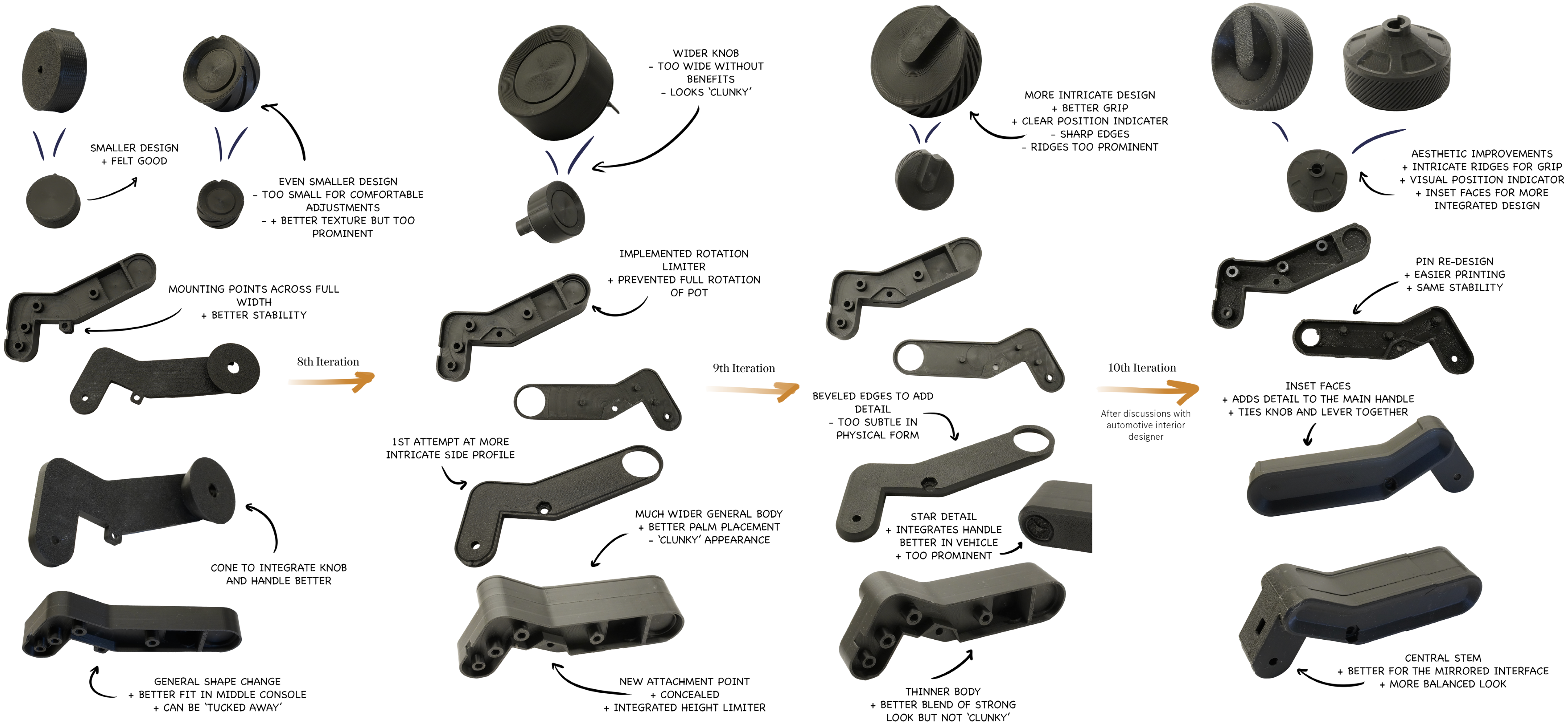


Figure 75: Handle process - pt.2


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## Graphic User Interface

The second component of the user interface was the GUI. This is an important component of the concept as providing passengers with information regarding the AVs decisions can increase trust in the vehicle and therefore the comfort of passengers [40]. Hence, visualising the driving style and system parameter adjustments should further support passenger trust [19]. Additionally, this interface also serves as a reference for passengers. Whilst the tangible interface already communicates the chosen states of the other passengers through haptic feedback, the GUI puts this into a visual form. Hence, visualizing the information could additionally improve the usability, as passengers can relate movements in the tangible interface to changes in the GUI.

### Iteration 1: Technical Implementation of System Parameters

The first version focussed on creating moving elements that reacted to changing inputs. This version was not focussed on visual appeal yet but only on the technical implementation of the three system parameters. Three sliders controlled the parameter visualizations: moving a grey square for distance adjustments, changing road marking velocity for vehicle speed, and resizing arrows for acceleration. (Figures 76 & 77)

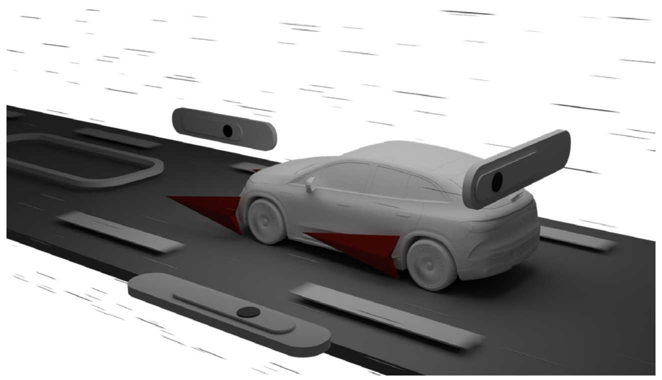

Figure 76: First render in Blender of interface elements

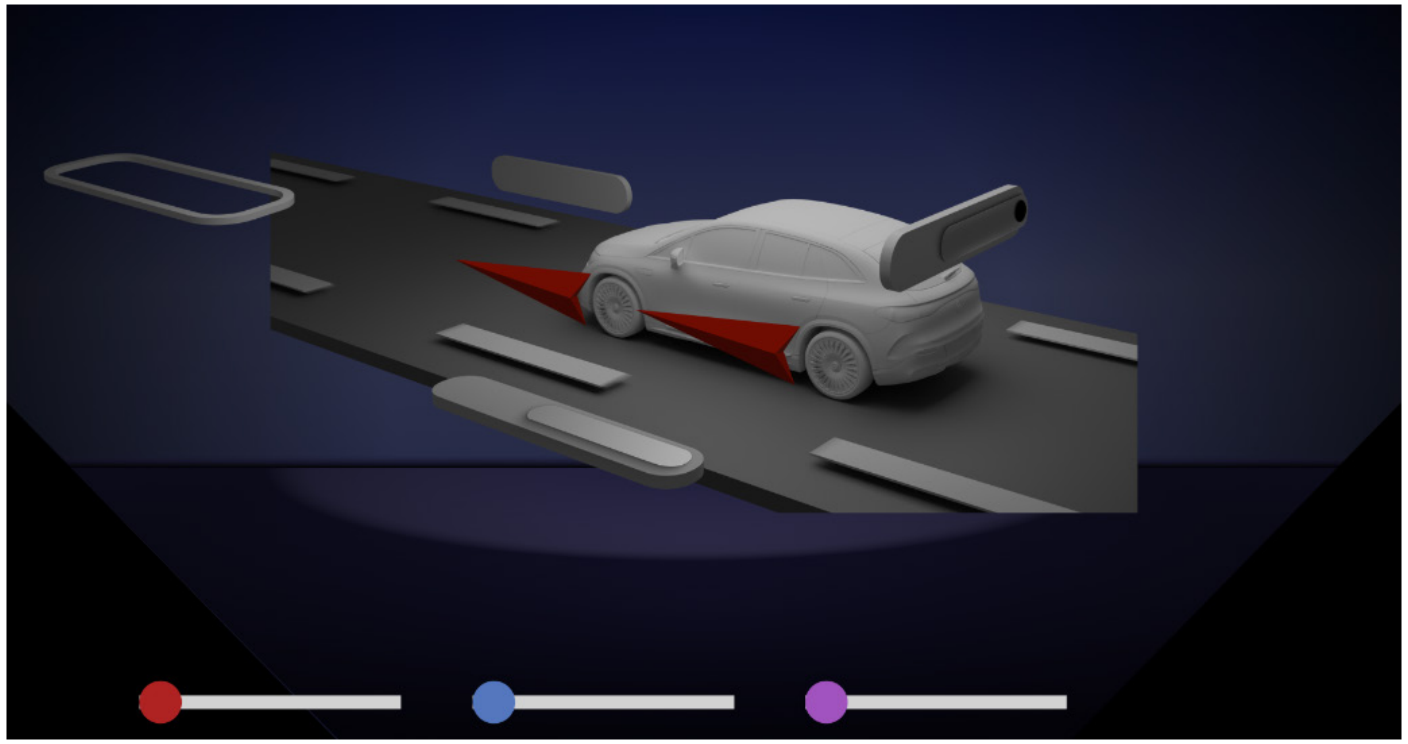

Figure 77: First integration in Protopie and the three sliders used to control the parameter visualisations



### Iteration 2: Aesthetic & Technical Improvements

This version balanced functionality and aesthetics. Firstly, it implemented the gradient indicators, the ‘range’ - set by the driver, and the black dots – set by the passengers. Additionally, the gradients were changed in shape and position to align with physical interface actions.

