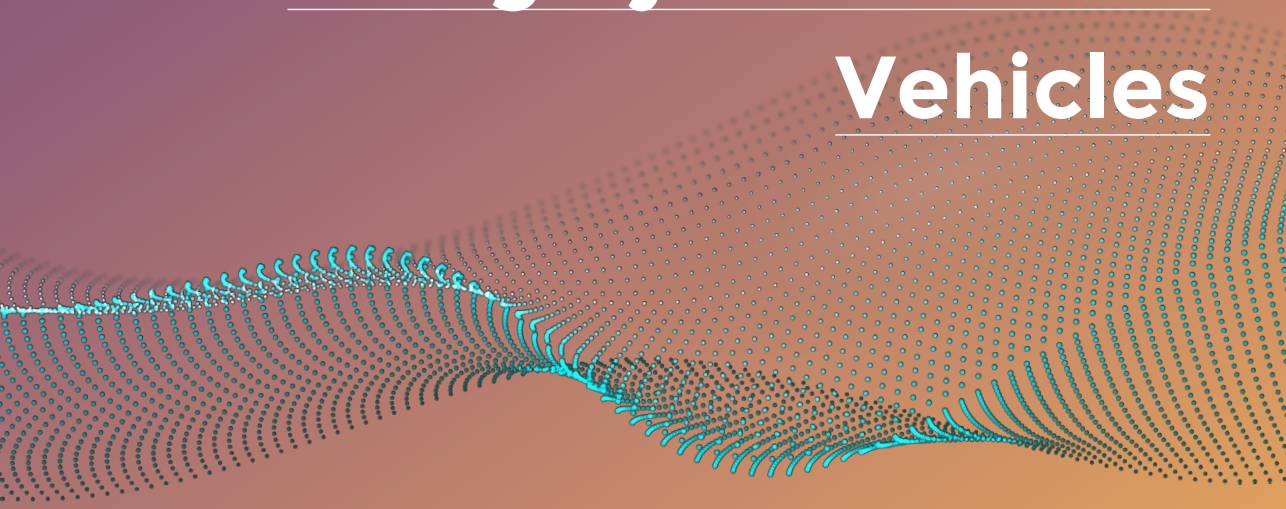
Master Thesis

Human-Machine Interaction Design for NEGOTIATION in Highly Automated Vehicles



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PREFACE
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Executive summary

Automated transportation technology has been rapidly evolving across all modes of transportation, with enormous potential to improve road safety and travel comfort. New challenges arose during the transition to full automation, such as increased instances of disagreements between the driver and the automation system over who should take control. Negotiation plays a crucial role in resolving such conflicts. The Mediator project, a research and innovation programme of the European Union's Horizon 2020, is developing an intelligent system to meditate between human drivers and highly automated vehicles. This graduation project aims to design a human-machine interaction that can resolve conflicts with appropriate negotiations, thereby creating a pleasant user experience in highly automated vehicles. The challenge lies in striking the right balance between the driver's safety and autonomy in order to ensure that the Mediator system is accepted by a wide range of users.

To tackle the challenge, conflicts between human drivers and highly automated vehicles were analyzed to identify the most severe conflict as a main focus. To resolve it, research referred to human-to-human negotiation styles to inspire possible ways of human-to-machine negotiation styles in a context of high automation. To determine the most appropriate negotiation styles, desirable human-to-machine interaction was investigated through interviews. It was found that most participants preferred to have a certain extent of autonomy only when safety is secured. It resulted in an approach of resolving conflicts with negotiation styles based on the reasons for the automation's takeover requests. More specifically, persuasive negotiation should be employed with a competing style when the reason is about safety. When it comes to comfort, seductive negotiation should be employed with a collaborating style. These insights were translated to interaction qualities for negotiation in the design concept. A design goal was formulated after establishing a future worldview by using the Vision In Product Design (ViP) method. The goal was to create a pleasant experience through negotiation during control conflict. Furthermore, the driver's motivation to follow the automation's recommendations was investigated through two design interaction cycles. It was found that increasing intrinsic and extrinsic incentives by audio interaction and rewards could effectively motivate drivers to follow recommendations.

The final concept is a negotiation ritual consisting of voice messages and rewarding features. When there is a disagreement over who should take over,

the negotiation ritual of either persuasive or seductive negotiation will be activated. In the persuasive negotiation ritual, the system will give takeover requests twice, emphasizing the urgency and consequences with a commanding tone and wording. In the seductive negotiation ritual, the system will only ask the driver once, emphasizing the benefit of control transfer with a friendly tone and wording. Furthermore, drivers will get rewards such as parking discounts when following recommendations.

Personal motivation

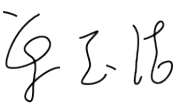
I am a technology enthusiast, especially interested in AI-based automation systems. My objective in graduating from MSc Design for Interaction at TU Delft is to be able to design appropriate interaction between human users and advanced technologies through a human-centred approach. I believe technologies should play an assistant role in facilitating human users to have better performances in their daily lives. This project provided me with the opportunity to bring my vision to life. The emergence of self-driving cars opens a new era for interaction designers with more complex challenges. I was very motivated to take on such challenges paving the way towards my dream job, envisioning the future of the interaction between human and advanced technologies.

Acknowledgements

I would like to give my sincere gratitude to my supervisory team Elmer van Grondelle and Ilse van Zeumeren for their support of my graduation project during these 100 days. It was a great pleasure to work with them and I gained plenty of valuable feedback for this project as well as for my own working style. I appreciated that Elmer always asked interesting and challenging questions that pushed me to think further. I gradually learned to embrace comfort when receiving critiques. It was also a lot of fun to work with him because of his unique sense of humor. I really appreciate Ilse's patience, empathy, as well as her willingness to spend extra time with me when I need guidance. Her advice on how to effectively explain complex research findings by using visuals was extremely helpful and I will probably apply it to other projects too. Overall, I am so glad to have such a well-balanced team to make me get out of my comfort zone and with sufficient support.

Other than the supervisory team, I also want to thank Anna Aldea, Max Fuhrer, Matteo Franciolini, David Klug, and my family for supporting me whenever I needed it. Furthermore, thank 93 participants who took part in the interviews, creative workshops, questionnaires, and concept evaluations. Their contribution to this project was significant.

Yujie Shan



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01

INTRODUCTION

Motivation
Approach
Reader guide

INTRODUCTION
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Motivation

The human driver has started to have a more supervisory role than a role that only engages driving tasks. Therefore, in order to ensure safety and comfort during the switch of control, effective communication between the human driver and the automated systems through the Human Machine Interface (HMI) is required.

To mediate between the driver and the automation based on both their strengths and weaknesses in a driving context (see figure 1), the European Union has funded a project called Mediator. It is a 4-year international project led by SWOV, the national institute for road safety research, in collaboration with research organizations, top universities including TU Delft, as well as manufacturers and suppliers. Within the Mediator consortium, TU Delft is in charge of HMI development and design. Currently, knowledge is missing on how to predict the occurrence of conflicts and how to resolve them.

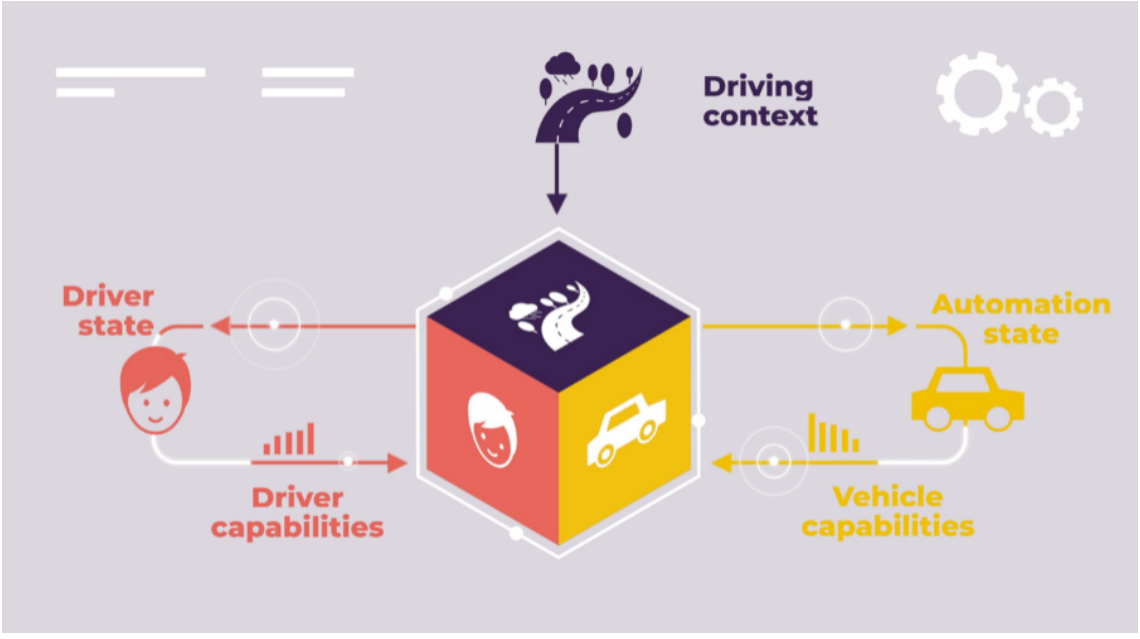


Figure 1. The concept of the Mediator project.

This Master's graduation project was a part of the Mediator project. It focused on researching negotiation of conflicts due to disagreement of the two parties relating to taking control and designing an automotive HMI to resolve conflict. HMI should be able to assist persuasive and seductive negotiation when control conflicts occur on high and low necessity levels. Several design challenges were taken to resolve control conflict: identifying the most severe conflict between the automation and the driver, envisioning appropriate interaction by finding a balance between driver autonomy and automation dictated actions, anticipating conflict scenarios within use cases, and designing negotiation rituals to resolve conflicts.

Put simply, the graduation project aimed to gain new insights regarding control conflict that may contribute to the possible development of HMI for MEDIATOR.

Approach

The Mediator project aims to deliver a functional prototype in 2023. This means that the design solution of this graduation project should sustain itself until at least 2023. Traditional user research methods, such as interviews, have the problem of resulting in a conservative solution due to the current situation's limits. To solve the design challenge in a more creative way and to find the reason for the existence of the design solution in a future context, the project approach referred to the Vision In Product Design (ViP) method. Furthermore, to iterate the design concept rapidly, the later phase of this project was based on the Sprint method, an agile project management that contains a process through design, prototyping, and testing ideas with users in one design iteration. Figure 2 illustrated the overall approach of the project. The steps of the ViP method, in combination with several other research and design methods, used in this project were explained as follows.

Step 0 - Preparation for ViP:

Desk research regarding existing negotiation systems was undertaken to learn how highly autonomous vehicles and other technical systems have been conducting negotiations.

Step 1- Discover a domain:

To gain a better understanding of the context, background information on automation levels was gathered through desk research. Analysis of control conflict and interviews were conducted to determine appropriate negotiating styles in different situations.

Step 2 - Collect contextual factors:

Contextual factors from a wider range of resources were gathered in preparation of future worldview creation.

Step 3 - Establish a future worldview:

A future worldview was created by clustering contextual factors. The goal was to anticipate the context in which the design will exist in the future.

Step 4 - Design statement:

A design goal was elaborated according to the future worldview. It aimed to react upon the future context.

Step 5 - Create an interaction vision:

An interaction vision was created by referring to metaphors to inspire the desired relationship between the human driver and the Mediator system through HMI.

Step 6 - Identify HMI qualities:

To elicit the defined interaction, HMI needs to have certain characteristics. A few qualities were identified from the previous interview results, and were modified to suit the design goal and interaction vision.

Step 7 - Formulate initial concepts:

Three initial concepts were created through two creative workshops and a brainstorm session.

Step 8 - Design iteration:

This step was based on the Sprint method. Low fidelity prototypes were built to evaluate initial concepts. Key findings were translated to new design ideas. Through 2 Cycles of design iteration, the final concept was created and evaluated with High fidelity prototypes.

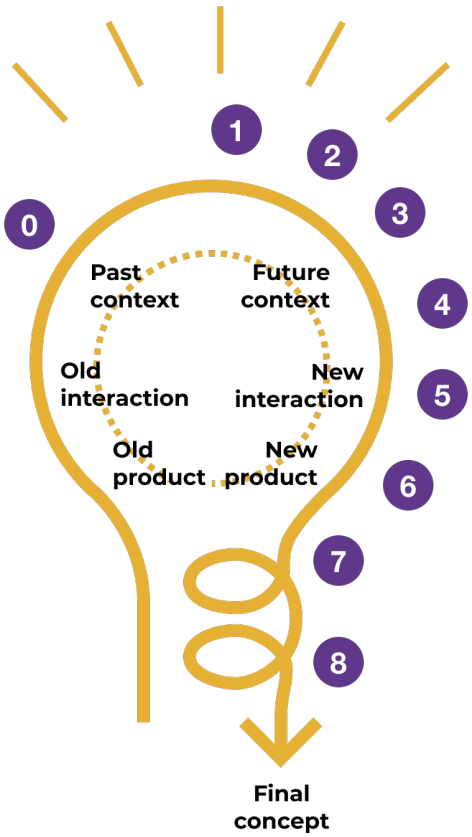


Figure2. The overall approach of this project.

Reader guide

The structure of the thesis is introduced in this subchapter to guide the reader through the essential components of the upcoming chapters.

Chapter 2 outlines background information that readers need to know in order to understand the domain of the research topic. It summarized findings of step 0 & 1 of the project methods. Readers will learn about existing negotiation HMI (subchapter 2.1), Mediator HMI (subchapter 2.2), automation levels (subchapter 2.3), the cause of control conflict (subchapter 2.4) and negotiation challenges (subchapter 2.5).

Chapter 3 gives interpretation of the context based on the background knowledge, further research findings and analysis. This chapter identified the most severe conflict (subchapter 3.1), human-to-human and human-to-machine negotiation styles (subchapter 3.2), as well as desirable interaction between human drivers and highly automated vehicles (subchapter 3.3).

Chapter 4 explains the process of defining the design direction. It dives into clusters of contextual factors (subchapter 4.1) that contribute to the construction of a worldview (subchapter 4.2), which leads to a statement of a design goal (subchapter 4.3). An interaction vision was created to further define the design goal on an interaction level, leading to definition of HMI qualities (subchapter 4.4). This chapter summarized the process of step 2 - 6 of the methods used in this project.

Chapter 5 summarizes the iterative process of concept creation. Readers will learn about conflicts within Mediator's use cases (subchapter 5.1) and negotiation rituals created to resolve them (subchapter 5.2). Through creative workshops (subchapter 5.3), initial conceptions were created and evaluated (subchapter 5.4). Through two cycles of design iteration (subchapter 5.5 & 5.6), the final concept was formulated and evaluated (subchapter 5.7). Overall, this chapter summarized the creative process of step 7 & 8 of the project approach.

Chapter 6 gives conclusions, recommendations, discussions and reflection.

02

DOMAIN EXPLORATION

Existing negotiation HMI in transportation
- Negotiation HMI in aviation
- Negotiation HMI in automotive

Mediator HMI
Automation levels
Cause of control conflict
Negotiation challenges
Chapter conclusion

DOMAIN EXPLORATION /

In preparation for ViP, important domain subjects were investigated to gain a basic understanding of the context. The exploration gathered background information on the following topics:

1) existing negotiation HMI in transportation (i.e. aviation and automotive), 2) Mediator HMI, 3) automation levels, 4) cause of control conflict, and 5) negotiation challenges.

Photo: Travelblog

Existing negotiation HMI in transportation

First of all, it is necessary to understand what HMI is, what it can do, as well as the principle of HMI design. HMI offers a set of interfaces that enables humans to interact with the vehicle and its systems. As a result, it helps to facilitate communication, including negotiation, between the car and the driver. The clarity of the HMI signals to the user (Lilis et al., 2019) increases user understanding of the situation, which can smoothen control transfer and creates trust. Trust will lead to user acceptance. It can also prevent mode confusion and overreliance, by conveying trustworthy and transparent messages timely, concisely and clearly to the driver. The underlying principle for the design of HMI should be to elicit safe and sustainable behaviour of the driver in his/her interactions with the vehicle.

The existing HMI-supported negotiation systems in the transportation domain were researched to find out how conflicts are solved and what challenges are to be solved. First of all, research referred to the aviation industry where high automation has already been developed and used for a much longer period than automotive industry. Then, the negotiation systems of automobiles were investigated.

Negotiation HMI in aviation

In D1.5 document of the Mediator project (Grondelle, E.D. van, Zeumeren, I. van, Bjorneseth F., Borowsky, A., Chandran, T., Cleij, D., ... Christoph, M., 2021), it mentions that the Traffic alert and collision avoidance system (TCAS) in aviation informs the pilot of the conflicting situation. The location of other aircrafts' paths in the sky was communicated to the pilot via visual display (see figure 4) and haptic interaction. On the visual display, Traffic Advisories (TA) and Resolution Advisories (RA) systems warn the pilot early enough and give straightforward and simple advice (i.e. rise or fall) to the pilot. This gives pilots more time to respond to the conflict and shortens the decision making process, which increases chances of avoiding collision. (see figure 3) The display provides information to assist the pilot in making a decision. It is up to the pilot to decide how to avoid a possible collision (i.e. either choose to rise or fall). The benefit of this system is that it provides the pilot with some autonomy. On the other hand, pilots must have a thorough

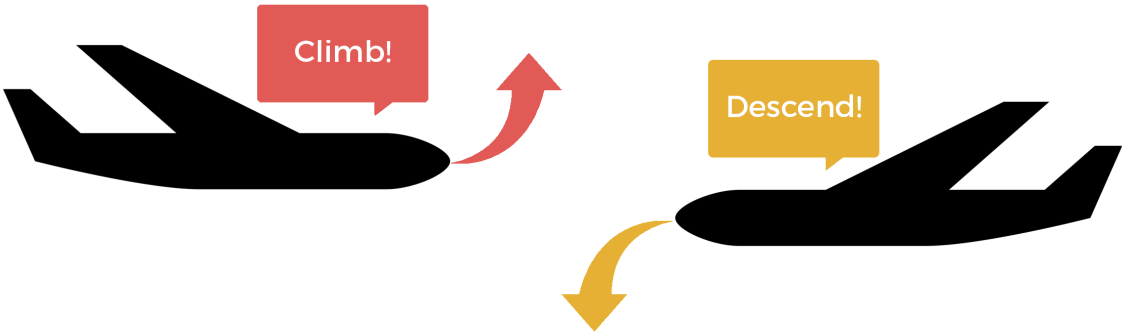


Figure3 . Straightforward advice to the pilot.

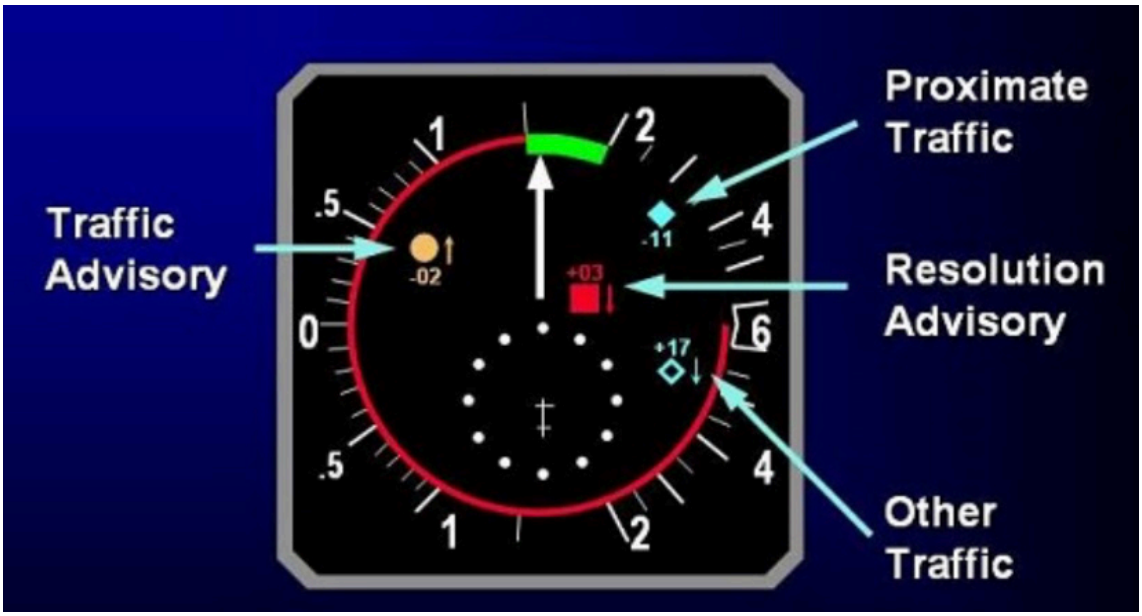


Figure4 . The user interface of TCAS II. (TCAS II Ch. 7.1, n.d.).

understanding of the system and its complex interface. Therefore, this negotiation system is not the greatest option for autonomous cars drivers. Moreover, even if the driver does not fully comprehend the signals, the system should have countermeasures to secure driver's safety. Furthermore, road situations are more complicated, requiring the user interface to give a variety of conflict causes and solutions.

Take away

1. In the context of autonomous cars, user interfaces should be understandable even by inexperienced drivers of the Mediator system.
2. Countermeasures can be activated to serve as the last guard to secure driver's safety.
3. The causes of conflicts in autonomous cars needed to be investigated, so that solutions can be created accordingly.

Negotiation HMI in automotive

1. Visual and sound signals:
Visuals (e.g. displays) and sounds (e.g. alerts) are most commonly used HMI components to negotiate with drivers in cars, but it can cause information overflow or misinterpretation of warnings.

2. Haptic feedback:
Research shows that providing different types of information through haptic feedback (e.g. vibrotactile or force feedback) can lessen the user's cognitive load. (Väänänen-Vainio-Mattila, K., Heikkinen, J., Farooq, A., Evreinov, G., Mäkinen, E., & Raisamo, R., 2014) However, only delivering haptic feedback, can also cause novice user's misinterpretation,because it does not explicitly state why the car does so and how to respond to it.

3. Voice messages:
Drivers have better understanding about the context through voice messages in car navigation systems. It also minimizes the amount of time drivers spend staring at displays, which lowered the danger of driving (Wu, C. F., Huang, W. F., & Wu, T. C. (2009)).

Take away

1. 1. Voice messages improve the driver's understanding of the situation, which supplement visual and sound signals.
2. To reduce information overflow caused by visual and aural signals, haptic feedback could be added in the negotiation system.

Mediator HMI

The Mediator consortium already defined several HMI components that activate tactile, auditory, and visual interaction. It is recommended to build HMI on general known affordances, so they do not conflict with long-time learned affordances for the driver. Therefore, these components also provided the potential HMI design affordances for negotiation. The only condition is that functions provided by the same component should not conflict with each other.

The HMI components of the Mediator project are as follows.

1.Dashboard screen & heads-up display: communicate specific visual information, such as speed, automation mode, navigation, takeover time budget etc.

2.Sound systems: communicate precise information to compensate for ambiguity of information from other HMI elements.

3.Force feedback shifter: the only component to transfer control between the driver and the automotive (see figure 5).

4.LED-strips & ambient lighting: communicate automation mode status.

5.Retractable steering wheel: communicate automation mode change.

6.Inflatable seats: prepare driver's active sitting position for automation mode change.

7.Vibrating and retractable seat belts: seatbelts vibrate to increase driver's fitness and retract to emphasize mode change.

8.Vibrating backrest: backrest vibrates to increase driver's fitness.

Within 8 components, the top 3 are the most relevant and essential HMI elements for negotiation. The dashboard screen & heads-up display as well as sound systems could support visual and auditory communication during negotiation. The shifter is directly involved in a conflict between the driver and the car, since it is the only place to switch control and offers affordance for the driver to indicate his or her preference of driving mode.

The driving modes on the shifter were based on the automatic car's interfaces (see figure 5). They are: Park (P), Reverse (R), Neutral (N), Drive (D), Assisted (Da) & Piloted (Dp). The latter three modes are Mediator HMI automation levels (see further explanation on page 18). Force feedback will be given when drivers intend to switch the shifter to unrecommended automation levels. How other HMI elements should collaborate

Figure5 . The prototype of the force feedback shifter in context.

3D model built by Anna Aldea(Aldea, A., 2021)

with the shifter in negotiation needs to be designed, as well as considering its application in other use cases.

Automation levels

The Society of Automotive Engineering (SAE) has classified autonomous vehicles into five stages of automation (i.e. SAE level 0-5), ranging from entirely manual to fully autonomous. Each level requires a different amount of control from the driver. The Mediator project focuses on automation level from 0 to 4, since level 5 technologies will not be available in near future. In addition, previous Mediator project research suggested simplifying the automation levels on HMI to lower the chance of mode confusion. Thus, combining the SAE levels with human capabilities, the Mediator project specified automation levels for HMI as the following (see figure 6), which displayed on the shifter as driving modes. This definition serves as the reference for this project. Each mode has a representative colour or length of strips & ambient lighting (see figure 7).

HMI automation levels:
Drive mode (SAE level 0): No automation. The driver takes full control. Thus, it is also called Manual mode.

Assisted mode (SAE level 1-2): The driver has to maintain certain responsibilities, such as steering, braking, accelerating, and monitoring. The automation will support the driver in driving tasks.

Piloted mode (SAE level 3-4): SAE level 3 referred to as Stand-by mode and SAE level 4 as Time-to-Sleep (TtS) mode in the Mediator project. The automotive automatically switches between these two levels without driver's influences. At Stand-by mode, drivers should be aware of the driving conditions and be ready to take over within seconds. At TtS mode, the driver does not need to monitor the road anymore while the automation takes control. The driver remains responsible to take back control when needed.

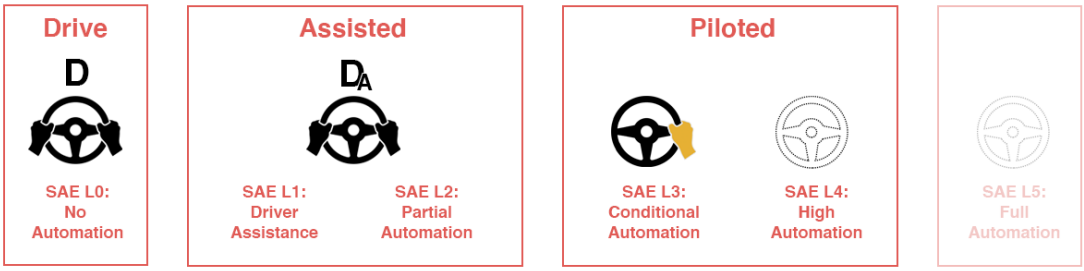


Figure6. Mediator's automation levels for HMI

Summary

This project will include three HMI automation levels, which are Drive (SAE level 0), Assisted (SAE level 1-2) and Piloted mode (SAE level 3-4).

Cause of control conflict

To understand what causes conflict between the driver and the automation during control transfer, it is important to understand how the Mediator system works. The mediator system contains a Decision Logic (DL), which gives a recommended automation level to the driver by evaluating three variables (see figure 8). The recommendation aims to improve safety and comfort. However, the driver may have a different perspective, causing disagreement with the recommendation. This leads to conflict during control transfer, which needs to be resolved through negotiation via HMI (see figure 9).

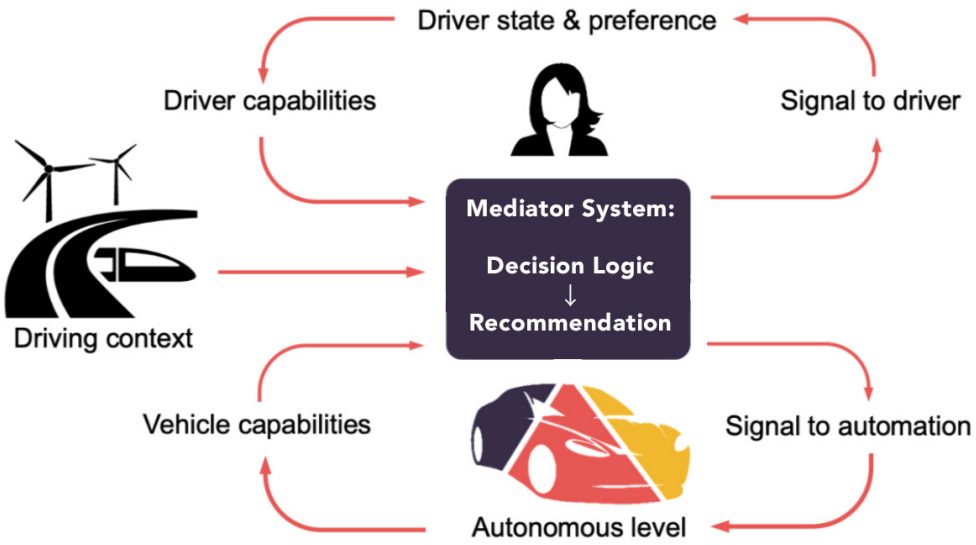


Figure 8. The mediator system makes recommendations based on Desicion Logic's appraisal of the driver, autonomous vehicle, and driving context.

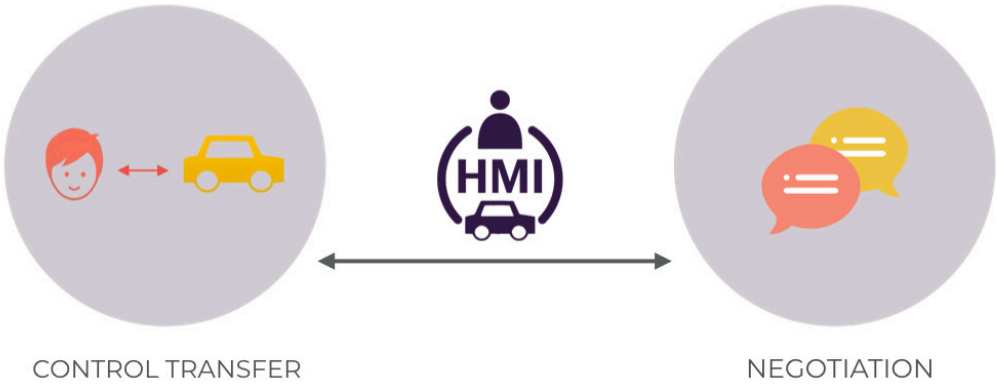


Figure9. HMI facilitates negotiation during control transfer.

① *Drive mode - white ambient lighting*

② *Assisted mode - amber ambient lighting*

③ *Piloted mode (Standby mode) - Purple ambient lighting (half length of LED strips)*

④ *Piloted mode (TtS mode) - Purple ambient lighting (full length of LED strips)*

Figure 7. Ambient colors and LED strip length are used to indicate the mode.

Summary

This project will include three HMI automation levels, which are Drive (SAE level 0), Assisted (SAE level 1-2) and Piloted mode (SAE level 3-4).

Negotiation challenges

Negotiation is a procedure of conflict management for resolving opposing preferences between parties to reach agreement (Carnevale, P. J., & Pruitt, D. G., 1992). It faces two challenges in the context of the Mediator project:

1. The first challenge is to understand different viewpoints of the driver and the automation by figuring out the worldview of the both parties and keep each other informed through HMI in an appropriate way (see figure 10). If the human driver fully understands the automation by understanding all given information and underlying reasoning of a decision, he or she will have a high chance in trusting in the automation to perform its task.

Figure10. Mediator negotiates conflicts of contradicting world views of human and technology.

2. Another challenge for negotiation is user acceptance. A key element to achieve user acceptance is finding a balance between actual driver autonomy and automation dictated actions (e.g. recommendations of driving modes made by the decision logic). HMI's success depends on its ability to facilitate driver autonomy, specifically towards chosen driving-modes (Christoph, M., et al., 2019). When there is no preference suggested by the decision logic, the driver will have the most autonomy to make choices. When there is preference suggested by the decision logic, if it is contrasting with the driver's preferences, then negotiation is needed. Both parties can have strong or moderate preferences for either party to take control. That is where persuasive or seductive negotiation takes place to resolve the conflict (see figure 11). Further research is needed to understand how persuasive and seductive negotiation can pair with driver's values in different situations, so that negotiation becomes easily acceptable.

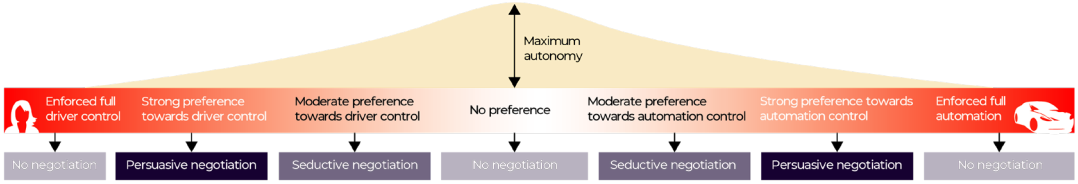


Figure11. Depending on the decision logic's preferences, negotiation types and the amount of driver autonomy differ.

Chapter conclusion

HMI enables interaction between the human driver and the autonomous vehicle. It facilitates negotiation in a conflict caused by disagreement of preferred automation level between the driver and the Mediator system. There are three automation levels on the Mediator's HMI, which are Drive mode, Assisted mode and Piloted mode, ranging from none automation to full automation. It is important to keep the user interface understandable even for inexperienced drivers, because understanding all given information and underlying reasoning of a decision made by automation can reduce conflict. If the conflict could not be resolved in a critical situation, countermeasures should be activated to secure safety.

The most relevant components of the Mediator HMI in negotiation are the dashboard screen & head-up display, sound systems, and the force feedback shifter, which involves driver's visual, auditory and haptic interaction. Voice messages can improve the driver's understanding of the situation, which supplement visual and sound signals, the most common interaction elements used in automotive HMI. Haptic feedback can reduce information overflow caused by visual and sound signals.

The challenges of this project are to find appropriate ways to resolve conflict caused by different world views, and achieve user acceptance of this system by finding a balance between actual driver autonomy and automation dictated actions.

03

DOMAIN INTERPRETATION

Conflict analysis
Resolving conflicts
- Negotiation styles
- Desirable interactions

Chapter conclusion

DOMAIN INTERPRETATION
/

Background information gathered in the previous chapter provided a basic understanding of the context. Further research on the following subjects were studied to interpret the context and acquire insights for conflict resolution: 1) conflict analysis, 2) resolving conflicts by negotiation styles and desirable interactions between human drivers and highly automated vehicles.

Conflict analysis

In this subchapter, the most severe conflict was identified through conflict analysis.

Conflict in control transfer is generated by different preferences of the driver and the vehicle. Figure 12 illustrated the automation's preferences towards either driver or automation control, paired with negotiation types.
For high necessity levels of take-over, persuasive negotiation is applied, where the automation has strong preferences. For low necessity levels, seductive negotiation is applied, where the automation has moderate preferences. To achieve user acceptance, it is necessary to determine necessity levels that make most sense to drivers. This was explored in user interviews (see page 30).

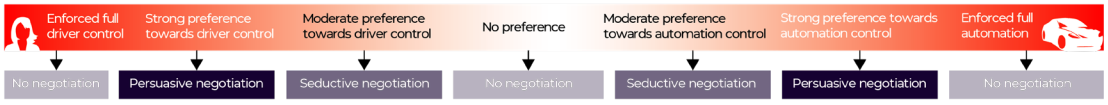


Figure12. Automation's preferences towards either driver or automation control.