On the technical side, this iteration integrated real-time inputs from the tangible prototypes, enabling dynamic adjustments in the GUI. (Figures 78 & 79)

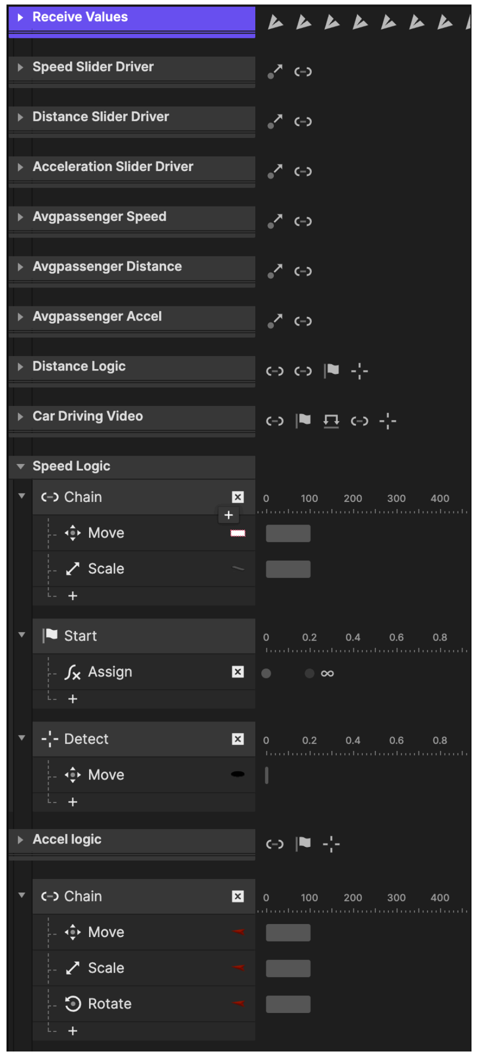


Figure 78: Protopie Actions

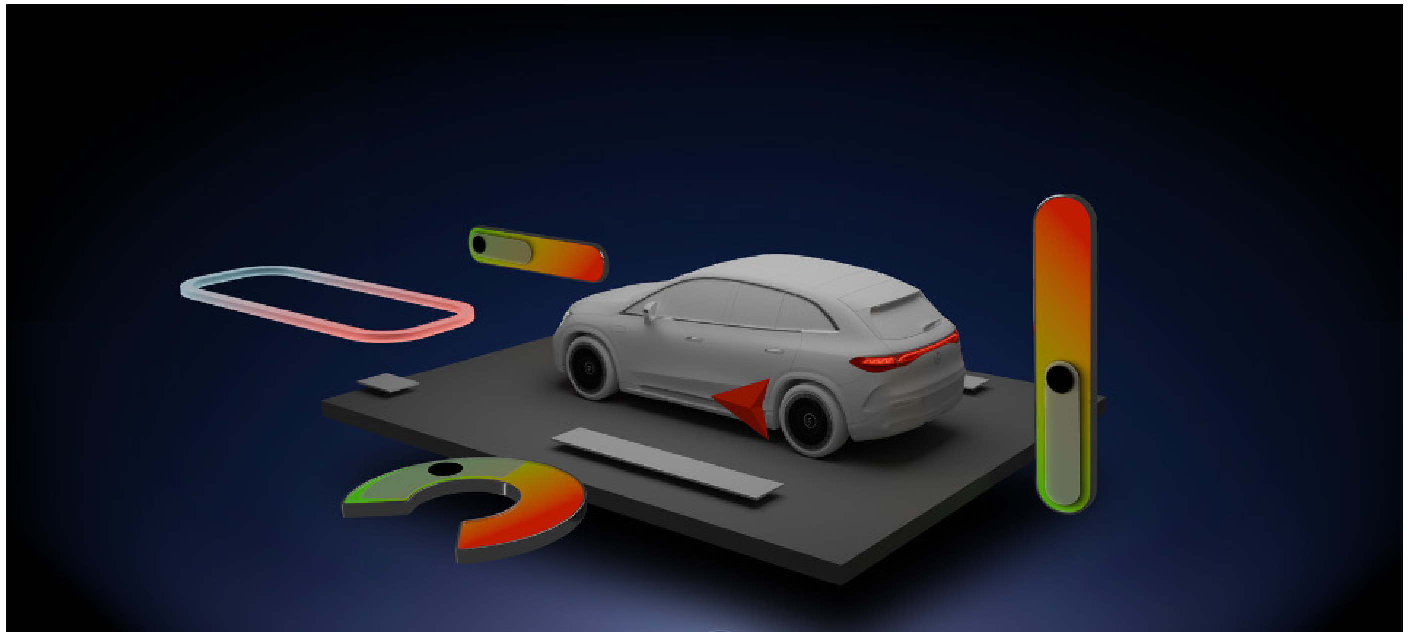

Figure 79: Second Protopie Interface with changed visuals

## Iteration 3: Final Adjustments

The last iteration focused on clarity and user understanding. Visual changes were made to include a ‘ghost car’ as the leading vehicle. The acceleration visualisation was re-designed, and the location of the gradient indicators was changed for clarity: e.g., the speed indicator was physically integrated into the road. The interface now also reacts dynamically to the number of connected interfaces. A single passenger can control the full range, while multiple passengers share it. (Figures 80 - 83)

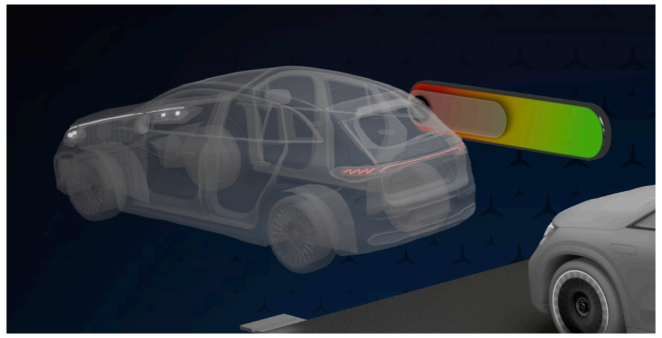

Figure 80: Ghost Car

Figure 81: Acceleration Lines (in Protopie)

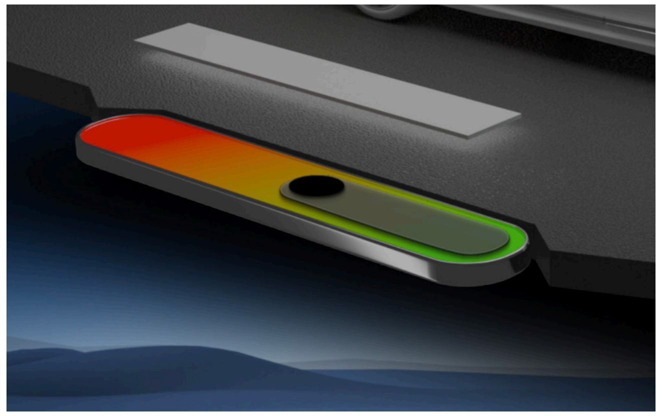

Figure 82: Speed gradient integrated in the road


Figure 83: Interface integrated in the ‘Hyperscreen’ - interactive element highlighted red





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# FINAL CONCEPT

'Glide' aims to enhance passenger comfort in AVs by offering a tangible interface for adjusting driving style and a graphic interface for visualizing these adjustments. The concept also proposes an innovative control division between the passengers of the vehicle where each passenger is provided with an adequate amount of control to ensure a better user experience when driving in AVs. The driver is given the ability to set a permissible range in which the AVs driving style can be adjusted and the passengers are provided with the ability to fine-tune the style within this range without undermining the driver's authority.

The concept translates a theoretical control distribution model into a physical, experiential system, demonstrating the feasibility of shared control in AVs and serving as a steppingstone for further research. Whilst the earlier focus was on creating a rich and meaningful interactive interface, it has become a concept that demonstrates the possibilities of shared control between passengers in AVs.

Figures 94 - 96 at the end of the chapter show a user interacting with 'Glide'.


Figure 84: Final Demonstrator



## Tangible User Interface

Each passenger receives a physical interface that can be pushed forward, lifted, and rotated to adjust the distance to the vehicle ahead, relative speed, and acceleration behaviour respectively. Integrated haptic feedback communicates other passengers' inputs through force and vibration feedback, fostering unobtrusive, intuitive communication, which helps passengers understand each other's driving style preferences without interruptions. The tangible interface allows for a quick adjustment of the parameters via a single gliding motion instead of individually adjusting each parameter by, for example, using separate sliders.

The visual design of the tangible interface aims to match the luxurious feel inspired by Mercedes-Benz's brand identity and incorporates high-quality materials like brushed and polished steel, which are used to divide large elements into more intricate ones; piano black accents which are used to tie it together with other interior elements, and to create a visual link between the handle and knob. Lastly details such as a 'Lorbeerkranz' on the knob's inner chamfer, emphasize the elegance and heritage [41].

The following links lead to short animations visualizing the movements of the handle: Forward/Back, Up/Down, Rotate.

Figure 86: Handles in Middle Console

Figure 85: Handle in Rear Right Door


Figure 87: Close up of Handles



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## Graphic User Interface

Displayed on the central infotainment screen, the GUI visualizes driving style changes using three gradients representing the adjustable system parameters. Each of the gradients is subdivided by a ‘range’ indicator which represents the drivers’ inputs whilst the black dot inside of the ‘range’ is the amalgamation of the driving style preferences of the passengers.

The GUI simplifies system parameters into intuitive visuals. These visualisations adjust to changes in the physical interfaces and therefore aids comprehension of the adjustments. (Figures 88 - 92)

The following link leads to a short video of the visual system parameter changes in the GUI: [https://youtu.be/P-IIYYsQQ5M](https://youtu.be/P-IIYYsQQ5M)

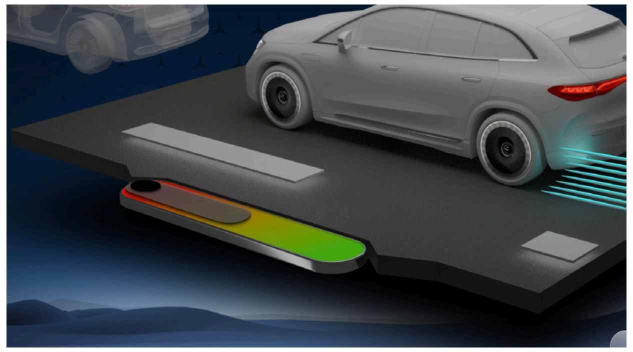


Figure 88: Road markings speed up with higher sportiness - for a visualisation please view the link.

Figure 89: Smaller Acceleration Indicators

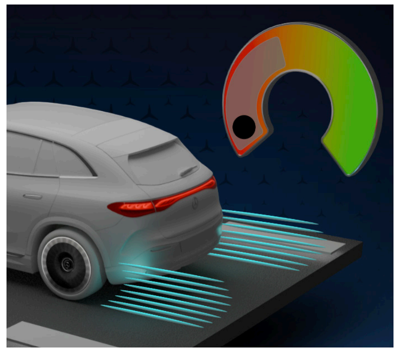


Figure 90: Larger Acceleration Indicators

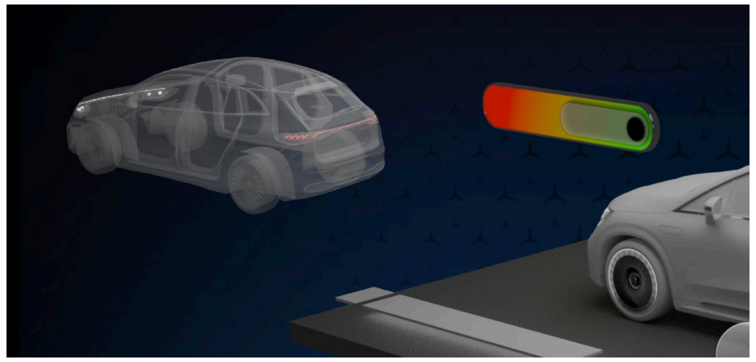


Figure 91: Car ahead further away

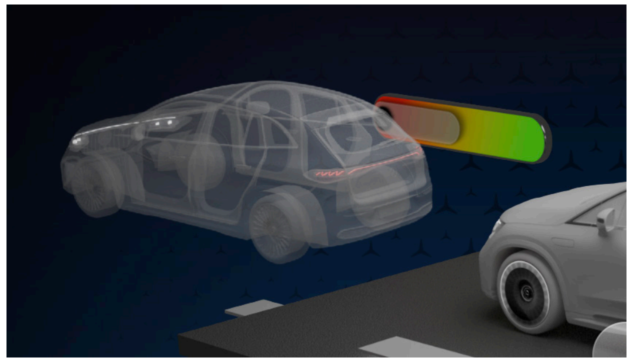


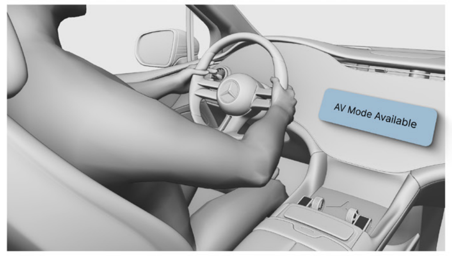
Figure 92: Car ahead closer by



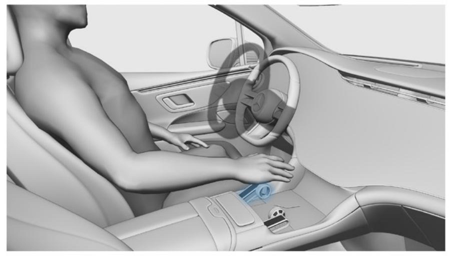
## Storyboard

Once the autonomous driving takes place, the system becomes available. The interface can then be ‘woken up’ by hovering over it. In the scenario below (Figure 93), a rear passenger starts feeling uncomfortable and therefore decides to ‘wake’ his own interface. Since the driver already activated their interface and set their own preferred driving style, it initially aligns with the driver’s input. The passenger can then move the interface to input their own preferred driving style.

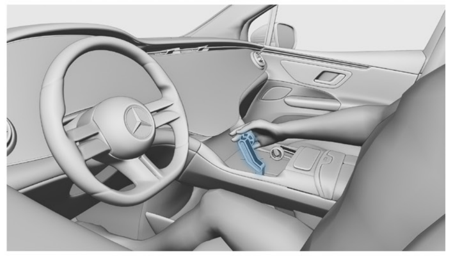
Haptic feedback subtly informs the passenger of the driver’s preference during adjustments via a force acting in the direction of the drivers chosen position. This, on the one hand, provides a more prominent experience of making a change, but it also clearly communicates to the passenger that the driver prefers a different driving style. If either of them would make subsequent changes, they would always perceive a force pulling towards the position of the other active interface. Additional passengers activating their interfaces would see the interfaces assuming an average position between the active users.



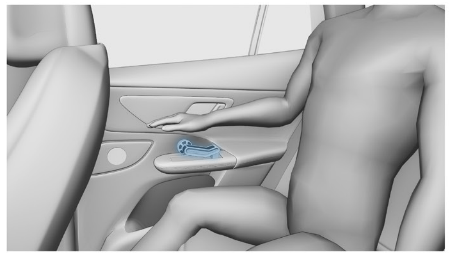

1. The driver drives the vehicle until the automated driving can take over and a takeover is initiated.



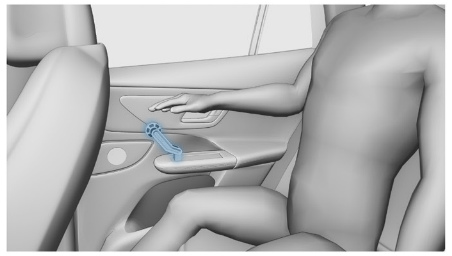
2. Once the automated driving takes over, the driver can activate ‘Glide’. This retracts the steering wheel and moves the tangible interface into the base position.



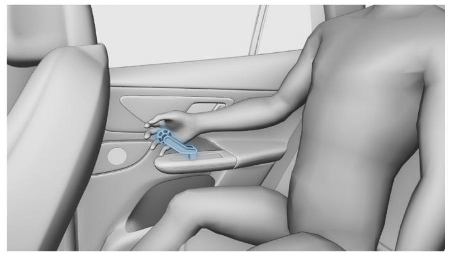
3. The driver can set the parameters of their choice. In this case the most sportive settings are chosen.



4. The rear passenger who starts feeling uncomfortable with the driving style of the AV decides to activate their own interface.



5. Once the interface is activated it assumes the position of the other activated interfaces in the vehicle. In this case the driver’s interface.



6. The passenger can then adjust his tangible interface to their preferred settings.

Figure 93: ‘Glide’ Storyboard (Driver - Rear Passenger Interaction)



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## Special Situations

**Deactivating the Interface**
Passengers who don't want to be involved in adjusting the driving style any longer can deactivate the interface by pushing it down.

**Takeover situation**
If the vehicle requires the driver to take over full control, the system automatically reverts the driving style to the most comfortable settings. By doing so, the driver will not be required to take control in situations outside of their comfort zone.

**Equal control for everyone**
'Glide' could technically allow drivers to provide equal control for everyone in the vehicle. Given that the tangible interfaces look identical for everyone, there would be no physical hierarchy.



## Demonstrator


Figure 94: Visitor interacting with 'Driver' Interface


Figure 95: Visitor interacting with 'Driver' Interface


Figure 96: Visitor interacting with 'Driver' Interface



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# FINAL EVALUATION

## Expert Evaluations

### Methodology

Given the time constraints of the semester and the shift in project scope, there was no time left to conduct a user study which would provide accurate results regarding comfort or control improvements for passengers. Nevertheless, to understand whether the concept could be considered a success, evaluations were conducted with five experts: two focused on AV design, two on automotive UX design, and one on automotive interior design.