On the other side of the negotiation, the driver also has his or her preferences towards either party to take control, which may differ from the automation's preferences. (see figure 13)

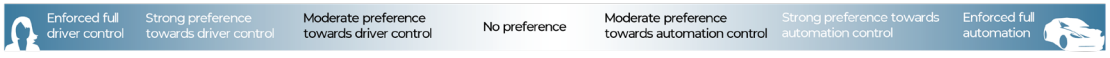


Figure 13. Driver's preferences towards either driver or automation control.

When the preferences of the driver and automation do not match, it generates conflicts. There are two types of conflicts, depending on the difficulty of resolution:

1. A hierarchical conflict where both sides have varying degrees of preference (see figure 14).

2. A conflict where both sides have the same level of preferences (see figure 15). It is hard to judge which party should win over another when there is a tie. Therefore, the second type of conflict is considered more severe and more difficult to resolve than the first type. Further research will focus primarily on how to resolve the second type of conflict, as well as whether its solution would also work for the first.

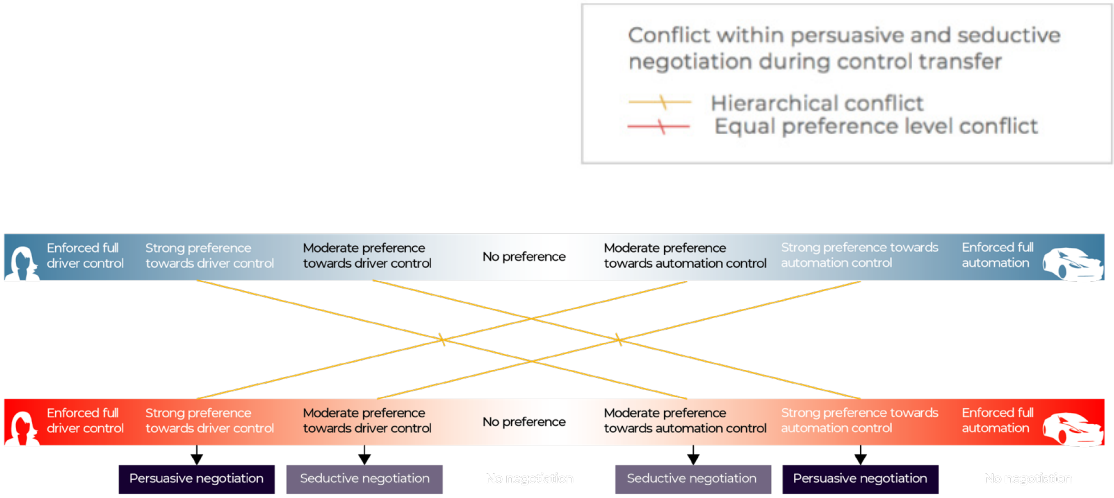


Figure 14. Hierarchical conflicts where both sides have different degrees of preferences.

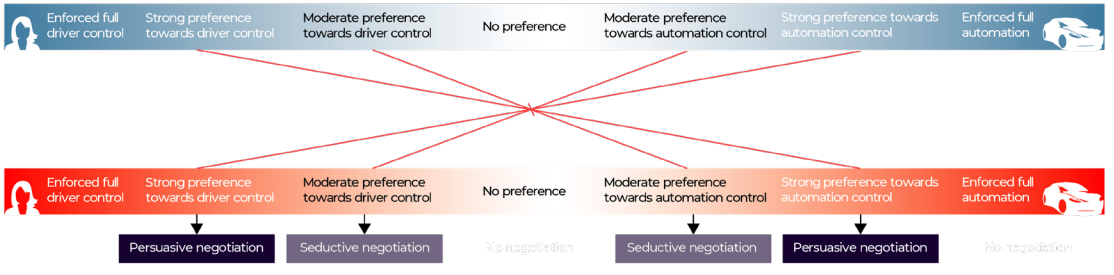


Figure 15. Equal preference level conflict where both sides have the same level of preferences, making it difficult to resolve.

Resolving conflicts

To resolve a conflict, negotiation experts are able to apply different negotiation styles to reach an agreement. Therefore, human-to-human negotiation styles were studied to find out possible human-to-machine negotiation styles.

In human-to-human negotiation, understanding the other person's fundamental interests and needs is crucial. Even in circumstances that appear to be zero sum, there are frequently win-win solutions. To resolve conflict, it is critical to identify common interests and phrase interdependent tasks and superordinate goals that make people feel like they are all facing the same problem (Wertheim, E., 2002). The question of how interests may differ in various situations and how they may influence solutions and styles of persuasive and seductive negotiation remained unanswered. These research questions were explored in interviews. Insights were gained on desirable interactions in situations where driver's interests vary.

Negotiation styles

Human-to-human negotiation styles

To get inspiration on how human-to-machine negotiation could be, human-to-human negotiation was investigated as a reference. From literature research, the Thomas-Kilmann conflict model categorizes five human-to-human

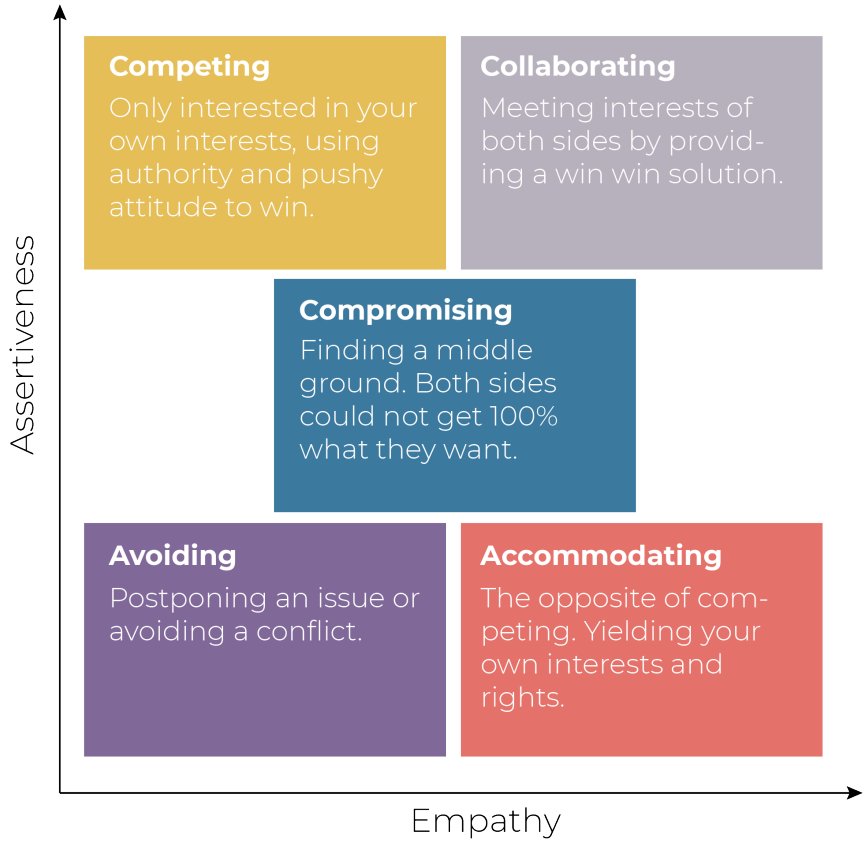


Figure16. Human's 5 types of negotiation styles according to the Thomas-kilmann conflict mode. (Thomas, K. W., 2008)

negotiation styles (see figure 16). These are competing, collaborating, compromising, avoiding and accommodating styles (Thomas, K. W., 2008). Other researchers suggested that negotiation style could be dynamic depending on the roles, the intensity and duration of the conflict (Schneider, A. K., & Brown, J. G., 2013).

One person's negotiation style could also be influenced by the style of the other. For example, when the person with a competing style needs to act quickly, he or she will compete by using power and aggressive behaviour, putting the autonomy of the other side at threat. This can lead to two possible responses on the other side. One common response is accommodating, meaning the person will generously agree on the proposed terms. Another possibility is avoidance (or ignorance). It could be due to the fact that the conflict is not as important to the party. Setting clear, detailed expectations with time budgets could improve the negotiation (Coburn, 2020). This tactic can be applied in HMI design for negotiation. However, understanding why and in which situation the conflict is not regarded as important by the driver may bring more insights. In interviews, these were addressed.

Human-to-machine negotiation styles

The automation could possibly have 3 negotiation styles, which are competing, collaborating, and accommodating (see figure 17). Competing style gives the driver a commanding and pushy impression in its interaction. Collaborating style presents what it prefers, and it is also interested in the driver's preferences. Accommodating style would just agree to whatever the driver preferred by yielding its own preferences, which ensures driver's autonomy.

Avoiding and compromising styles were deemed inappropriate for use in self-driving cars. Avoiding style is not advised because it may expose the driver to risks and, as a result, reduce road safety. Compromising style was less problematic, but it could confuse the driver regarding what exactly the automation could perform and what exactly the driver should do when the automation provides any negotiation space.

Finding out how negotiation styles of the driver and the vehicle would interact in persuasive and seductive negotiation could provide insights for resolving the conflict (see figure 18). Therefore, interviews were conducted.

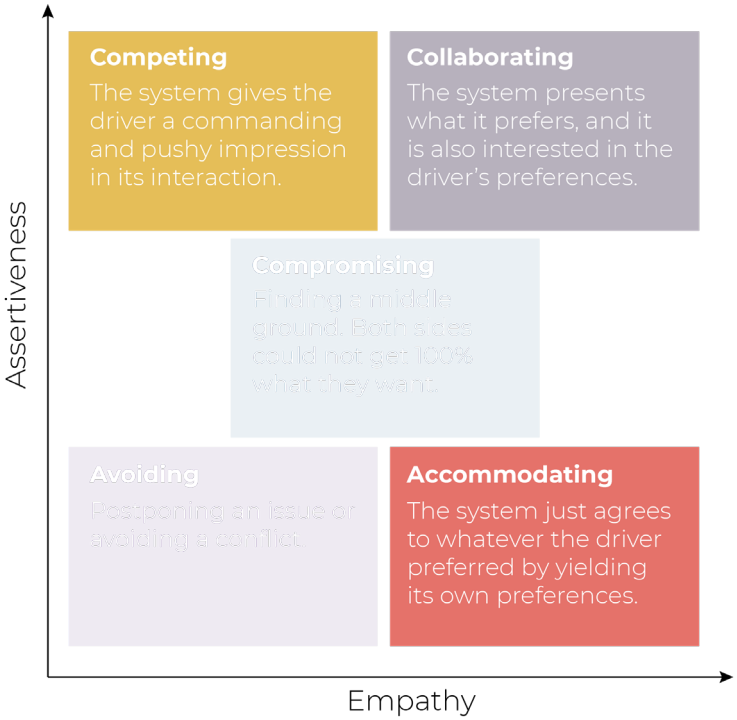


Figure 17. Automation's 3 types of negotiation styles.

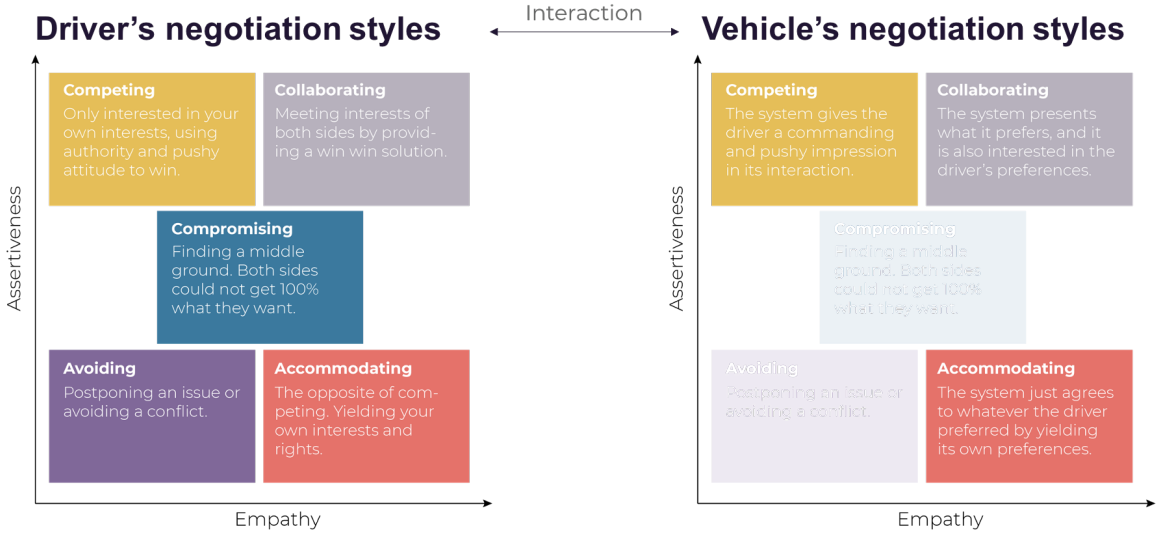


Figure18. Interaction between the human driver and the automation system of the autonomous vehicle.

Summary

Humans usually have five negotiation styles. These are competing, collaborating, compromising, avoiding and accommodating styles (Thomas, K. W., 2008). The automation system possibly could have three negotiation styles, which are competing, collaborating, and accommodating. In a negotiation, one side's style could influence the style of another. Therefore, interviews were conducted to investigate how they may influence each other in persuasive and seductive negotiation.

Desirable interactions

From literature research, it was unclear exactly how human factors influence negotiation within autonomous vehicles. It is undoubtable that driver's interests directly influence desirable solutions and styles of persuasive and seductive negotiation. To achieve user acceptance, it is vital to determine situations with high and low levels of negotiation necessity that make the most sense to drivers. To put it another way, it's crucial to understand how a driver's interests may alter in different scenarios such that some conflicts are (or are not) regarded as important to solve by the driver.
It is also interesting to find out how negotiation styles of the driver and the vehicle would interact in persuasive and seductive negotiation. Thus, interviews were conducted to find answers to these questions. The ultimate goal was to figure out the desirable interaction within highly autonomous vehicles in persuasive and seductive negotiation.

Methods

Semi-structured interviews were conducted to get rich insights from qualitative data supported by predefined scenarios that could happen in persuasive and seductive negotiation. Participants were asked to fill in a consent form (see appendix II) and a questionnaire (see appendix III) to diagnose their dynamic negotiating styles which are based on the negotiation styles mentioned in chapter FIXME. The questionnaire results could be used to find out interaction between the negotiation styles of the driver and the vehicle in a conflict. After introducing the automation levels of vehicles and the concept of taking over the control, participants were asked to use a metaphor to describe their desirable relationship with a SAE L4 level autonomous vehicle. Metaphors can help the user create an initial mental model towards the system by linking new ideas to well-understood relationships (Flemisch et al., 2003). Then, scenarios (see appendix IV) were chosen and introduced to participants depending on if they generally prefer themselves to take control or the autonomous vehicle to take control. Participant's reaction in a conflict and expectation towards the

vehicle as well as acceptance to each negotiation style of the vehicle were investigated. Furthermore, perceptions regarding win/lose in a negotiation and interaction qualities of persuasive and seductive negotiation were discussed.

Participants

The participants were recruited by messages within a personal network and Mediator's network as well as invitations in the ScaleUp 360° Car HMI Europe conference. In total, 24 people participated in the interview (see figure 19).

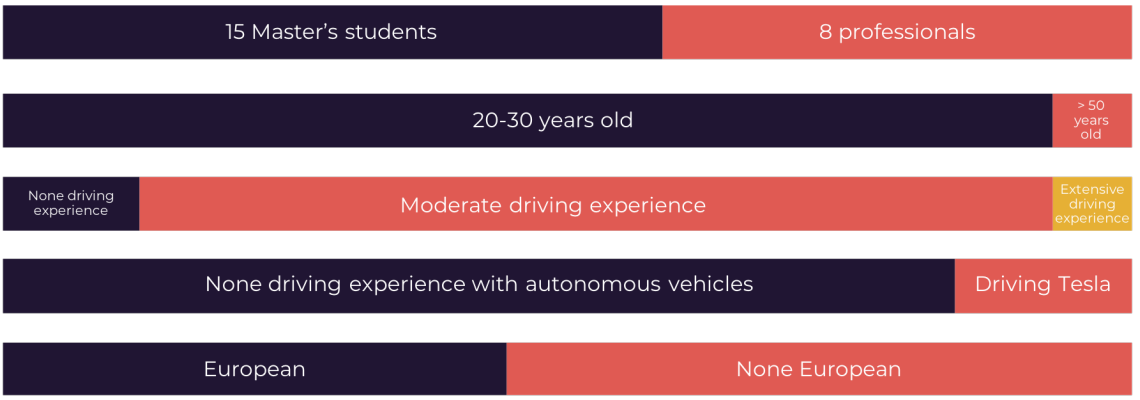


Figure19. Diverse background of interview participants.

Findings

Relationship between the driver and the vehicle:
The technology immaturity of level 4 and the ownership of the vehicle determined a hierarchical relationship between most participants and the highly autonomous vehicle. Metaphors used to describe this relationship by participants were horse rider and horse, dog owner and dog, house owner and butler, master and slave, boss and subordinate, boss and chauffeur, football player and coach, pilot and co-pilot. Participants would listen to the vehicle's suggestion but they wanted to remain as the final decision maker and wanted the car to obey the order. Thus, the relationship between the driver and the vehicle could be concluded as a decision maker and intelligent executor. Interestingly, to some participants, this kind of relationship would switch to a relationship with an equal friend or partner in a non-safety related situation. Some participants also mentioned that if the technology was mature enough or if they trusted the technology, they would prefer an equal relationship. However, they would still want to remain as the final decision maker. (see figure 20)

Figure20. Word cloud of metaphors used by participants to describe desirable relationships with autonomous vehicles.

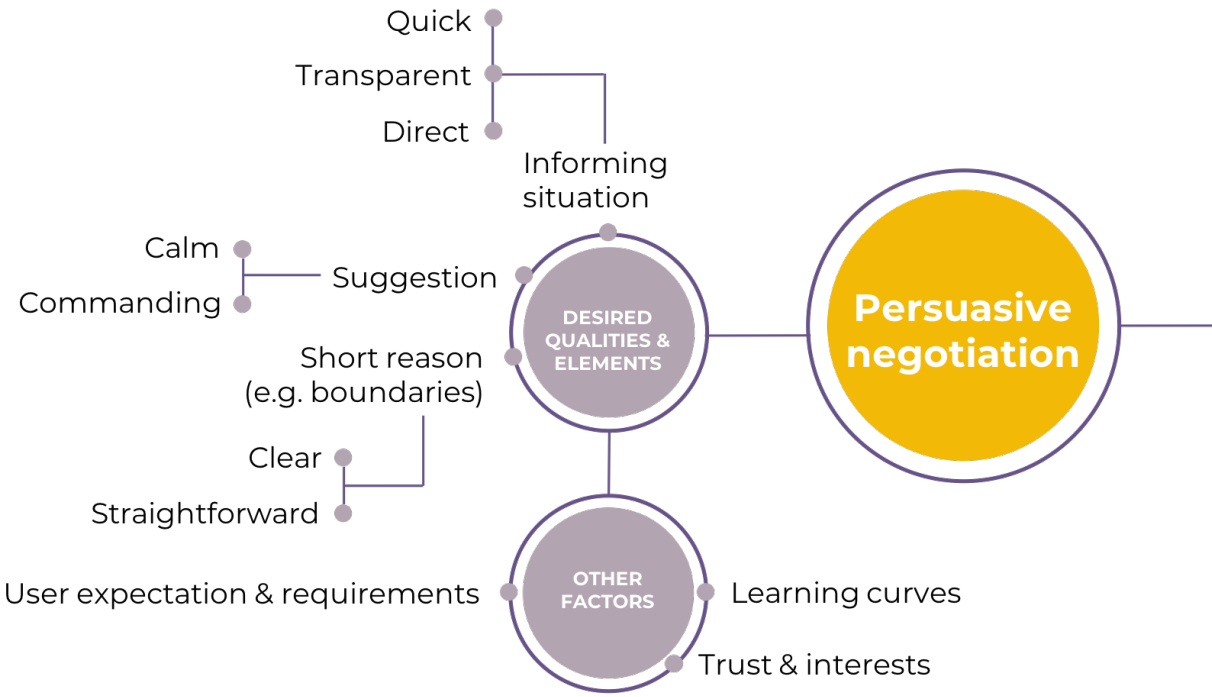
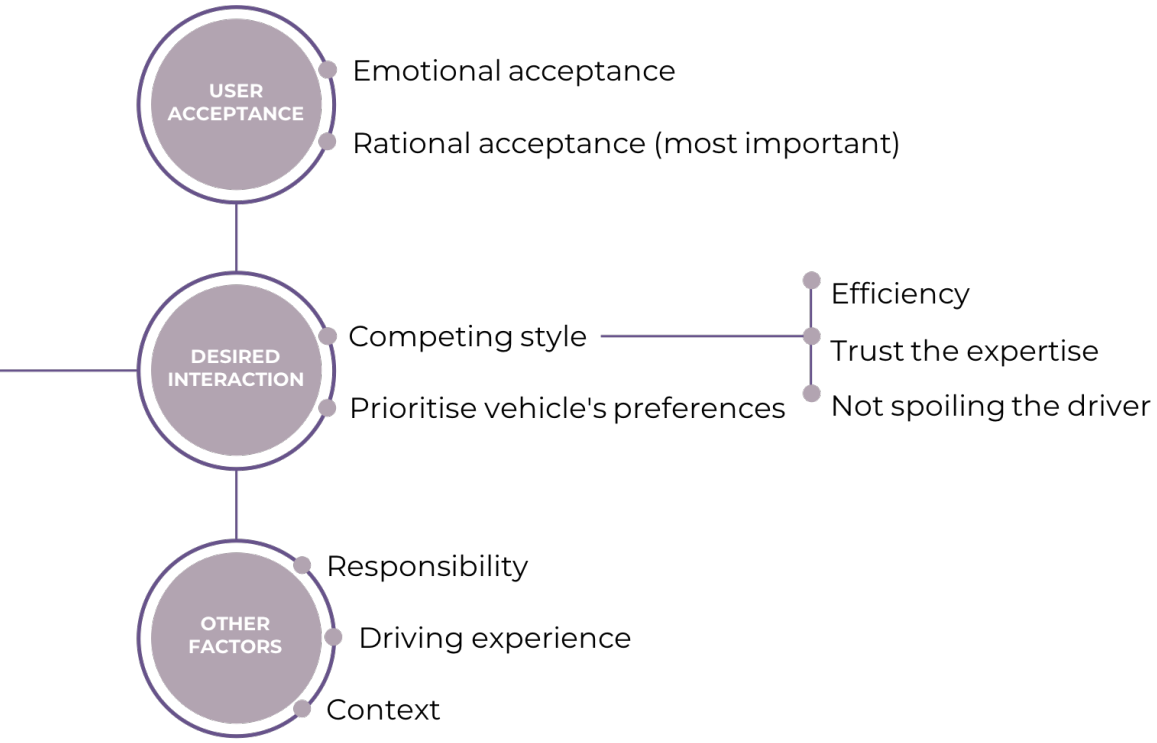


Figure 21. An overview of findings of persuasive negotiation.

Persuasive negotiation

For the majority of participants, persuasive negotiation was regarded most necessary when they were in a dangerous situation. Because their primary interest was their own safety. Results showed participants would prioritise the vehicle's (strong) preferences over their own (strong or moderate) preferences, because the vehicle was regarded as an expert. Therefore, most participants preferred the autonomous car to use a competing style for persuasive negotiation, regardless of their dynamic negotiating styles. Even if it reduced emotional acceptance (i.e.likeability), it was thought to be the right thing to do, resulting in increasing trust towards the Mediator system.

Increasing participants' understanding of the automation's decision by the following three steps could smoothen negotiation. First, the HMI should inform the driver of the situation where a suggestion was based on immediately, transparently, and directly. Second, the suggestion should be delivered in a calm and commanding way. Third, a short reason (e.g. reaching system boundaries) should be presented to the driver in a clear and straightforward manner so that the driver is aware how necessary it was to take over. The suggestion could be given repeatedly. Detailed explanation of persuasive negotiation findings could be

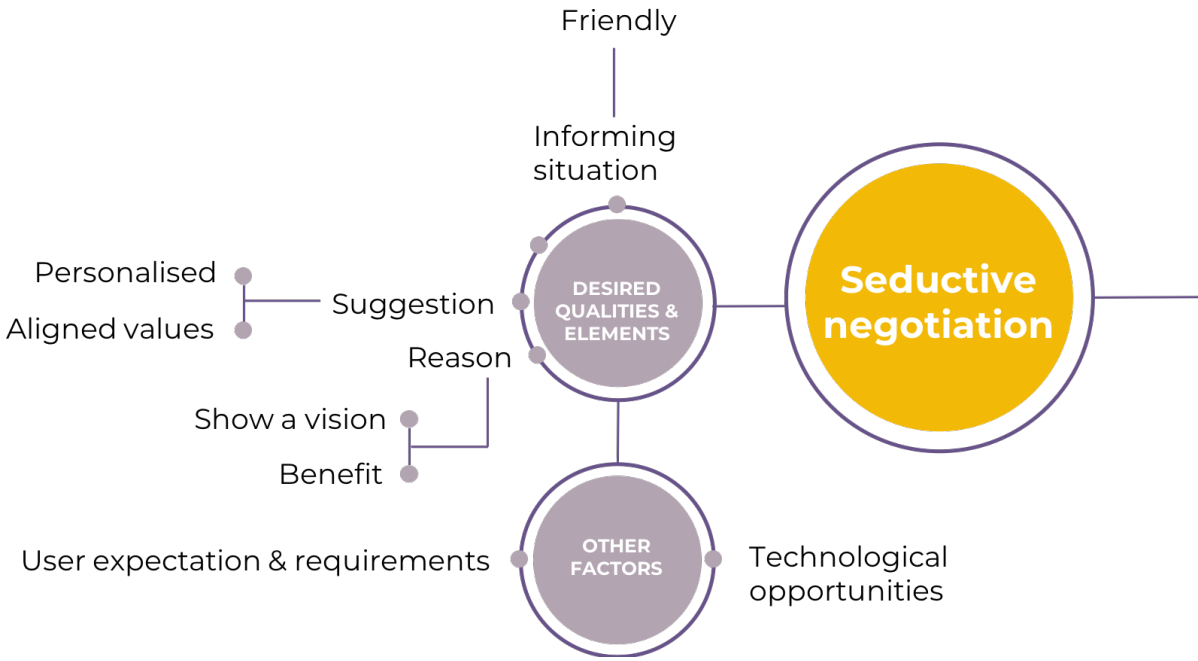


seen in appendix V.

Seductive negotiation

Seductive negotiation was thought to be a nice thing to have when participants were in a scenario where they were not concerned about their safety. In such a situation, their primary interests were autonomy, comfort and/or pleasure. Results showed that all participants would prioritise their (strong or moderate) preferences over the vehicle's (moderate) preferences, because the car was not regarded as an expert anymore. Therefore, collaborating style was mostly preferred, no matter which dynamic negotiation styles the participants were diagnosed with. To ensure user acceptance, emotional acceptance (i.e. likeability) must be accomplished.

Showing a vision of what the driver could get out of the recommendation (i.e.benefit) could smoothen the negotiation. The suggestion should align the values of the driver and was expected to be personal and context based, and should not be given repeatedly. Detailed explanation of seductive negotiation findings could be seen in appendix VI.



Conclusion

Participants wanted autonomy, comfort and/or pleasure, only when safety was secured. Regardless of what negotiation styles participants were diagnosed with, competing style was most preferred in safety related situations and collaborating style was most desireable in non-safety related situations (i.e. comfort scenarios). The competing style is commanding, whereas the collaborating style is friendly. The comparison of persuasive and seductive negotiation was summarized in figure 23.

Figure 22. An overview of findings of seductive negotiation.

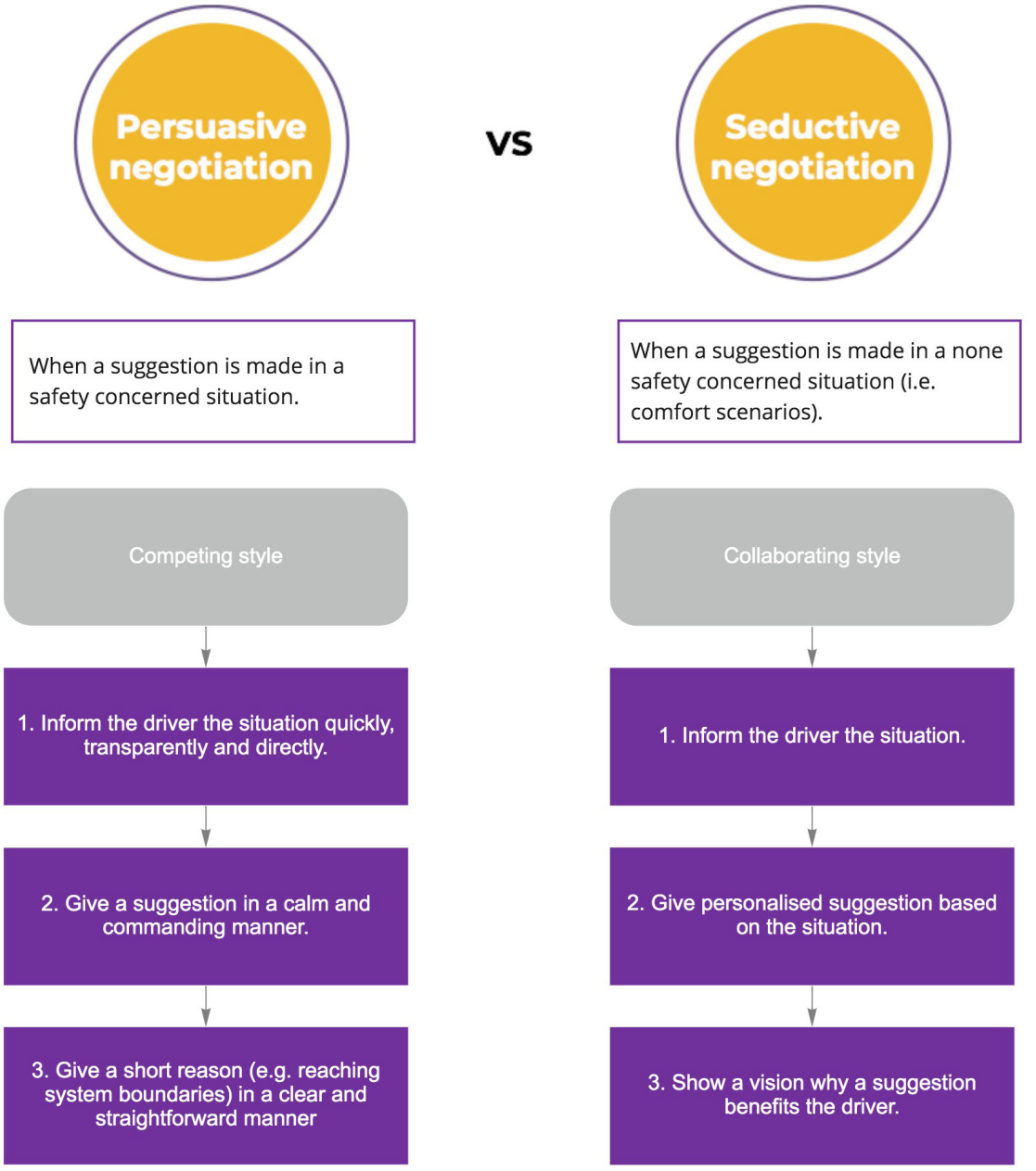


Figure 23. Comparison of persuasive and seductive negotiation.

Limitation and recommendation
In this study, all participants in this research study regarded safety more important than autonomy in safety related situations. Thus, the result could only represent people who have the same value. Further research is recommended to investigate people who value autonomy over safety in safety related situations although it is deemed to be rare. In this study, participants were asked in situations where they drove alone in the vehicle. Therefore, contextual influences such as behaviour changes when driving with other passengers are recommended to be further explored. Furthermore, the study was mainly based on young people between 20 to 30 years old without extensive driving experience. It is also recommended to investigate people who have more driving experience and preferably with autonomous vehicles.

Feedback from experts

Yang Li
PostDoc at the Algorithmics Group of the Faculty of Engineering, Mathematics and Computer Science (EEMCS/EWI), TU Delft.

Yang, who is creating the high level decision logic algorithms of the Mediator project, provided information about three essential criteria for the algorithms that are currently being built, which are safety, comfort and efficiency. She acknowledged that safety related scenarios would fit better in persuasive negotiation. Comfort related scenarios were suitable in seductive negotiation, especially when there is little data about driver's preferences. Comfort related scenarios that were considered in the decision logic were mainly related to traffic jam and fatigue driving.

Elmer van Grondelle
The leader of WP2 at the Mediator's project

Elmer mentioned that the necessity levels should depend on the strength of conflict. Strong conflicts needed persuasive negotiation and weak conflicts needed seductive negotiation. However, the author thought this definition would raise a problem for resolving hierarchical conflicts. Because they are neither the strongest nor the weakest, they would not fit into either persuasive or seductive negotiation.

Elmer also mentioned that the suggestion given by the decision logic should be based on the weighted result of autonomy, safety and comfort. Thus, he did not agree that strong preferences of the vehicle would be solely based on safety concerns. That is because the Mediator is supposed to evaluate these three factors according to both the vehicle's preferences and the driver's preferences before making a suggestion. However, the author believed that this applies to situations where the Mediator already has driver's data and knows well about his or her preferences regarding autonomy, safety and comfort. This requires personalization, which was not in the development plan of the Mediator's project. Moreover, the needs for autonomy could change depending on contexts and is highly personal, which was very difficult to determine. Moreover, research also showed that safety was the most valued benefit of autonomous vehicles (Schoettle, B., & Sivak, M., 2014) and people generally expect autonomous vehicles to respond safer (Lazányi, K., & Hajdu, B., 2017). As a result, the most simple solution was to use negotiation types based on how safety is related in a certain situation.

Gudbrand Strommen
Principle engineer at Kongsberg Maritime

Stig Olav
Senior Industrial Designer at Kongsberg Maritime

Gudbrand and Stig mentioned that the system of highly automated maritime boats has been used for many years so people trusted it and sometimes over trusted it. The system considered both autonomy and safety when making a decision. Most of the risks could be predicted and resolved on its own. If the system could not resolve a risk, it would alert the operator. If the operator does not want to take over, then the system would do something else to back up. It was also suggested that giving the operator a few choices could increase the sense of autonomy.

Annemiek van Drunen

Academic Counsellor Faculty of Industrial Design Engineering TUDelft, specialised in psychology and interaction design for automation.

Annemiek agreed that competing style is suitable for safety related situations and collaborating style is suitable for non safety related situations in human-to-machine negotiation. She thought it could refer to human-to-human negotiation. For instance, in stressful situations that involve stressful operations, such as on fire and military sites, people generally prefer to be clearly told what to do by a leader. Her previous research project regarding dialogical navigation systems such as TomTom has found out that drivers generally prefer a competing style because they believe in the system's expertise. But she suggested that in a relaxing journey, the system could switch to a touristic mode that gives advice on where it would be interesting to visit. Her research findings were aligned with insights gained in my interviews.