#### Procedure and Analysis

Semi-structured interviews, tailored to each expert's field, were used to gather as much relevant information as possible. The project and features of 'Glide' were presented and explained to each expert before starting the interviews. They were also able to interact with the interface to experience its haptic feedback and control distribution. Each session lasted between 30-45 minutes.

#### Analysis

The responses were transcribed or noted down depending on the location of the session and analysed using a summary-based approach adapted to their diverse area of expertise.

### Findings

#### Automotive UX Designers

Trust and Comfort: Both experts believed the interface could enhance passenger trust and comfort in AVs. Designer 1 mentioned that passengers would feel comfortable adjusting the driving style and would likely use the interface actively. Designer 2 agreed and shared an anecdote about using current driver assistance systems with multiple passengers, that would have felt more comfortable if they could control the driving style or communicate their preferences. He emphasized that having control would significantly enhance both comfort and trust.

Haptic and Visual Feedback: Both experts appreciated the implementation of haptic feedback. Designer 1 valued the ability to 'feel' choices made by other passengers but cautioned against making the haptics too complex. Designer 2 praised the haptic feedback as an effective method for users to understand each other's choices, noting that it is well-implemented and allows passengers to comprehend the selections made by others. Regarding visual feedback, Designer 1 praised the visuals of the GUI but pointed out a misalignment between the physical interface and visual hierarchy. Designer 2 was also positive and stated that he almost immediately knew which gradient stood for which parameter.



#### Autonomous Vehicle Experts

Interface Complexity: Expert 2 appreciated the innovative combination of physical and graphic elements, commenting, "As a design challenge, I really like it a lot. I think it's an innovative idea". However, the experts raised concerns about the cognitive load, and both suggested simplified alternatives like single sliders or button interfaces, as otherwise it might hinder intuitiveness and user adoption. Expert 2, however, did acknowledge that such solutions would be "far less interesting".

Intuitiveness: The interface was described as not initially intuitive but quickly understandable after brief interaction. Expert 1 remarked, "Not intuitive per se but if I buy a car like this then one minute later when I see the system I know what it is." Expert 2 pointed out that certain elements were intuitive but described the overall interaction as "rather complex," suggesting a need for further refinement. Concerns were also raised about the GUI's colour choices, with Expert 2 recommending a gradient from green to dark orange instead of red, stating, "red assumes that this is unsafe."

Multimodal Feedback: Both experts agreed that given the AVs ultimate control over the car, the interface would not affect safety-critical tasks. Therefore, while multimodal feedback could enhance the user experience it may not be necessary.

Haptic Feedback: Expert 1 confirmed that the haptic feedback is effective, explaining that tactile responses are well-designed and contribute positively to the user experience. Expert 2 highlighted a potential conflict in haptic feedback, noting, "You can feel what the driver has selected, but on the other hand, it is also stimulating the user to move towards that position".

Passenger Trust: Both experts believed the interface provided sufficient control to increase passenger trust, with Expert 1 stating "I think it could increase the level of trust especially from a passenger side".

#### Automotive Interior Designer

As a whole, the Expert found the design to be very attractive, especially with the inset faces creating a sense of lightweight construction. He was particularly impressed with the 'loorbeerkranz' detail in the knob, describing it as his highlight, next to which he also appreciated the texture around the outside. However, he expressed some disappointment that the detail loses impact in rear seats due to the handle orientation. He also commented that the uniformity of the overall design could be enhanced. He recommended focusing the next iteration on creating a more cohesive design that seamlessly combines both elements into one by removing the inset elements on the knob. Whilst he liked these elements, he felt they contributed to a sense of restlessness. Lastly, he suggested lowering the entire element, to reduce its footprint.




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## Discussion

### Interpretation of Findings

The evaluations provided valuable insights into the interface's design and its potential impact on trust, comfort, and user experience in AVs. The findings suggest that while the concept demonstrates significant promise, a few areas would need to be refined. Both the UX Designers and Automation Experts emphasized the ability of the interface in enhancing passenger trust and comfort. The possibility for passengers to adjust driving styles was highlighted as a feature that could significantly improve user perception of safety and control, which means the project could be considered a success.

The promising feedback supports continuing the project to conduct a user study to validate its effectiveness.

The haptic and visual feedback components received mixed responses. While the haptic feedback was deemed intuitive for communicating of passenger preferences, its complexity was a concern. Similarly, the GUI and the visual design of the physical interface, though generally well-received, requires some more refinement.

### Strengths and Limitations

The incorporation of expert evaluations from diverse fields provided a multifaceted understanding of the interface's strengths and highlighted areas in need of improvement. However, the absence of direct user testing remains a significant limitation preventing the ability to draw definitive conclusions about the interface's effectiveness.





# Intuitiveness Questionnaire

Next to the expert interviews, a questionnaire was developed to assess the intuitiveness of the tangible interface movements. The interface was intended to be used without paying full attention, and therefore it was important that the movements are intuitive. During the early stages of the tangible interface development, the movements were exploratively presented to fellow design students with the majority supporting the selected mappings. However, to avoid concluding this project with false assumptions, the questionnaire aimed to validate this aspect with the general public.

## Methodology

MS Forms was used for the questionnaire which consisted of two parts. First participants were introduced very briefly to 'Glide' and its purpose of adjusting the three system parameters. The second part consisted of three subsections: 1. Participants were shown a 5-second animation demonstrating a movement. 2. They were asked to select the parameter they felt the movement best represented. 3. They were asked for a justification of the chosen parameter. This process was repeated for all three movements.
In total, 18 participants answered the questionnaire, which was distributed via social media. The answers were summarized and are presented below.

## Results and Analysis

The forward/backward movement was almost evenly split between the distance and speed. When asked for their reasoning, one participant stated, "I picture the handle to be the car, handle moves forward - car moves forward relative to other vehicles". Another participant who answered with speed argued that it reminds them of how speed is adjusted in video games. Interestingly, two participants who also answered with speed stated that it reminded them of airplane controls.

The upward movement yielded a surprising result, with 80% of participants associating it with acceleration, with only three participants linking it to the vehicle speed. Looking into the answers revealed that even though most participants agreed to the acceleration mapping, there were differentiating opinions whether lifting it indicated slower or faster acceleration.

The rotational movement displayed the most varied responses. Almost half of the participants mapped this movement to vehicle speed, with 33% linking it to distance and 22% linking it to the acceleration. Looking at the open responses, one participant explained that the rotation matched the mental model of a speedometer, whilst another participant explained that it reminded them of a motorcycle throttle.

## Interpretation of Findings

The results indicate that while the interface aimed to be intuitive, it did not achieve this goal. However, this does not imply that the concept is a failure. As mentioned above, 'Glide' as a concept is a first iteration which translates the theoretical control distribution into a physical interface. It will require more iterations to work out details such as the intuitiveness of the movements. Additionally, this could also benefit user understanding as discussed by Hornecker [20].

## Discussion

These results must be considered carefully as the participants were not able to physically interact with the actual interface. If these parameter mapping results are used to influence future designs, they should, nevertheless, be re-evaluated in a user-study.



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## Supervisor Evaluation

*It has been a pleasure to have Lucas with us for his master design project. His focus on creating a democratic interface for autonomous driving, allowing multiple users to negotiate the driving style of a self-driving car, was both innovative and thought-provoking.*

*Lucas developed an interactive prototype that effectively demonstrated his concept. The quality and finish of his presentation were exceptional, and the technical setup was notably impressive. His solution stood out by incorporating rich physical interactions supplemented by a screen, making it far more engaging than a standard touch screen interface.*

*Lucas exhibited a commendable work ethic throughout his project. He was often in the office more than many of his colleagues. Despite a slower start during the research and brainstorming phase, he gained significant momentum during the prototyping phase, enabling him to produce multiple iterations of his design.*

*Although Lucas worked independently, he made excellent use of his colleagues by involving them in brainstorming sessions and interviewing them as experts to gather feedback on his concept. One of his best decisions was to simplify the number of variables that could be set and to make the concept slightly less democratic by putting the person in the traditional driver's seat in charge. This refinement significantly enhanced the user experience of his interface.*

*Lucas was also keenly interested in other projects within the company, seeking to understand how different approaches or technologies could be integrated into his work. This curiosity and willingness to learn were evident throughout his project.*

*At Mercedes-Benz, we pride ourselves on being pioneers in autonomous driving, notably being the first OEM to receive permission to sell Level 3 capable vehicles to customers in Germany and some US states. We are also renowned for our luxurious interiors. Lucas' approach to combining advanced technology with rich physical interaction aligns perfectly with our brand ethos.*

*I am delighted to share that Lucas will be joining us for an internship to work on some of our production car topics. His creativity, technical skill, and dedication will undoubtedly be valuable assets to our team.*

Zane Amiralis
Manager Advanced UX Design, Mercedes-Benz
Sindelfingen, Germany
zane.amiralis@mercedes-benz.com



# FUTURE WORK

The expert evaluations of 'Glide' highlight its potential to enhance passenger trust and comfort by providing passengers with control over the driving style. However, due to project constraints, it was not possible to test the concept in an immersive, real-world environment. Therefore, future work should focus on making the concept ready for user tests.