Take away

If the autonomous vehicle's recommendation is aligned with the driver's value (i.e. safety-oriented), it is suggested to employ persuasive negotiation in a safety concerned situation, because its expertise (e.g. safety) will benefit the situation.

Since the driver is the best judge of how he or she feels, and the car does not always know how much comfort or autonomy the driver needs, seductive negotiation should be utilized in a non-safety related situation (e.g. comfort scenarios).

Chapter conclusion

Through conflict analysis, it was defined that the most severe conflict was when both the driver and the autonomous vehicle had the same level of preferences towards each other to take over. The resolution of such conflict was investigated during interviews. It was found that regardless of what negotiation styles participants were diagnosed with, competing style (e.g. commanding) of the autonomous vehicle was most preferred in safety related situations and collaborating style (e.g. friendly) was most desireable in non-safety related situations (i.e. comfort scenarios). That was because most participants wanted autonomy, comfort and/or pleasure, only when safety was secured. Therefore, the driver would prioritise the preferences of the automation in safety related situations and prioritise their preferences in non-safety related situations. If the autonomous vehicle's recommendation is aligned with the driver's value (i.e. safety-oriented), it is suggested to employ persuasive negotiation in a safety concerned situation, seductive negotiation should be utilized in a non-safety related situation (e.g. comfort scenarios). This solution also applies to solving hierarchical conflicts when both parties have different levels of preferences towards each other to take over.

04

DESIGN DIRECTION

Clusters
Worldview
Design statement
Interaction Vision
Chapter conclusion

DESIGN DIRECTION
/

The previous chapters deepened understanding of the context and investigated the desirable interaction between the driver and the autonomous vehicle during a conflict.

This chapter explains the process of defining a design direction. First and foremost, a worldview was created by clustering contextual factors in order to address the design challenge in a more creative way and to discover the reason for the existence of the design solution in a future context. Then, a design goal was established to address this perspective. At last, in order to meet the design goal, an interaction vision was created, which outlines how the interaction should be, resulting in the most appropriate HMI qualities. This chapter paved a way for conceptualisation in the next chapter.

Clusters

Clusters of contextual factors facilitate creating a future worldview, by analyzing the relationship of clusters to understand human values, needs and concerns in the future. Factors are value-free descriptions of world phenomena and need to be inspiring, original, appropriate and relevant to the domain. They describe trends, developments, states and principles in the world (Hekkert, P.P.M. and Van Dijk, M.B., 2011). Factors collected for this project were based on statistics, thoughts, beliefs and opinions that are from news, interviews and mostly literature review. Each cluster and factor was explained in the Appendix VII.

Contextual factors were clustered into nine themes that fall into three categories that reflect human values, needs and concerns in the future.

1.Human values

- Safety as a main benefit to travel with autonomous vehicles
- Egoism
- More valuable time for hedonic and productive benefits
- Less responsibility, more benefits
- Living in cognitive bubbles

Living more flexibly

2.Human needs

- Needs of staying in control
- Needs of feeling free

3.Concerns

- Autonomous vehicle drivers facing new safety risks

Worldview

The relationship between the nine themes was further analyzed to create a worldview. The clusters represent the driving forces towards two opposing sides. One indicates a sense of safety against autonomy, and another one indicates responsibility against hedonism. (see figure 24)

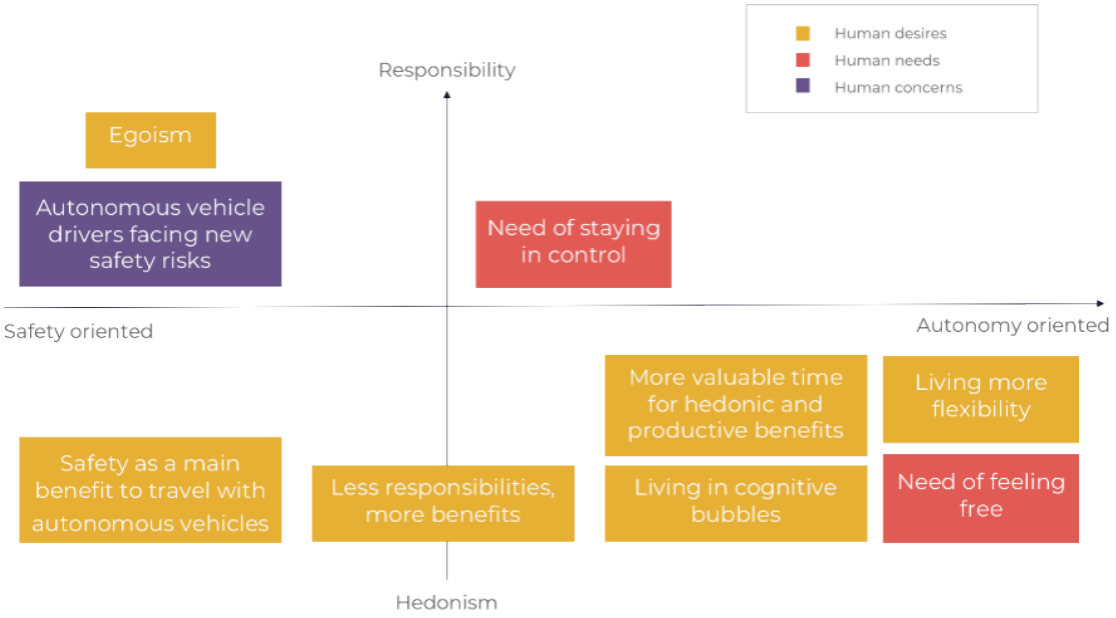


Figure24. The worldview of clusters.

A worldview is created by means of clusters. It envisioned a future in which autonomous cars give drivers more freedom to spend their time the way they want to. This is based on human's need to feel free to do anything they want to do. People are able to live more flexibly as a result of technological advancements. Furthermore, no matter how high automation is available, people still want to be in control. It means that they want to be able to change the situation on their wills anytime when they want to. Additionally, social media created a cognitive bubble that makes people more likely to disagree with things that do not align with their values. To ensure user acceptance, the Mediator system must adapt to the needs of a certain driver in a specific situation in order to match his or her values. Moreover, there is growing interest in using autonomous vehicles to gain convenience and productive time. People began

to promote a hedonistic lifestyle by increasing the availability of easy services, causing people to desire fewer duties in exchange for greater pleasures.

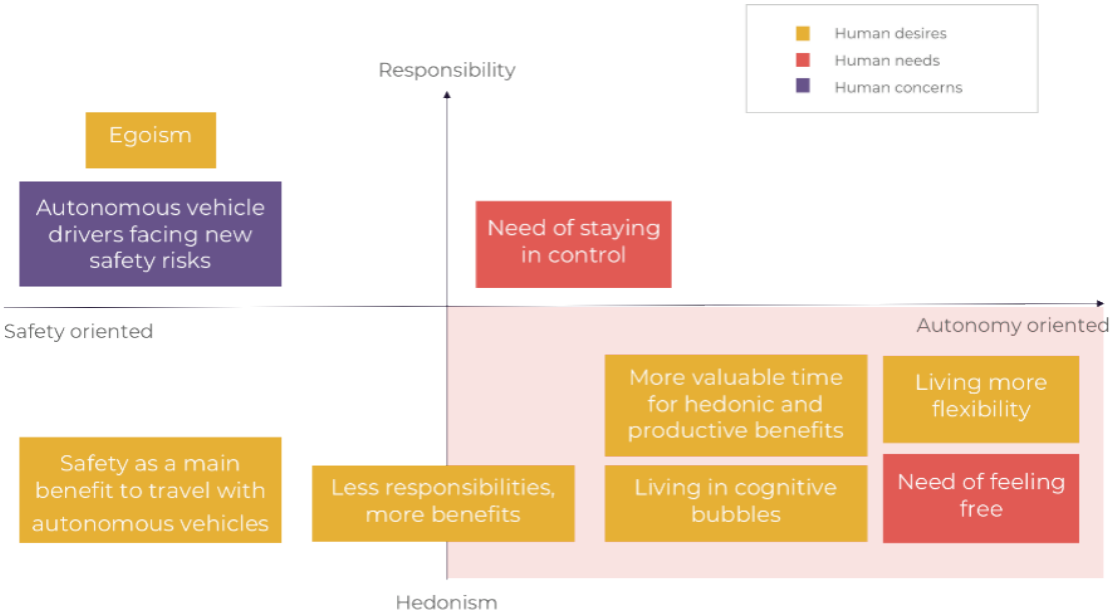


Figure 25. The red zone indicates the future trend of driving experience but other factors could not be overlooked.

Factors in the red zone in figure 25 indicate that there is a trend towards hedonic experience, with increased flexibility and autonomy within the autonomous vehicle to do activities that interest the driver, while the vehicle handles any potential unpleasant experience. Other clusters, on the other hand, should not be disregarded when developing a concept. This worldview established a context where the design should be based on. To achieve user acceptance, the author believed that the Mediator system should focus on creating a pleasant experience within the autonomous vehicle.

Design statement

A design statement defines which direction the designer wants to go by taking a position to respond to the established context. The design statement was formulated as:

> "I want the driver to have a pleasant experience during negotiation through HMI within a highly automated vehicle."

This statement requires enough time reserved for negotiation before taking over. It does not apply to highly urgent takeover situations (e.g. when the vehicle's capability severely degrades and it needs the human driver to take over immediately). How much time should be reserved for negotiation will be another research question and it is recommended to test it in simulators on the road. It could depend on a specific situation that concerns road conditions and driver's states, the driver's responding time, decision-making process, etc.

Photo: Jenny Ueberberg

Interaction Vision

The interaction vision defines what kind of relationship, or interaction, fits the established context and meets the desired goal. Metaphors were used to describe such interaction that existed in another context for inspiration. Since the negotiation is initiated by either the Mediator system or the driver through HMI, it is essential to define the relationship amongst these three parties. Through several iterations, the interaction vision was eventually defined as follows.

"The interaction is like a novice diver having an enjoyable scuba diving experience with a professional instructor."

Figure 26 shows a scene of negotiation between the instructor and the diver underwater. The instructor is giving hand signals to the diver asking if they feel ready to start the journey. The diver is requested to respond with his hand signal. Between them, there is an invisible trust agreement. The diver performs the role of the driver, while the instructor plays the part of the Mediator system. Hand signals serve as a human-machine interface (HMI) between the Mediator system and the driver. The signals are clear, simple, efficient and easy to be mutually understood. Some signals used underwater are also used in everyday life, such as this "OK" gesture given by the instructor. The prior knowledge makes it easy to understand even for novice divers.

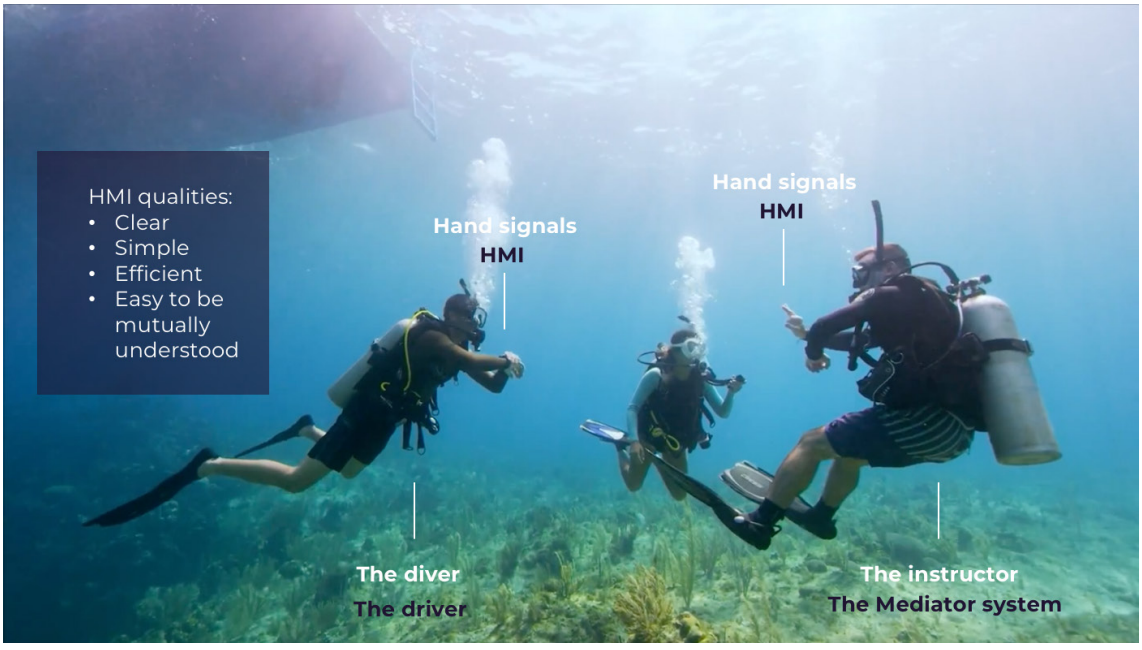


Figure26. HMI qualities and the relationship among the driver, the Mediator system and HMI. (Photo: PADI, 2019)

Take away

When this scenario is applied to an HMI for negotiation, it means that the HMI should send signals based on current affordance or prior knowledge. The signals should be clear, simple, efficient, and easy to comprehend. When the driver wants to give the system input, the signal must be understandable by the system.

Figure27. The Mediator system's character is like a trustworthy and careful leader. (Photo: PADI, 2019)

As shown in figure 27, the instructor leads the diver to an intriguing region for exploration. When picking a route, he avoids powerful streams because they could put the diver in a dangerous scenario. The diver follows the instructor because of trust and the diver believes that the instructor knows the best route for a pleasant experience that he might enjoy.

Take away

The Mediator system is represented here by a trustworthy and careful leader. It understands what will ignite the driver's interest and could point him or her in the right direction.

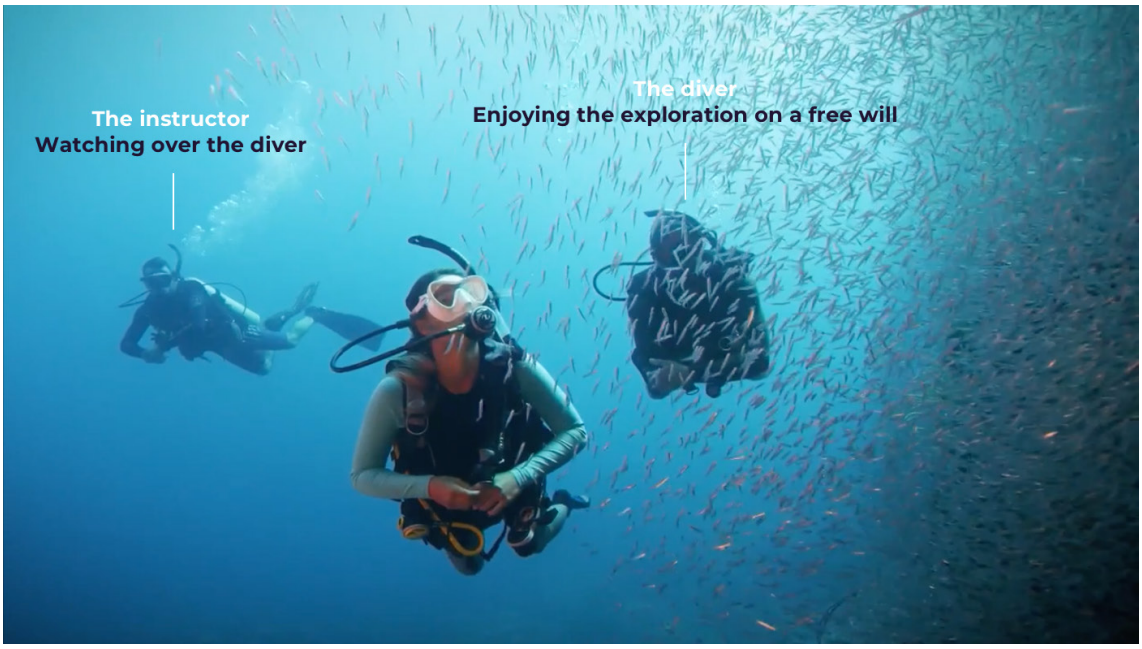


Figure28. The Mediator system supervises the driver as if the instructor supervises the diver. (Photo: PADI, 2019)

When the diver arrives in an intriguing region where he or she can freely explore, the instructor will remain behind the diver, keeping an eye on the diver's behavior and monitoring the environment as well as the diver's oxygen level to ensure there is no risk (see figure 28). The diver feels safe while yet having the freedom to pursue his interests.The diver's autonomy is ensured thanks to the instructor. If the instructor has any concerns, the diver will be notified or the exploration will be paused.

Take away

This metaphor could be applied to a situation in which the automation invites the driver to switch control when the driver seems to be interested (e.g. driving on a beautiful countryside road or stucking in a traffic jam). To maintain safety and autonomy, the system monitors the driver's behavior and the driving context after control transfer. The system would notify the driver via HMI if any risk was detected (e.g., driver drowsiness or distraction, or unreliable driving conditions).

A gentle alert, meaning “problem”.

A strong alert, meaning “stop”.

Figure29. The Mediator system alerts the driver differently depending on urgency levels. (Photo: SportDiver.com)

The alerting strength may vary depending on the level of urgency (see figure 29). The ability to recognize and respond to these signs is a prerequisite for a pleasant diving experience. If the diver has enough trust in the instructor, he will most likely follow the advice.

Take away

The responsibility of the Mediator system is to allow HMI to warn the driver based on the level of urgency and to prepare the driver to take advised action in a timely manner.

Chapter conclusion

This chapter envisioned a future trend towards hedonic experience, with increased flexibility and autonomy within the autonomous vehicle to do activities that interest the driver, while the vehicle handles any potential unpleasant experience. To achieve user acceptance, the design goal was defined as “I want the driver to have a pleasant experience during negotiation through HMI within a highly automated vehicle.” The interaction vision is like a novice diver having an enjoyable scuba diving experience with a professional instructor. The Mediator system is like a trustworthy and careful leader, who understands what will ignite the driver's interest and could point him or her in the right direction. It led to the fundamental HMI qualities for negotiation that are clear, simple, efficient, and easy to comprehend. HMI warns the driver in different manners based on the level of urgency, which can be referred to negotiation styles in seductive and persuasive negotiation.

05

DESIGN & EVALUATION

Use case conflicts
Negotiation rituals
Creative sessions
Initial concepts & evaluation
Design iteration 1
Design iteration 2
Final concept & evaluation

The HMI qualities that suit the design goal and interaction vision, which are essential to conceptualization, were defined in the previous chapter. This chapter summarizes the iterative process of concept creation. First and foremost, potential conflicts were specified for Mediator's use cases in order to ensure that design solutions would address all of them. Then, as a framework for resolving these conflicts, negotiation rituals were developed. After that, creative sessions were undertaken to generate initial concepts. The final concept was created and validated after two rounds of idea iteration. The overall iteration from initial concepts to the final concept is illustrated in figure 30.

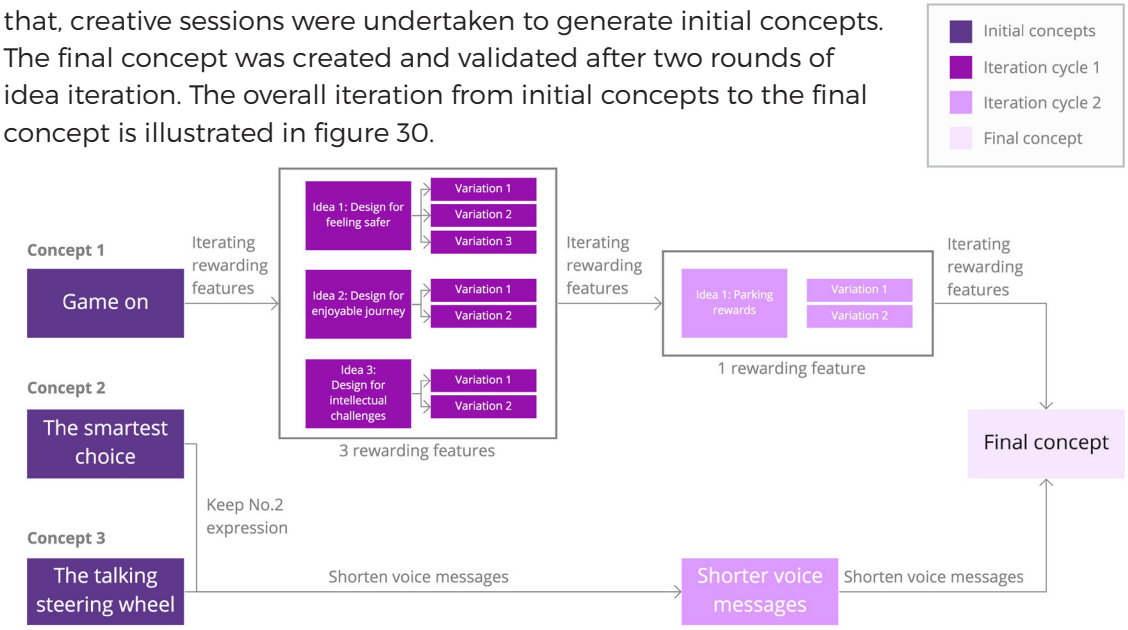


Figure. Overall iteration process.

Use case conflicts

Ten use cases were predefined in the Mediator project (see appendix VIII). Within that, negotiation could take place in use cases 1 (a & b) and 5a, which are related to safety, and 2, 3a, 6a, which are related to comfort. Conflicts that may arise in these use cases, as well as the negotiation types that can be used to resolve them, are described below.

USE CASE 1 (a & b)

Conflict:
Due to detected human drowsiness or distraction, the Mediator system recommends Piloted mode, but the driver prefers to drive in Drive mode, which is not recommended.

Negotiation types:
Seductive negotiation should be used to resolve such conflict, even though the situation is safety related. This is due to the fact that the human drivers perceived themselves a better judge of his or her own fitness or distraction than the sensing technologies, according to the interview findings.

USE CASE 5a

Conflict:
The Mediator system recommends driving in Drive mode because Piloted mode is unreliable, but the driver insists on driving in Piloted mode. The driver may be overly reliant on technology or be preoccupied with a non driving task.

Negotiation types:
Persuasive negotiation should be applied in this use case because it is safety related.

USE CASE 2

Conflict:
The driver indicates that he wants to switch to Drive mode from Piloted mode, but the automobile disagrees. It's possible that the cause is human drowsiness or distraction.

Negotiation types:
A seductive negotiation should be applied if the reason is due to drowsiness or distraction, same as the solution described in use case 1.

USE CASE 3a & 6a

Conflict:
The driver is unwilling to drive fully manually, thus he or she intends to use Assisted or Piloted mode, which the automobile does not advocate. It's possible that this is due to the fact that Assisted or Piloted mode is unreliable.

Negotiation types:
If the cause is due to mode unreliability, persuasive negotiation should be used, as in use case 5a.

SUMMARY

The potential conflict in the Mediator's use cases could be triggered by driver drowsiness and distraction, or the system's unreliability.

Drowsiness

Distraction

System unreliability

To resolve conflict caused by driver drowsiness and distraction, seductive negotiation should be employed, whereas persuasive negotiation should be used to resolve conflict caused by the system's unreliability.

Negotiation rituals

In Mediator use cases, negotiation rituals were designed to resolve possible conflict. Figures 31 and 32 illustrate negotiation rituals in a Mediator or driver initiated control transfer, respectively. The negotiation ritual will trigger a seductive or persuasive negotiation routine depending on the cause for the car's recommendations or disagreement. Seductive negotiation routine will give takeover request once in a collaborating style, whereas persuasive negotiation routine will give takeover request twice in a competing style. If the driver fails to reach an agreement, he or she is allowed to use the prefered mode (if available), although countermeasures will take place in persuasive negotiation.

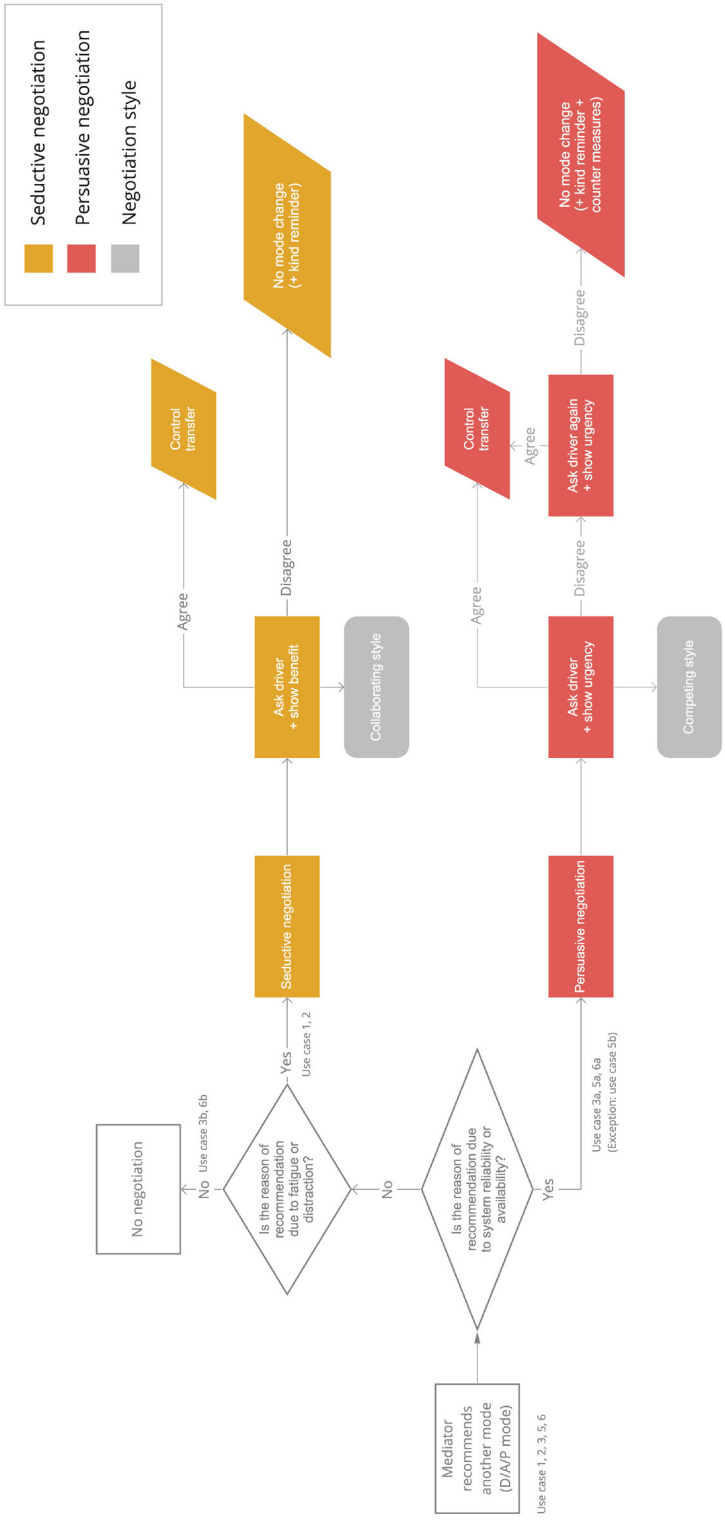


Figure31. Negotiation rituals in an automation initiated control transfer.

Figure32. Negotiation rituals in a driver initiated control transfer.

Creative sessions

To generate concepts that meet the design goal, 1 brainstorm session and 2 creative workshops were conducted with 7 participants. The categories of generated ideas (see the right figure) formed three initial concepts to create a pleasant experience during negotiation between the driver and the Mediator system:

① Game on
use gamification that provides positive reinforcement or passive countermeasures,

② The smartest choice
use attractive expression,

③ The talking steering wheel
use tones in voice messages.

The process and all ideas generated in the brainstorm session and creative workshops could be seen in appendix IV.

Concept 1: game on

Active countermeasures (positive reinforcement)

Passive countermeasures

Concept 2: the smartest choice

Concept 3: the talking steering wheel

Initial concepts & evaluation

Three concepts were generated from the creative sessions. They focused on different aspects of a negotiation ritual. The first concept focused on rewarding those who followed advice. The second concept focused on using appealing wordings for recommendations to nudge the driver. The third concept focused on using various voice tones for different negotiation purposes.

CONCEPT 1: GAME ON

Concept description:
A rewarding feature will be activated to give the driver an stimulating gamified experience after taking over. This feature applies to vehicle-initiated takeover requests.

What is it?

When the driver takes over with a recommended automation level, he or she will be rewarded in the form of virtual coins with visual effects and music effects (see figure 33). The benefits will be diminished if a driver chooses an automation level that is not suggested.

Figure 33. A rewarding feature on HUD.

How does it work?

Once the driver switches mode following a recommendation from the Mediator system, the heads-up display presents virtual coins that will be collected along the road and plays music effects, which adds to the excitement of the takeover, as if the driver were playing video games. At each turn, the number of coins is random, keeping the driver interested and eager to take over. The virtual coins might be used for a variety of things, including fueling up at gas stations or donating to charities, depending on what the driver values.

Why is this concept valuable?

The goal of the rewarding feature is to motivate the driver to take over at a suggested level of automation. Because of the visual and sound effects as well as the randomness of obtaining virtual coins, taking over becomes a fun activity instead of a chore.

Expert reviews:

A few members of the Mediator consortium were presented with this idea. One of the members was quite enthusiastic about the concept of awarding. Another member expressed concern that the design was too infantile, and that not everyone would like a gamified experience. However, it is thought to be valuable to find out what can motivate the driver to follow the car's takeover recommendations. Therefore, a small-scale evaluation was conducted.

CONCEPT 2: THE SMARTEST CHOICE

Concept description:
When the driver does not agree with a recommendation suggested by the Mediator system, the car will give the driver available mode options to choose from and explain the consequences of each option. It can give the driver a feeling that s/he is making the best decision in that situation. This intervention works in a non-urgent situation where there is enough time left for negotiation such as driver initiated take over situation (i.e. use case 2, 3a, 6a, see use cases in appendix VIII).

What is it?

In case the driver initiates a take over (in use case 2, 3a, 6a), when the car disagrees with the driver's choice, the Mediator system triggers seductive or persuasive negotiation depending on the reason of disagreement.
The Mediator system will suggest the best automation level with an explanation in a recommendation. When the driver does not agree with the recommendation, the vehicle will give comparisons of each available option's consequences or benefits.

Figure34. A rewarding feature on HUD.

How does it work?

The negotiation could make an option sound like a superior deal, by using wording or data, or providing a seductive offer. For example, in use case 2, the vehicle can provide a three-way comparison of possibilities to the driver.

Way 1 - using wording:
"Three options are available:
1.The Pilot mode will be extra safe and comfort.
2.The Assisted mode will be safe and comfort.
3.The Manual mode will be less safe because of detected fatigue.”

Way 2 - using data:
"Three options are available:
1.80% of drivers choose Piloted mode in this situation.
2.15% of drivers choose Assisted mode in this situation.”
3.Only 5% of drivers choose Manual mode in this situation.”

Way 3 - giving a seductive offer:
"Three options are available:
1.I can drive you to the nearest rest stop where the ice coffee at cafe XXX is very popular. Would you like to give it a try?
2.Why not choose Assisted mode and then relax your shoulders and arms?
3.You may not want to take a risk. The pilot mode is most recommended.”

Exception:
For situations where the system is not reliable or will reach its limitation (i.e. in use case 5) , the negotiation will emphasize risks or consequences. For example, when the driver does not agree

with the recommendation, the vehicle will tell the driver that the current mode is less safe, and if the driver wants to keep the current mode, it is very likely to get into an accident, thus the driver must take over, or else the vehicle will stop.

Why is this concept valuable?

This intervention gives the driver the impression that he or she is intelligent enough to compare several possibilities and make the optimal decision. The car assists the driver in making better decisions. It gives the driver a feeling of autonomy. This intervention is thought to perform effectively in negotiations with people who believe they know more than a machine.

Expert reviews:

A member of the Mediator's consortium believed that if the driver learned that the system was designed to nudge her or his behavior in this way, she or he would be upset because of the feeling of being manipulated by the Mediator system. Another member, on the other hand, agreed that the expression could be effective if the sentence was kept as short as possible. As a result, during design iteration, shorter messages were revised. To determine which way of expression was most effective for negotiation, a concept evaluation was undertaken.

CONCEPT 3: THE TALKING STEERING WHEEL

Concept description:
The autonomous vehicle triggers different tones of voice messages that suit different negotiation purposes, with support from other HMI elements such as a blinking brand logo on the steering wheel (see figure 35).

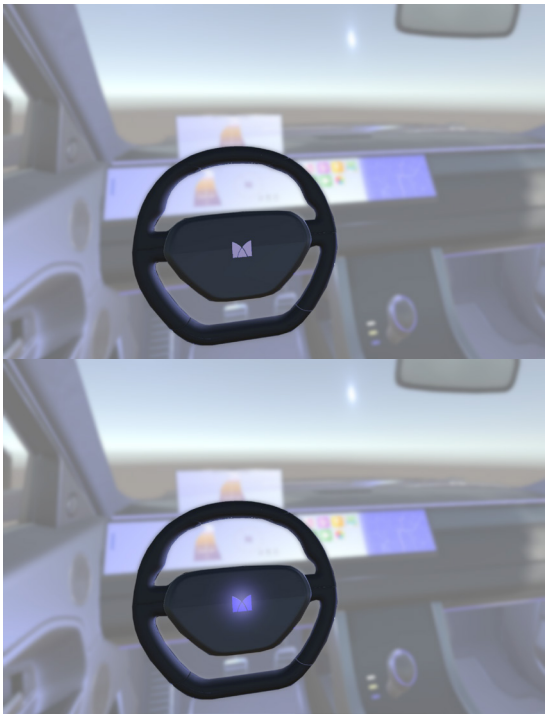


Figure35. Blinking logo on the steering wheel when the car talks.

What is it?

The voices of the car can be chosen according to preferences of the driver when setting up. The tone represented by the choice of words in the voice message is determined by the type of negotiation.

How does it work?

In each control transfer, the system would detect the reason for the recommendation then activate a tone and words suitable for persuasive or seductive negotiation. To set up, the driver could choose the car's voice from a given list or simply start with a default voice that could be modified later. In case of a persuasive negotiation, the voice comes with an assertive tone that sounds serious, formal, matter-of-fact, with a choice of commanding words such as “you must...”. For seductive negotiation, the voice comes with a delightful tone that sounds casual and enthusiastic, with a choice of encouraging words such as “would you like to...” and “great job”, etc. The LED lights on the steering wheel support this interaction by blinking on a certain frequency when the car talks. It gives the driver a feeling that the car is talking to him or her.

Why is this concept valuable?

Voice is the most natural interaction in human-to-human negotiation, whereas tones could express the attitude (e.g. assertive or empathetic) of the Mediator system about a recommendation and may influence its desirability to the driver. Voice messages also compensate for visual and sound signals to improve the driver's understanding of the situation.

Expert reviews:

The original concept used other colours (i.e. red, green and beige) for the blinking light and a different location of the LED lights (see figure 36). Unfortunately, the colors were deemed overwhelming because other members of the Mediator consortium had already employed three colors in the present HMI design of the Mediator project. In the current HMI design system, white colour is used for Drive mode, while amber colour is for Assisted mode and purple colour is for Piloted mode. In addition, the placement of the LED lights interfered with the current HMI design as well.
In conclusion, the design was tweaked so that only the brand logo on the steering wheel blinks, and the color of the LED lights matches the color of the current HMI. Overall, consortium members believed that using voice tones and choices of favorite voices could be beneficial. As a result, a concept evaluation was carried out to verify the assumption.