Firstly, another iteration could focus on the intuitiveness of movements and ergonomics of the handle, and the GUI should be evaluated according to display design guidelines [42]. Next to this, the positioning of the handle should be reconsidered as this was another point of discussion during the evaluation. But of most importance is the preparation of an immersive user test using a simulator or the Wizard of Oz methodology as this would ensure experiencing the interface in action. The current technical infrastructure already allows for the collection of input data from the physical interface, meaning the primary challenge lies in designing a study setup that can simulate a driving scenario effectively.

Secondly, it should be investigated whether such an interface could work in current passenger cars as a communication tool between the passengers and driver. Such an interface could prove valuable in contexts where passengers have limited interaction with the driver such as in ride hailing services, or when using chauffeurs. Instead of directly influencing the driving style, the interface could be used as a communication tool to inform the driver about the passengers preferred driving style.

# CONCLUSION

The development of 'Glide' is an exploration into the design of a shared control system for automated vehicles, aimed at improving passenger comfort and trust. A foundation is created for a reimagined interaction concept between passengers and AVs by using tangible interfaces with integrated haptic feedback and a graphic interface.

The newly developed control mode in 'Glide' ensures that the driver retains a larger amount of control whilst still offering passengers enough autonomy to fine-tune within set parameters. The evaluation revealed that the concept could provide an acceptable solution for a fair control distribution. It also highlights that the integration of haptic feedback and a GUI could increase trust and comfort which could benefit adoption rates of automated systems.

However, there are areas for future improvement. The mapping of tangible interface movements to system parameters requires refinement to enhance intuitiveness. Additionally, immersive user testing remains a critical step to validate the interface's impact on trust and comfort in real-world scenarios. Overall, 'Glide' presents insights and innovations that can inform future research in the field of automated vehicle design regarding human-vehicle interaction.




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# ACKNOWLEDGMENTS


## Acknowledgments

This project represents the final chapter of my journey in the Industrial Design program at the TU/e. Its completion would not have been possible without the support, guidance, and encouragement of many incredible individuals.

First and foremost, I would like to thank my coach, Joep Frens. Your guidance throughout this semester has been an incredible help. There were moments, where the pressure of delivering a project worthy of my master studies overwhelmed me. However, your encouragement and advice throughout those moments allowed me to reevaluate my position and approach issues from a different angle. Thank you for your honest critical feedback and dedication over the last semester.

I would also like to express my deepest gratitude to my supervisor at Mercedes-Benz, Zane Amiralis. Thank you for offering me the opportunity to join your team and for your kindness, openness to questions and willingness to share your expertise. I am truly thankful for the opportunity to work under your leadership.

Additionally, I would like to extend my gratitude to each member of the Advanced Design Team for participating in my co-creation and evaluative sessions. Their knowledge and expertise have been a cornerstone of this project. I would like to especially thank Dominick Conrad and Peter Buczkowski. Your willingness to help has been an incredible asset to this project.

Lastly, I would like to thank my family and friends for their endless support and encouragement throughout this journey. Your belief in me, even during the most challenging times, has been a driving force behind this project. I am deeply grateful for your love, patience, and understanding, which have made this achievement possible.






## Use of AI

Throughout the writing process of this thesis, I made use of OpenAI's language model, ChatGPT, to assist with proofreading and editing tasks. This tool was employed to improve spelling, grammar, and overall text clarity, as well as to refine sentence structure. Importantly, the use of ChatGPT did not involve the generation of any content, nor did it alter the original ideas, analyses, or academic integrity of this work. Specific prompts, such as "Improve grammar" and "Review text," were used solely for technical refinements. No part of this thesis was created or generated by AI.

Additionally, ChatGPT was used to assist in the development of the code for the technical implementation of this project. While I am fully capable of writing the code independently, the use of ChatGPT facilitated the process by providing potential solutions and reducing the time spent searching for them online. It is important to note that many of the solutions proposed by ChatGPT were incomplete or even incorrect, and my own knowledge and expertise were necessary in debugging, refining, and implementing the final code. Therefore, in this context, the use of ChatGPT did not compromise the originality or integrity of my work, as all decisions and implementations were ultimately my own.

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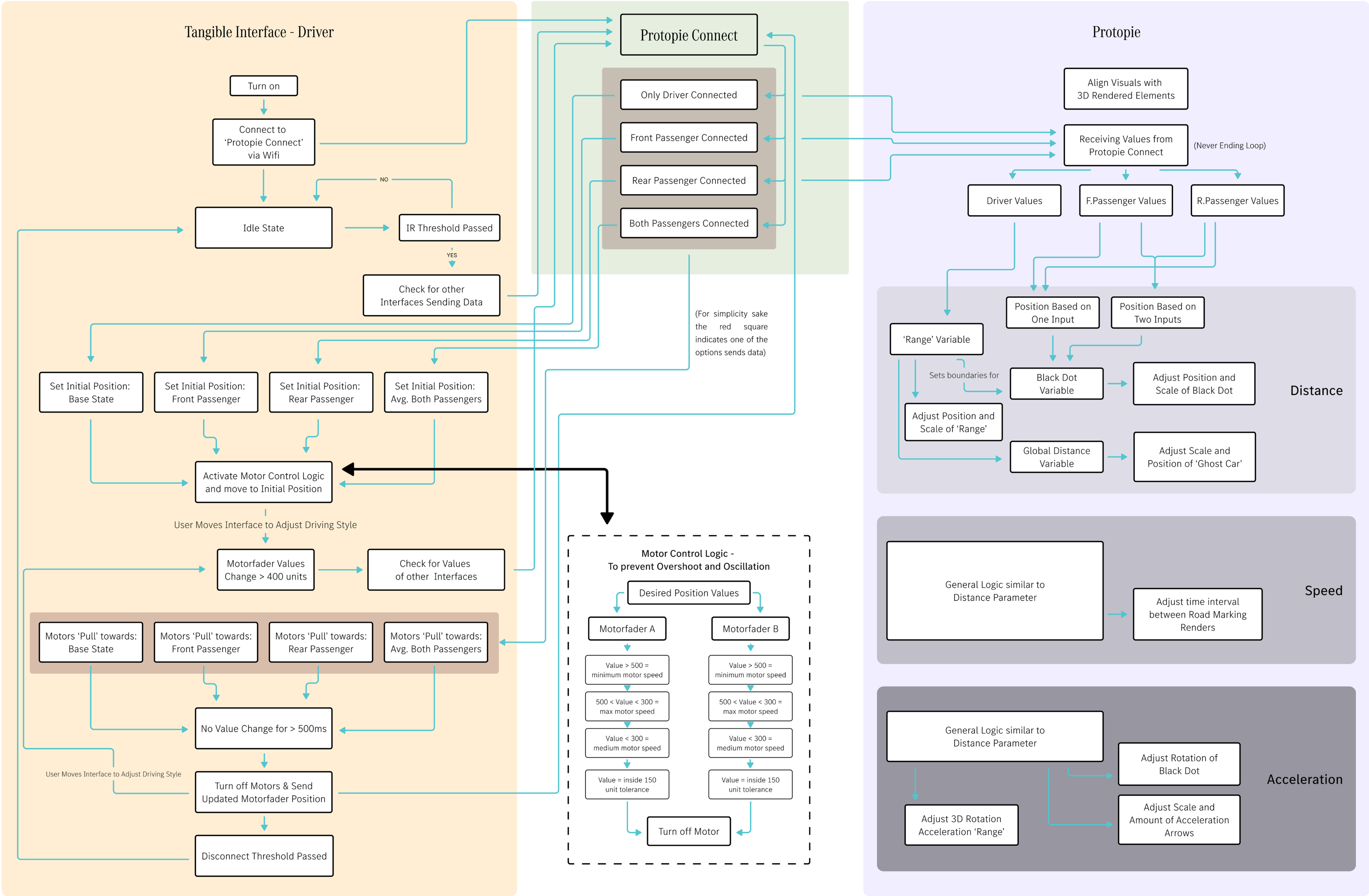
# APPENDIX

## Appendix 1- Data Flow Visualisation






Glide - FMP Design Project

# Appendix 2- Testing Materials 1

## Owner Interview Questions

**Personal Background**
1. Can you tell me a bit about your current career and professional goals?
2. What are some of your hobbies and interests outside of work?

**Car Purchase Decision**
1. What type of Mercedes do you drive? (Model and year)
2. What made you choose a Mercedes-Benz?
3. How important were factors like design and technology in your decision?
4. Were there any specific features or aspects of the car that particularly appealed to you?

**Car Usage**
1. How do you typically use your car on a daily basis?
2. Do you usually drive by yourself? Are there occasions where you drive with multiple people?
3. What features of your Mercedes do you find most useful or enjoyable?
4. How often do you use the car for social or leisure activities?
5. Do you use your car for any work-related purposes? If so, how?