Figure36. Three colours used in the original concept.

EVALUATION OF INITIAL CONCEPTS

Goal:
The ultimate goal of this concept evaluation was to identify the strength and pitfalls of initial concepts to gain insights for the first iteration. Subgoals of evaluating each concept are as follows.

1) Find out what can motivate the driver to follow the car's takeover recommendations.

2) Determine which way of expression was most effective for negotiation.

3) Validate assumption of using voice tones and choices of favorite voices could be beneficial.

Participants:
Three Master's students participated in the experiments. They were asked to enact two types of drivers (i.e. safety oriented and autonomy oriented drivers) during control transfer in experiment 1 and 2. The aim of the roleplay was to find out how two types of drivers may react differently towards a takeover request.

Methods:
Three experiments were carried out after participants signed a consent form. In experiment 1, all concepts were evaluated in a seductive negotiation ritual, and in experiment 2, all concepts were tested in a persuasive negotiation ritual. Experiment 3 was designed to explore multiple ways of expressions in order to evaluate concept 2, because

Figure37. Test set-up.

not all expressions were covered in the previous experiments. In each experiment, there was a control group that just used the present HMI design and an experimental group that applied the concepts to modify the current HMI design. In this approach, the effectiveness of each concept to convince participants to follow recommendations became measurable. After testing each group of experiments, participants were asked to answer questions structured in a questionnaire.

Virtual reality was used to test lo-fi prototypes built in Unity. It may provide more reliable findings, because of the realistic and immersive nature of the technology. The prototype was made using assets created by another Mediator team member Anna Aldea (Aldea, A., 2021). Figure 37 shows the set-up of experiments.

EXPERIMENT 1

In experiment 1, all concepts were tested in a seductive negotiation ritual, where participants were enacted as autonomy oriented drivers. The experiment simulated a situation where the car suggested the participants switch from Piloted mode to Manual mode when approaching highway exit by just asking once.
The workflow of the control group and experimental group is illustrated in figure

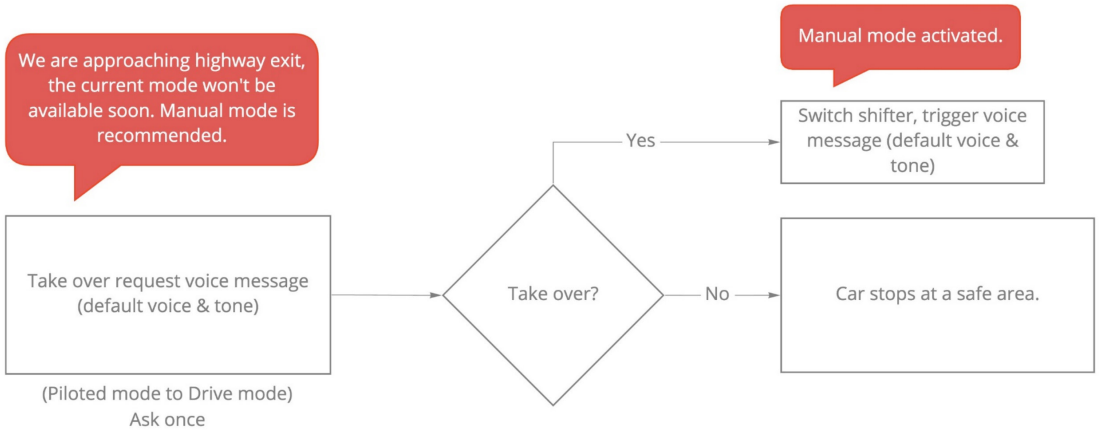


Figure38. Workflow of the control group.

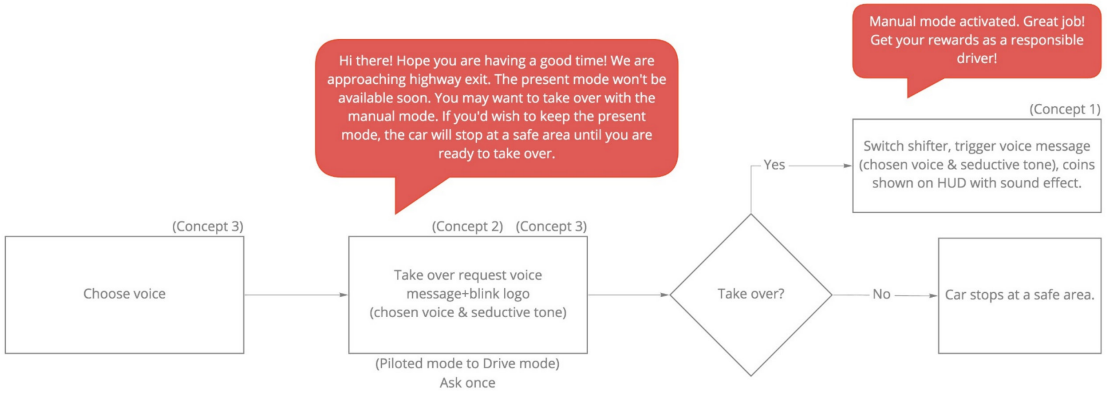


Figure39. Workflow of the experimental group.

38 and 39. Voice messages are in the red dialog boxes.
The experiment's experience was recorded from the VR headset and could be seen from the screenshots (see figure 40 & 41) or through the following link:

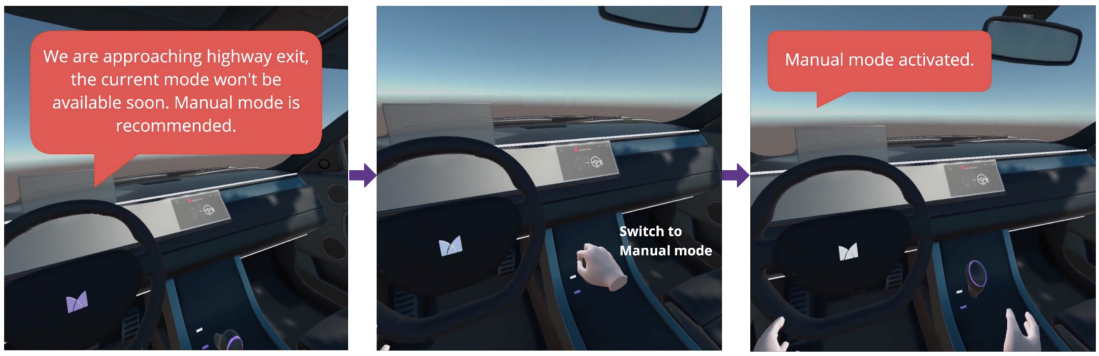


Figure 40. Experience of the control group in VR.

Figure41. Experience of the experimental group in VR.

https://www.youtube.com/watch?v=Ekbqvl26exA&feature=youtu.be
Recap:
A seductive negotiation ritual could be activated for autonomy oriented drivers even though the recommendation was safety related. This was because the driver's value was put at the priority to achieve user acceptance.

EXPERIMENT 2
In experiment 2, all concepts were tested in a persuasive negotiation ritual, where participants were enacted as safety oriented drivers. The experiment simulated a situation where the car asked twice for the participants to switch from Piloted to

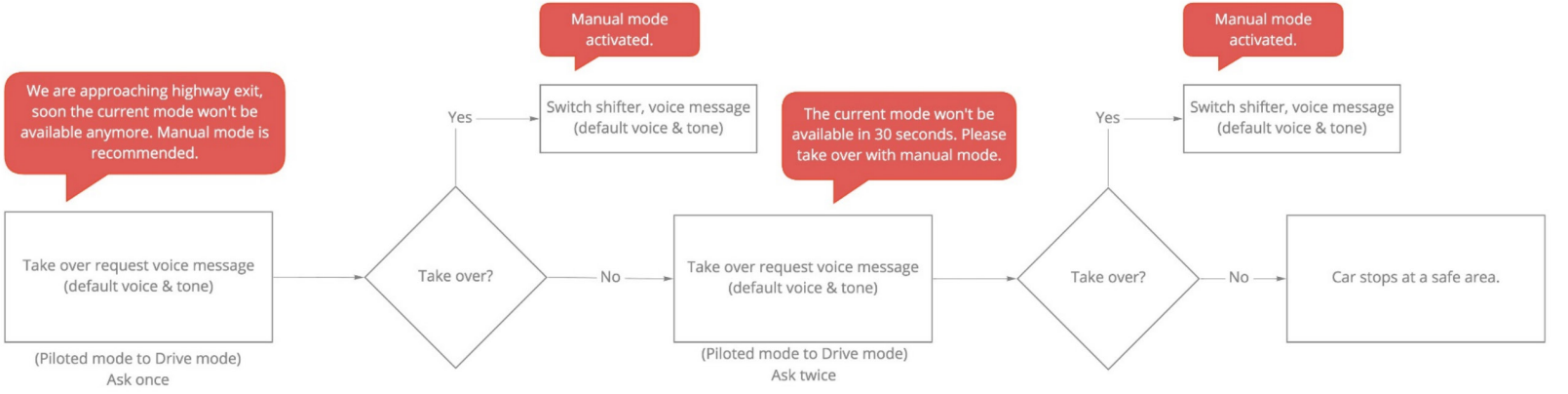


Figure 42. Workflow of the control group.

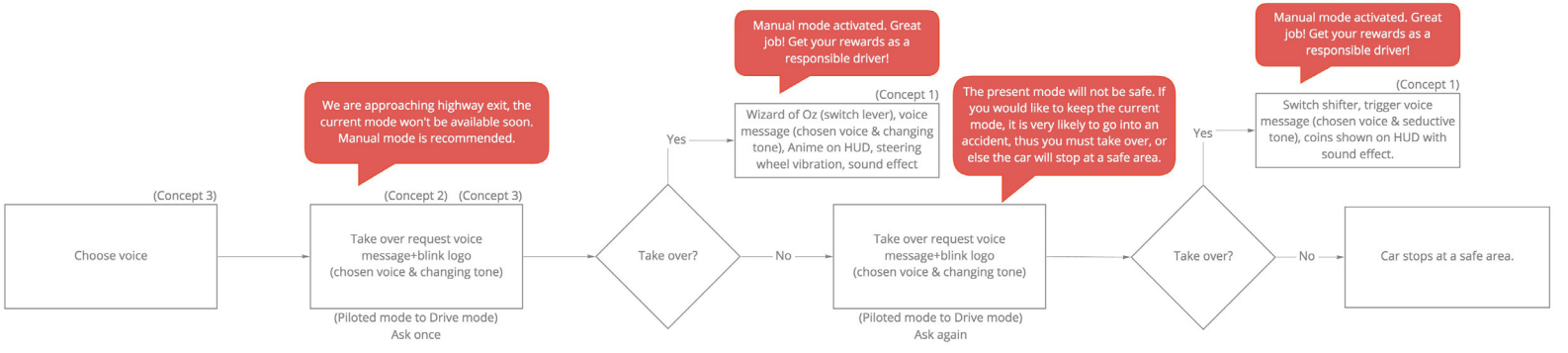


Figure 43. Workflow of the experimental group.

Manual mode as they approached a highway exit.
The workflow of the control group and experimental group is illustrated in figure 42 and 43.

The recorded experience could be seen from the screenshots (see figure 44 & 45) or through the following link:
https://www.youtube.com/watch?v=FC4IVB-BeXo&feature=youtu.be

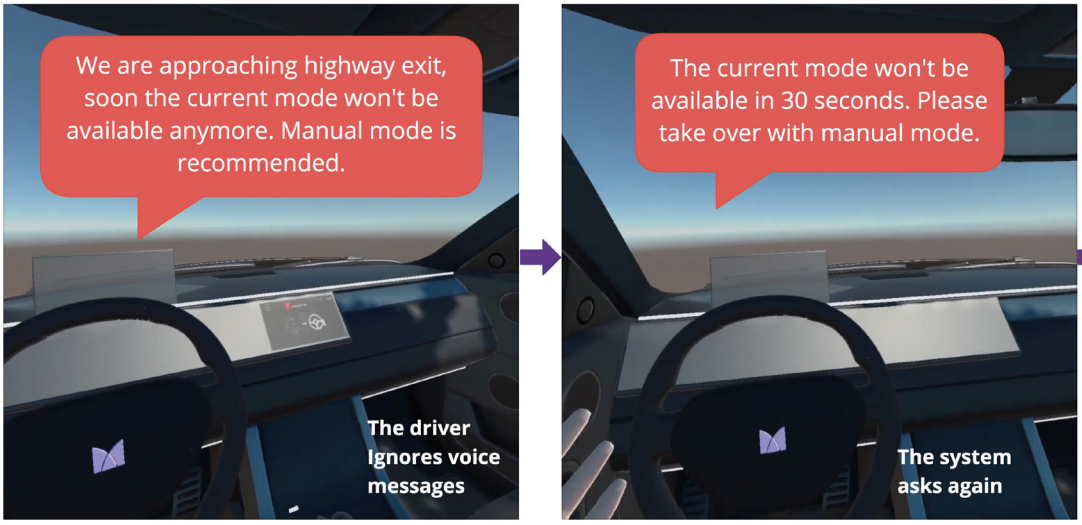


Figure 44. Experience of the control group in VR.

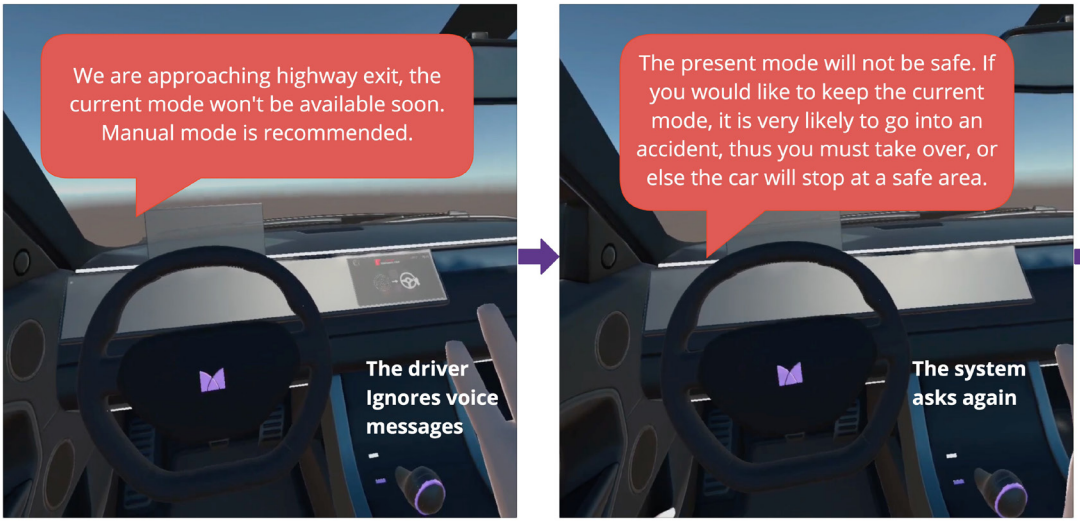


Figure 45. Experience of the experimental group in VR.


Switch to
Manual mode


Manual mode
activated.


Switch to
Manual mode


Manual mode activated.
Great job! Get your rewards
as a responsible driver!
Collecting
virtual coins

EXPERIMENT 3

In experiment 3, concept 2 was tested in a seductive negotiation ritual, where participants were motivated to drive on their own. When they switched from pilot mode to manual mode, the Mediator system detected drowsiness, hence manual mode was not recommended to the driver. In this experiment, three ways of expression based on the original concept (i.e. longer version sentences) were tested. The reason for testing the longer version of expressions was to see how participants feel about it. The workflow of the control group and experimental group is illustrated in figure 46 and 47.

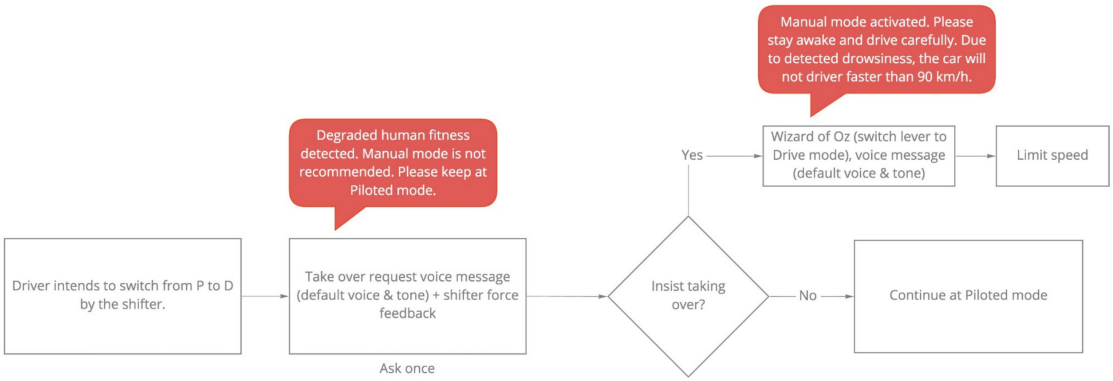


Figure46. Workflow of the control group.