**Car Infotainment**
1. How do you like the infotainment system?
2. Do you like to interact with it?
3. How does it communicate with you?

**Automated Vehicle**

My project considers the near future where fully autonomous vehicles will be a reality. I'm designing a tangible interface for these vehicles which would allow all passengers in the vehicle to provide feedback to the car about its driving style.

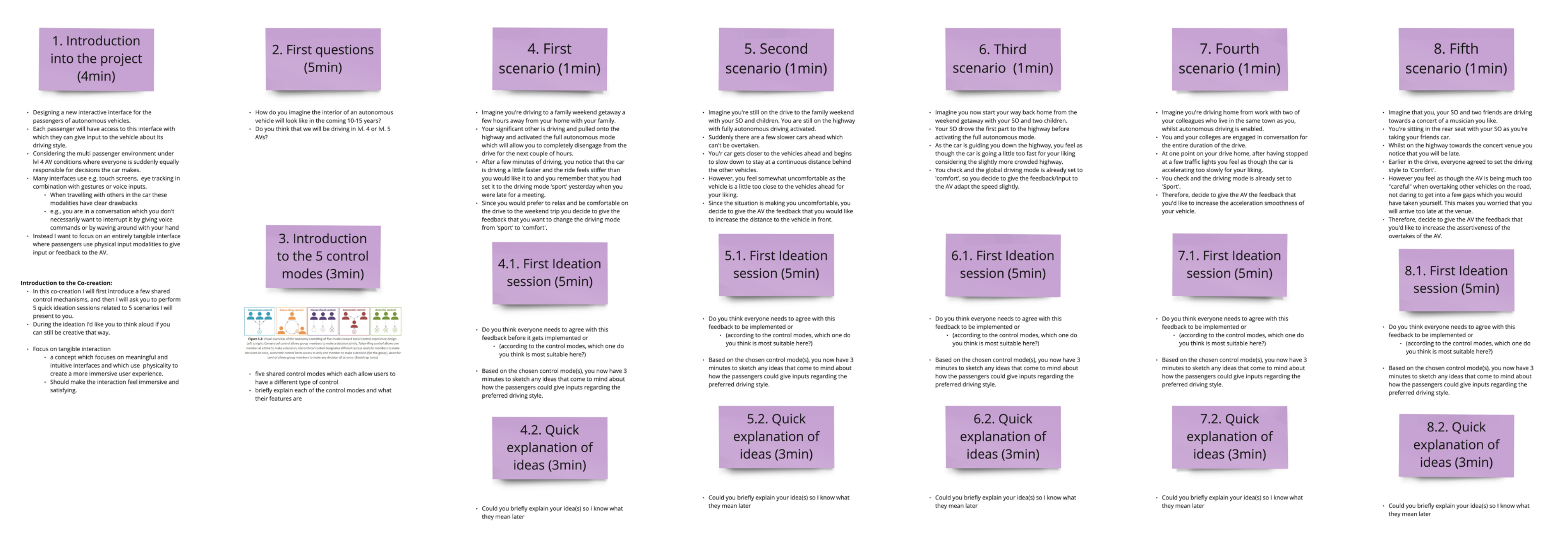
1. Would you consider buying an AV or do you prefer driving yourself?

Put yourself in the perspective where you can only buy AVs in the future. You no longer have to drive yourself and simply enter the address and it drives you there.

1. How do you imagine you will use your time in the car?
2. What sort of aspects regarding the drive to the destination would you like to remain in control in?

**Lifestyle and Preferences**
1. How important is the brand and image of Mercedes-Benz to you?
2. How do you feel your car reflects your personal style and aspirations?

## Co-Creation Setup and Questions






## Control Concept Evaluation Questions

**Questions**
1. Could you explain back to me how the control distribution in the vehicle works?
2. Do you believe the current control distribution gives passengers enough ability to influence the vehicle's driving style, with the driver deciding the overall driving mode?
3. How do you feel about the individualized control where each passenger can adjust the system parameters in the vehicle?
4. Would you feel comfortable adjusting the vehicle behaviour to the extent available through this concept even when the vehicle is driving in full self driving mode?
5. Do you have any other feedback or thoughts?

## Intuitiveness Questionnaire

Link to the full questionnaire: https://forms.office.com/e/kF1SGfbmZd

Section 2

### Concept Introduction

Please read the very brief concept introduction to get a better understanding about the concept before answering the questions:

The Problem: We are approaching the era of automated vehicles (AVs). In the coming decade the first production lvl. 4 AVs will likely hit the roads in Europe, which means that we need to ensure that passengers feel comfortable and trust the vehicle. One way to increase the trust and improve the experience of passengers is to give them control over the behaviour of the AV. Whilst current research projects primarily focus on the 'former' driver, I believe that every passenger should have the ability to adjust the driving style of the AV they are sat in, at least to a certain degree.

The Solution: With the concept I have developed in my masters thesis I aim to give passengers of AVs the ability to influence the driving behavior by adjusting three driving parameters: the **distance to the vehicle in front**, the **acceleration behavior**, and the **vehicle speed**. Each passenger can adjust these parameters using a physical interface and therefore change the behaviour of the AV. These are placed in the centre console (for the 'Driver' and front right passenger) and in the rear doors (for the rear passengers). You will now see three short animations visualising the movements afforded by the interface and you will be asked which of the three driving parameters you think fits best to each of the movements.

Below I have described the three parameters again in case you're unsure of what they entail.

**Distance to the vehicle in front:** This refers to the 'time headway' which is essentially the distance between your own vehicle and the vehicle in front of you. **Acceleration Behaviour:** This refers to the acceleration rate of the vehicle. A higher acceleration behaviour leads to for example a faster 0-100 kph time. **Vehicle Speed:** This refers to the speed the AV is travelling at in relation to other vehicles on the road. A higher speed will match faster vehicles on the road and vice versa.

2. Please watch the animation below depicting the forward/backward movement of the interface. Which parameter do you think this movement should adjust? *


- Distance to the Vehicle in Front
- Acceleration Behaviour
- Vehicle Speed

3. What reasoning did you use to decide which parameter matched the forward/backward movement?

Enter your answer

4. Please watch the animation below depicting the upward movement of the interface. Which parameter do you think this movement should adjust? *

Upwards

5. What reasoning did you use to decide which parameter matched the upward movement?

Enter your answer

6. Please watch the animation below depicting the rotational movement of the interface. Which parameter do you think this movement should adjust? *

Rotate

7. What reasoning did you use to decide which parameter matched the forward rotation movement?

Enter your answer



Glide - FMP Design Project

# Appendix 2- Testing Materials 2

## Expert Evaluations - Automotive UX Designers

**Overall UX:**

1. What do you think about the overall user experience of the interface?
   a. Are there any specific aspects of the user experience that stand out as particularly strong or weak?
2. Could you imagine that this interface increases the trust and comfort of passengers in autonomous vehicles?
3. Do you think that this interface provides passengers with enough control over the AV for them to feel more comfortable?

**Ease of use:**

1. How intuitive and easy to use to you find the interface for passengers of AVs?
   a. Are there areas that could be simplified or made more user-friendly?
2. Do you think users would first need to be trained to understand the interface?

**Feedback mechanism:**

1. How well do the haptic and visual feedback mechanisms keep the users informed about the adjustments and vehicles response?
   a. Are there any additional feedback mechanisms that would enhance the understanding and comfort levels?

**User engagement:**

1. How engaging do you find the interface? Do you believe that users will make adjustments to the driving style with it if they have the option?

**Visual Design:**

1. How would you rate the overall aesthetic appeal of the physical interface?
   a. Does the interface fit into the Mercedes-Benz interior?

**Overall feedback:**

1. How do you think this interface affects the feeling of control for the passengers?

## Expert Evaluations - Autonomous Vehicle Designers

**Concept Evaluation:**

1. Based on your expertise, how well do you think "Glide" addresses the need for shared control in autonomous vehicles?
2. In what ways does 'Glide' enhance or limit passenger trust and comfort in Autonomous Vehicles?

**User Understanding:**

1. How clear and intuitive do you find the interface and controls of "Glide" for passengers?
2. Are there any aspects of the design that might confuse users or require additional explanation?
3. How effective is the haptic feedback in communicating the preferences and actions of other passengers?
4. Do you think the combination of tactile and visual feedback in "Glide" is sufficient to keep passengers informed?
   a. Or should it be used in combination with other modalities?

**Human Centered Design:**

1. In what ways do you think "Glide" adds value to passengers and society?
2. How would you rate the overall user experience of "Glide" in terms of ease of use and satisfaction?
3. Are there any specific design elements that you think could be improved to enhance the user experience?

**Safety and Reliability:**

1. Are there any safety concerns with the way "Glide" allows passengers to adjust driving parameters?
2. How well does "Glide" (and the control distribution between 'Driver' and 'passengers') handle potential conflicts between multiple passengers' inputs?

**Adoption and Acceptance:**

1. How likely do you think passengers are to adopt and use "Glide" in autonomous vehicles?
   a. Do you think this would be used instead of just taking to the other passengers?
2. When you look at "Glide" do you think that it could increase adoption rates of AVs?

**Human Factors Challenges:**

1. Are there any human factors challenges you can see with the design of "Glide"?
2. How do you think "Glide" will perform in real-world scenarios with varying passenger preferences?

## Expert Evaluations - Automotive Interior Designer

**Overall:**

1. What is your overall impression of the "Glide" physical interface design?
2. Are there any specific areas where you think the design could be improved to better meet MB design language?

**Aesthetic Appeal:**

1. How would you rate the overall aesthetic appeal of the "Glide" physical interface?
   a. Are there any design elements that you think could be improved to enhance its visual appeal?
2. What are your thoughts on the materials chosen for the "Glide" interface?
   a. Are there any alternative materials you would suggest that could improve the look, feel, or durability of the interface?
3. How well does the "Glide" interface integrate with the overall design of the vehicle interior?
   a. Are there any design changes you would recommend to ensure a seamless integration with different vehicle interiors?

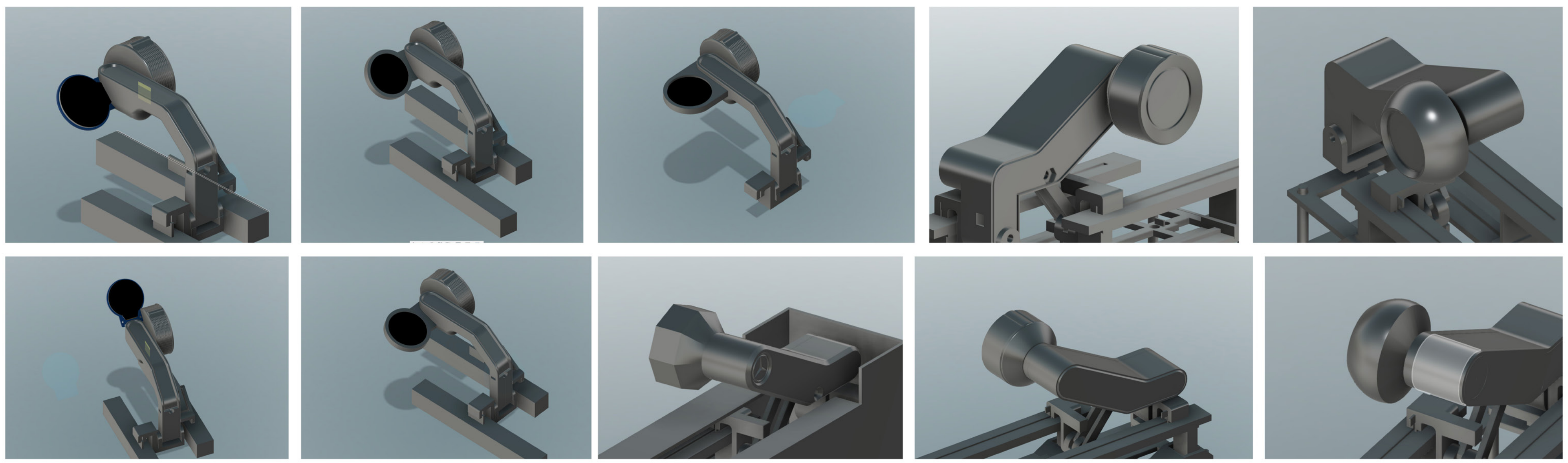
**User Interaction:**

1. Does the design allow for good user interaction?
   a. What are some alternative options that could have made the interaction better?
2. Are there any aspects of the interface that could be simplified or redesigned to improve user interaction?
3. Are there any design changes you would recommend to improve the visibility and accessibility of the interface?

**Durability and Maintenance:**

1. How durable do you think the "Glide" interface will be under regular use?
   a. Are there any design considerations you would suggest to enhance the durability and ease of maintenance of the interface?
2. Are there any design innovations you would suggest to further differentiate "Glide" from existing solutions?

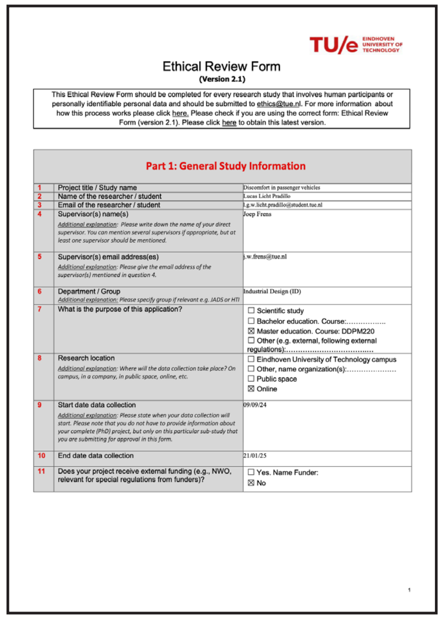
# Appendix 3- Additional Handle Designs (Fusion 360)




Glide - FMP Design Project

# Appendix 4- ERB, Consent Forms & Approval Email

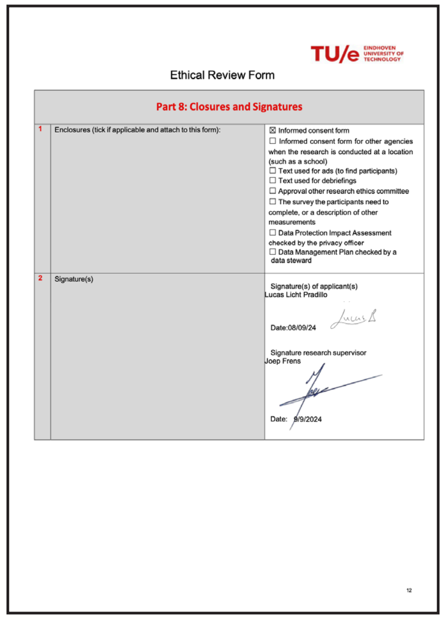
## ERB, Consent Form & Approval Email - Owner Interviews



Ethical Review Form

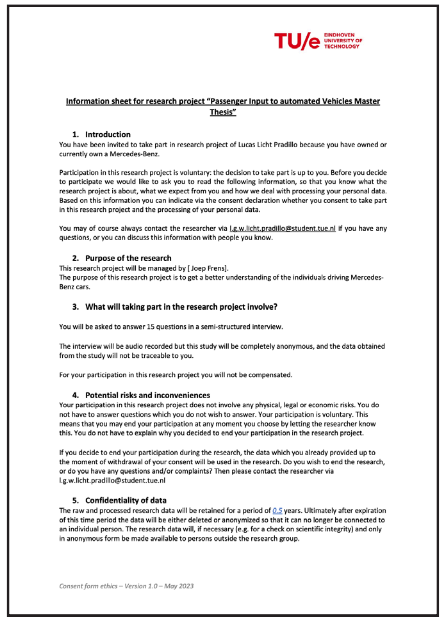
(Version 2.1)

Part 1: General Study Information

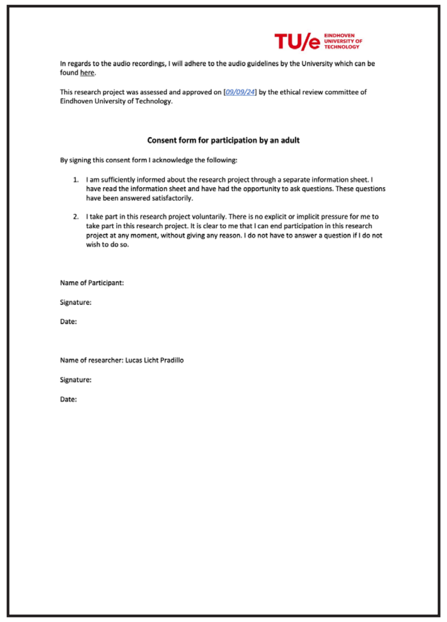


Ethical Review Form

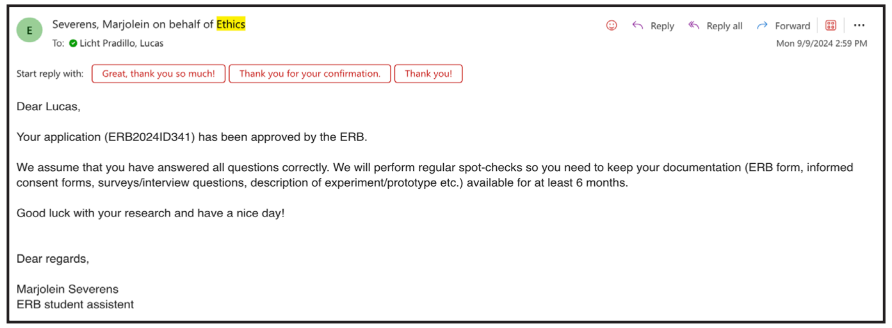
Part 8: Closures and Signatures



Information sheet for research project "Passenger Input to automated Vehicles Master Thesis"



Consent form for participation by an adult



Severens, Marjolein on behalf of Ethics

To: Licht Pradillo, Lucas

Reply Reply all Forward

Mon 9/9/2024 2:59 PM

Start reply with: Great, thank you so much! | Thank you for your confirmation. | Thank you!

Dear Lucas,

Your application (ERB2024ID341) has been approved by the ERB.

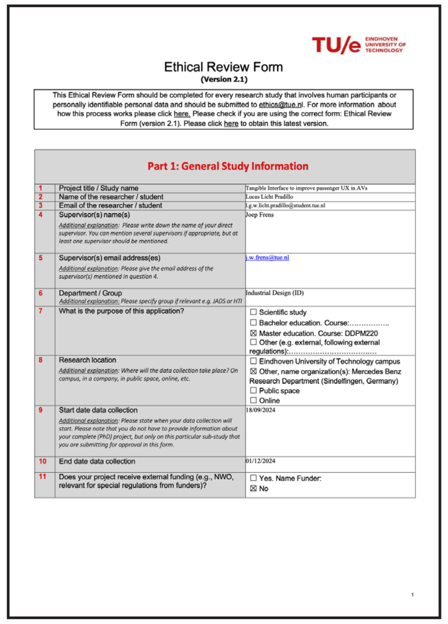
We assume that you have answered all questions correctly. We will perform regular spot-checks so you need to keep your documentation (ERB form, informed consent forms, surveys/interview questions, description of experiment/prototype etc.) available for at least 6 months.

Good luck with your research and have a nice day!

Dear regards,

Marjolein Severens
ERB student assistent

## ERB, Consent Form & Approval Email - Co-Creation



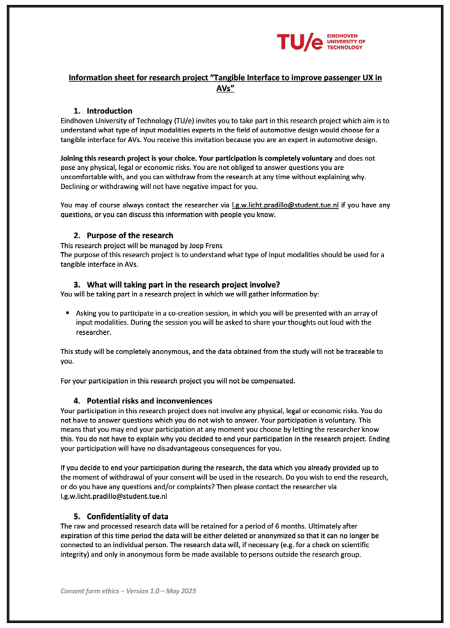
Ethical Review Form

(Version 2.1)

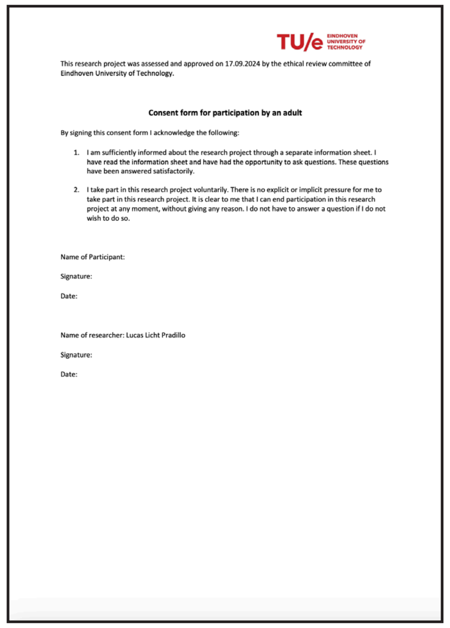
Part 1: General Study Information

Ethical Review Form

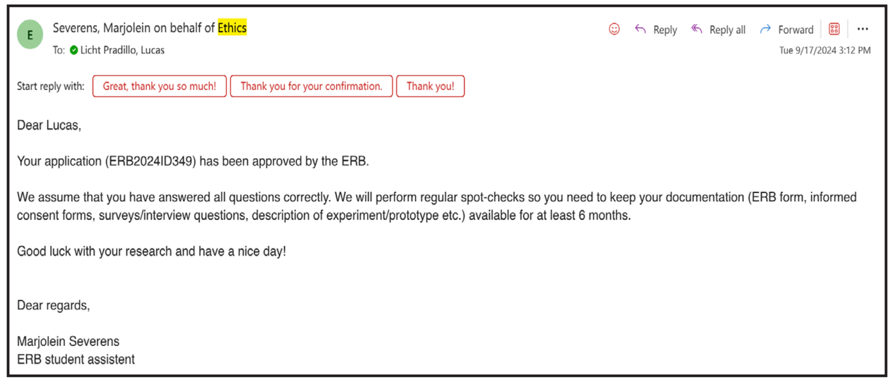
Part 8: Closures and Signatures



Information sheet for research project "Tangible Interface to improve passenger UX in AVs"



Consent form for participation by an adult



Severens, Marjolein on behalf of Ethics

To: Licht Pradillo, Lucas

Reply Reply all Forward

Tue 9/17/2024 3:12 PM

Start reply with: Great, thank you so much! | Thank you for your confirmation. | Thank you!

Dear Lucas,

Your application (ERB2024ID349) has been approved by the ERB.

We assume that you have answered all questions correctly. We will perform regular spot-checks so you need to keep your documentation (ERB form, informed consent forms, surveys/interview questions, description of experiment/prototype etc.) available for at least 6 months.

Good luck with your research and have a nice day!

Dear regards,

Marjolein Severens
ERB student assistent

## ERB, Consent Form & Approval Email - Control Concept Evaluation

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Ethical Review Form
(Version 2.1)

Part 1: General Study Information

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Ethical Review Form

Part 8: Closures and Signatures

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Information sheet for research project "Tangible Interface to improve passenger UX in AVs"

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Consent form for participation by an adult

Severens, Marjolein on behalf of Ethics
To: Licht Pradillo, Lucas
Reply | Reply all | Forward
Thu 10/17/2024 10:12 AM

Start reply with: Great, thank you so much! | Thank you for your confirmation. | Thank you!

Dear Lucas,

Your application (ERB2024ID424) has been approved by the ERB.

We assume that you have answered all questions correctly. We will perform regular spot-checks so you need to keep your documentation (ERB form, informed consent forms, surveys/interview questions, description of experiment/prototype etc.) available for at least 6 months.

Good luck with your research and have a nice day!

Dear regards,

Marjolein Severens
ERB student assistent

## ERB, Consent Form & Approval Email - Final Expert Evaluation

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Ethical Review Form
(Version 2.2)

Part 1: General Study Information

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Ethical Review Form

Part 8: Closures and Signatures

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Information sheet for research project "Tangible Interface to improve passenger UX in AVs"

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Consent form for participation by an adult

Severens, Marjolein on behalf of Ethics
To: Licht Pradillo, Lucas
Reply | Reply all | Forward
Tue 12/10/2024 10:53 AM

Start reply with: Great, thank you so much! | Thank you for your confirmation. | Thank you!

Dear Lucas,

Your application (ERB2024ID574) has been approved by the ERB.

We assume that you have answered all questions correctly. We will perform regular spot-checks so you need to keep your documentation (ERB form, informed consent forms, surveys/interview questions, description of experiment/prototype etc.) available for at least 6 months.

Good luck with your research and have a nice day!

Dear regards,

Marjolein Severens
ERB student assistent

## ERB, Consent Form & Approval Email - Intuitiveness Questionnaire

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Ethical Review Form
(Version 2.2)

Part 1: General Study Information

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Ethical Review Form

Part 8: Closures and Signatures

The link to the survey:
https://forms.office.com/e/kf150/bm2d

Section 1

### Informed Consent

You are being asked to participate in this questionnaire conducted by Lucas Licht Pradillo, who is supervised by Joep Frens of the Eindhoven university of Technology. Participating in this research is completely voluntary. There are no negative consequences if you don't want to take it. If you start the survey, you can always change your mind and stop at any time.

The purpose of this study is to investigate the mapping between movements of a physical interface and system parameters of automated vehicles. The questionnaire should not take longer than 5 minutes to complete. The collected data will be completely anonymised.

Only answer the questionnaire if you are 16 or older.

Thank you in advance!

1. Do you meet the criteria and would like to take the survey? *

- Yes
- No

Severens, Marjolein on behalf of Ethics
To: Licht Pradillo, Lucas
Reply | Reply all | Forward
Tue 12/17/2024 8:59 AM

Start reply with: Great, thank you so much! | Thank you for your confirmation. | Thank you!

Dear Lucas,

Your application (ERB2024ID587) has been approved by the ERB.

We assume that you have answered all questions correctly. We will perform regular spot-checks so you need to keep your documentation (ERB form, informed consent forms, surveys/interview questions, description of experiment/prototype etc.) available for at least 6 months.

Good luck with your research and have a nice day!

Dear regards,

Marjolein Severens
ERB student assistent




Glide - FMP Design Project