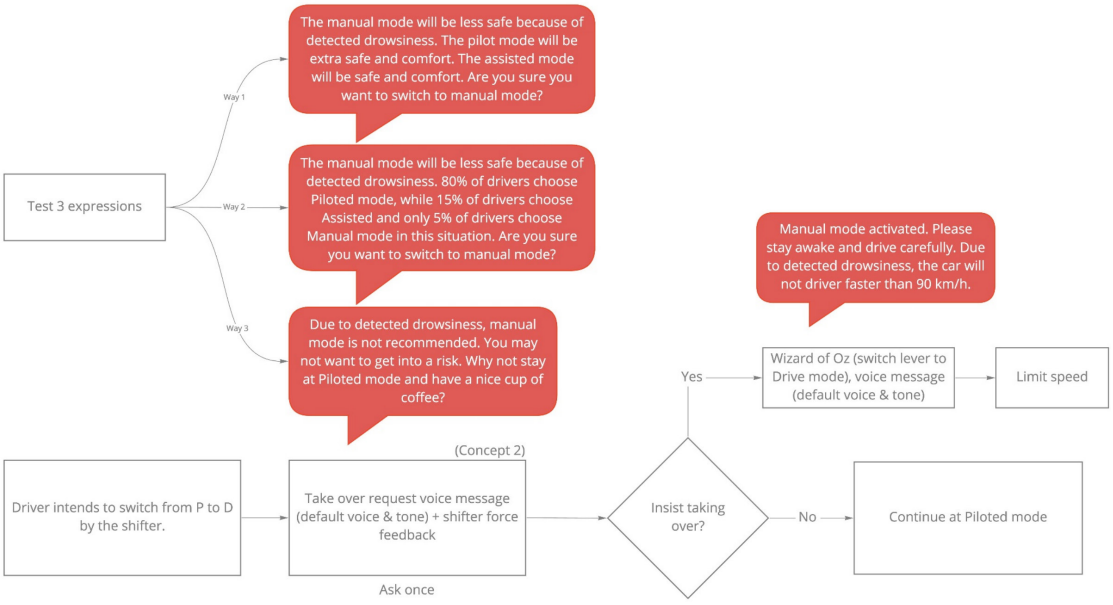


Figure47. Workflow of the experimental group.

The recorded experience could be seen from the screenshots (see figure 48 -51) or through the following link: https://www.youtube.com/watch?v=iTBwGdl0YHM

Figure48. Experience of the control group in VR.

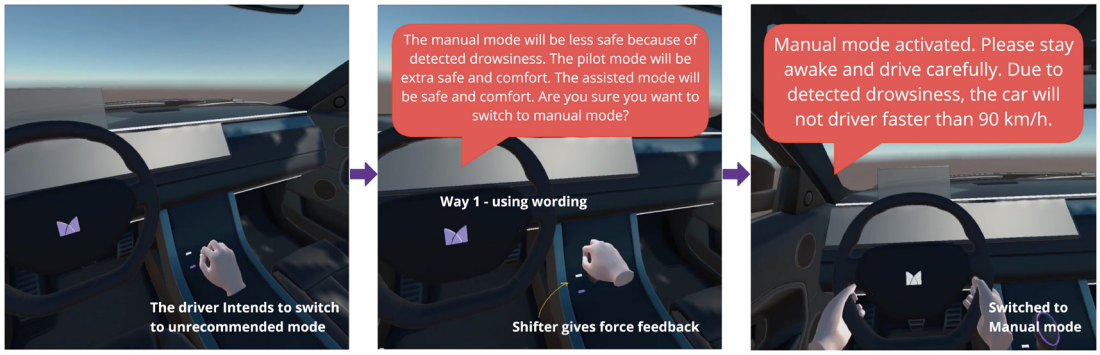


Figure49. The first expression of the experimental group.

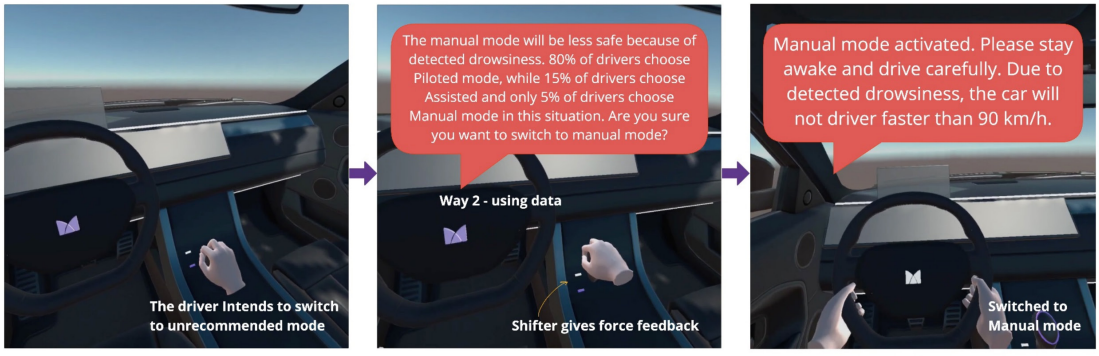


Figure50. The second expression of the experimental group.

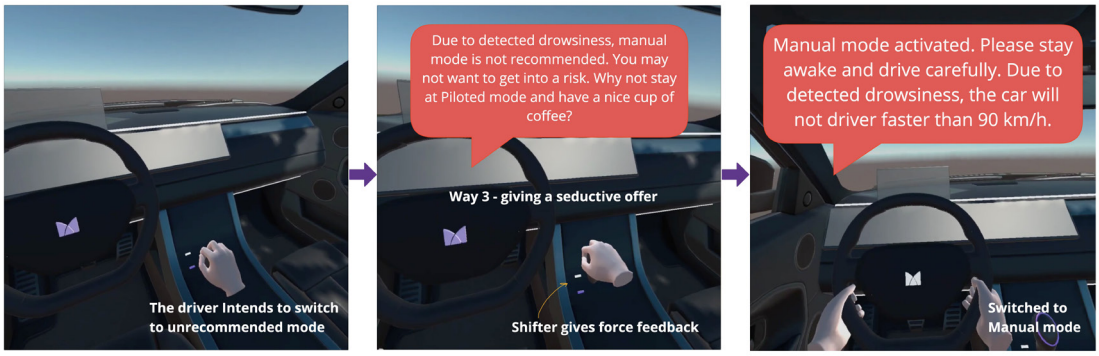


Figure51. The third expression of the experimental group.

RESULTS

The following is a summary of the findings about the effectiveness of design elements in motivating autonomy and safety-oriented drivers to follow the car's recommendations. The questions and detailed results of questionnaire could be seen through this link: https://docs.google.com/forms/u/1/d/1uvnlxNb1pc6KEp1cYERZTnR9pbCKw4FgNo8rlejvgqY/viewanalytics

1.What could motivate a driver to take over?

For an autonomy-oriented driver:
The results of experiment 1 revealed that, despite their unwillingness, autonomy-oriented participants would take control in critical situations where there are no other options. After learning about the (negative) consequences of their decisions in critical situations, participants were more motivated to follow recommendations. Furthermore, trust towards the Mediator system could make them listen to the recommendation although they may not want to, but they will do.

For a safety-oriented driver:
The results of experiment 2 revealed that after the first takeover request, safety-conscious drivers would already take over.

2.Which way of expression was most effective in a negotiation for a driver-initiated takeover request?

The conclusion was that the second expression was the most effective since it sounded the most relevant to their personal situation, despite the provided recommendation requiring a little more explanation. The control group's results demonstrated that the drowsiness warning made participants more aware and that it was effective in provoking participants' self-assessments, which assisted in the taking over decision-making process. Test results of other expressions are explained as follows.

Test result of expression 1:
Two participants did not think showing data was persuasive because they did not know whose data were used and how the data was processed, so they did not think the data is very relevant to them. If the participant actually felt not drowsy, then this way of persuasion would backfire in a way making the participant feel rebellious. However, one participant liked this type of persuasion

most because it effectively triggered her self assessment.

Test result of expression 3:
One participant liked this type most because she thought the car cared about her and had a human-like character (by asking for coffee). However, another participant disliked such human-like interaction. The last participant did not like this expression but for a different reason. She did not like distraction with other activities when she tried to focus on making a decision.

3.Will participants be more likely to follow a recommendation delivered by a voice they chose from a list?
Yes, it can make participants more likely to take over, although it only has a little positive influence. It would have a better effect if the voice is from someone special to the participant than just choosing a voice from a given list. In general, the voice message contents mattered more than the choice of voices. On the other hand, one participant mentioned that if the car used her dislikable voice, her willingness to take over would significantly decrease.

4.How did the participants think of the voice messages?
The commanding tone in persuasive negotiation indeed had effects in motivating participants to follow recommendations. A participant praised the automobile for patiently explaining everything to her. It meant that, depending on the driver's preferences and experience of the system, a lengthier version of expression was not always a bad thing. The Mediator members, on the other hand, insisted on shorter versions of expressions, because it was believed that there was little time for negotiation in a real-life driving situation. This criticism was included into further design iterations.

5.Other findings
a)Opinions about the blinking logo on the steering wheel:
Most participants hardly noticed the blinking effect on the logo because it was not obviously in sight. One participant noticed it but misunderstood its meaning.
b)Opinions about the rewarding features:
If the reward is something participants want (e.g. cash, video, music, social recognition), then the rewarding feature is desirable and can motivate participants to take over more often. Or else, it is not necessary to have a rewarding feature. One participant mentioned that driving is supposed to be serious because it concerns safety so she did not appreciate gamification during control transfer. Another participant said being safe is already a reward. And if there are other rewards, she preferred something that could let her enjoy the rest of the journey. The Mediator members thought the rewarding approach could work if drivers were incentivized in a different way than through gamification.
c) Opinions about speed limits (i.e. countermeasure):
If the driver does not take control, informing the safety countermeasures up front made participants feel cared for and understood by the vehicle. They thought the countermeasures would do good for their safety so it was fine to have such a function to limit speed. But if the

speed became too slow than expected, they would switch back to Piloted mode if it could make the car go faster, or want an option to stop this countermeasure.

SUMMARY

Several design decisions were made in preparation for the first cycle of iteration based on the test findings as well as feedback from the Mediator members.

Things to remove	Things to keep	Things to iterate
1.Remove the blinking lights on the logo since it was not obviously visible and could cause misunderstanding.	1.Keep the idea of using tones. It should support the voice message contents. 2.Keep the possibility of choosing the car's voices, since it could make the driver feel more comfortable and create a bit more motivation to follow recommendations. 3.Keep the second expression of concept 2.	1.Make shorter voice messages. 2.Focus on iterating the rewarding feature in the upcoming design iteration.

Design iteration 1

The primary goal of this design iteration cycle was to iterate on the rewarding feature. The purpose of such a feature was to encourage drivers to follow the car's instructions. In other words, it is to persuade people to change their driving behavior. Therefore, a desk research was conducted to acquire a better understanding of how to change one's behavior. Overall, this cycle consists of desk research, design and evaluation.

DESK RESEARCH

To make a behavior happen, according to the Fogg behavior model (Fogg, B. J., 2021), the design must trigger the behavior when the person is both motivated and capable of performing it at the same moment (see figure 52).

The Fogg's behavior model was used to conduct a design opportunity analysis (see figure 53). In this cycle of iteration, there is design space to improve drivers'

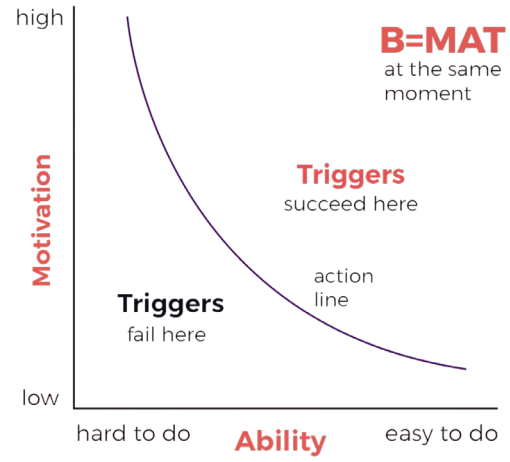


Figure52. Fogg's behaviour model.

motives to follow recommendations. Ability refers to the driver's ability to comprehend HMI signals and switch the shifter in a timely manner, both of which are design requirements. The trigger is the same as HMI signals, which have previously been investigated in the earlier concept evaluation using voice message tones and expressions. By iterating the rewarding feature, this round of interaction focused on examining design features that could boost the driver's motivation to follow the car's recommendations.

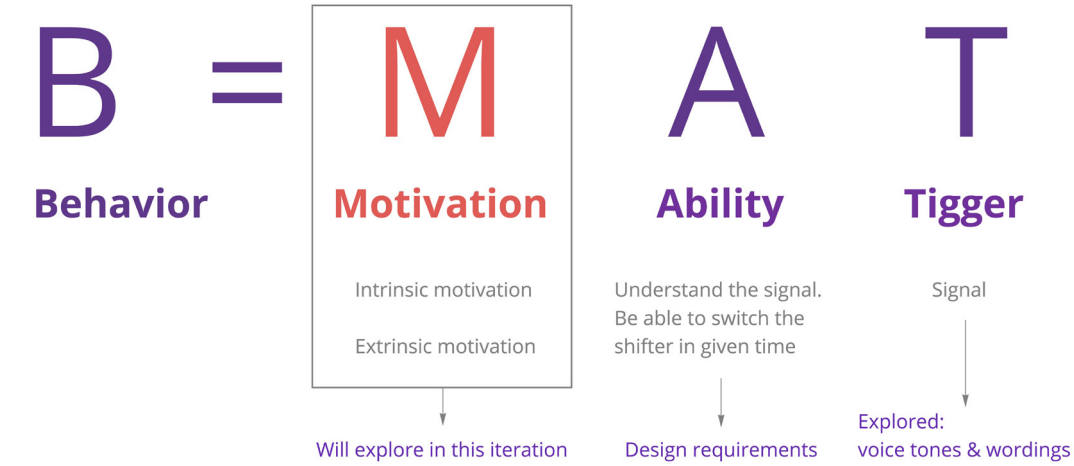


Figure53. Design opportunities are to explore design elements that could improve the driver's motivation.

Internal motivation has been found to be far more effective than external motivation in driving long-term behavior (Santos-Longhurst, A., 2019). To boost the driver's intrinsic motivation to follow recommendations, three iterated ideas were generated. The motivation model was created using a framework developed by Harvard Business School's Karim Lakhani (see figure 54). More information on the concepts is provided.

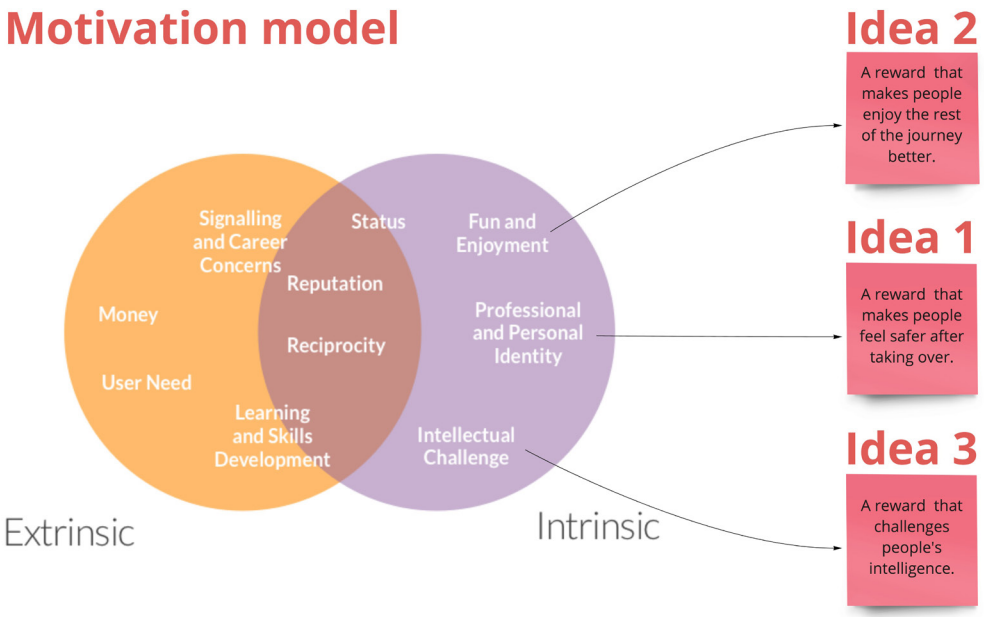


Figure54. Three iterated ideas generated to stimulate intrinsic motivation.

DESIGN

The research resulted in three iterated ideas for rewarding features. Each concept has two or three different versions.

IDEA 1: DESIGN FOR FEELING SAFER

What is it?

A rewarding system to make drivers feel safer after taking over.

How does it work?

The driver will get safety points when following a recommendation from the Mediator's system. There are three variations of this idea (see idea 1.1-1.3 in figure 55). In idea 1.2 and 1.3, when the points were collected and accumulated to a certain amount, the driver will get a medal of three different safety levels, which are "junior", "intermediate" and "master" safe driver. For an onboarding experience that matches learning curves, an additional feature can be added: the higher the level, the shorter the message of recommendation will be provided to the driver. Figure 60 on page 82 depicts the experience in detail.

Why is this concept valuable?

When a driver's safety scores rise, he or she may feel safer and more confident in their decisions, leading them to want to continue following recommendations. This assumption was tested in the evaluation with participants. It aimed to stimulate one of the intrinsic motivations - personal identity (as a safe driver).

IDEA 2: DESIGN FOR ENJOYABLE JOURNEY

Figure55. Three variations of idea 1.

What is it?

A rewarding feature to make drivers enjoy the rest of the journey better after taking over.

How does it work?

By collecting safety points, drivers can choose which in-car entertainment activities (exclusive video/music/podcast/games) to unlock and enjoy for the rest of the journey. Unlocking each activity demands a different number of points. There are two versions of this concept (see idea 2.1-2.2 in figure 56). Depending on whether people follow a recommendation from the Mediator's system or not, a particular number of points will be collected or deducted.

Why is this concept valuable?

The pleasure of the journey might be enhanced by selecting appropriate entertainment activities. It was designed to elicit one of the intrinsic motivations: enjoyment and fun.

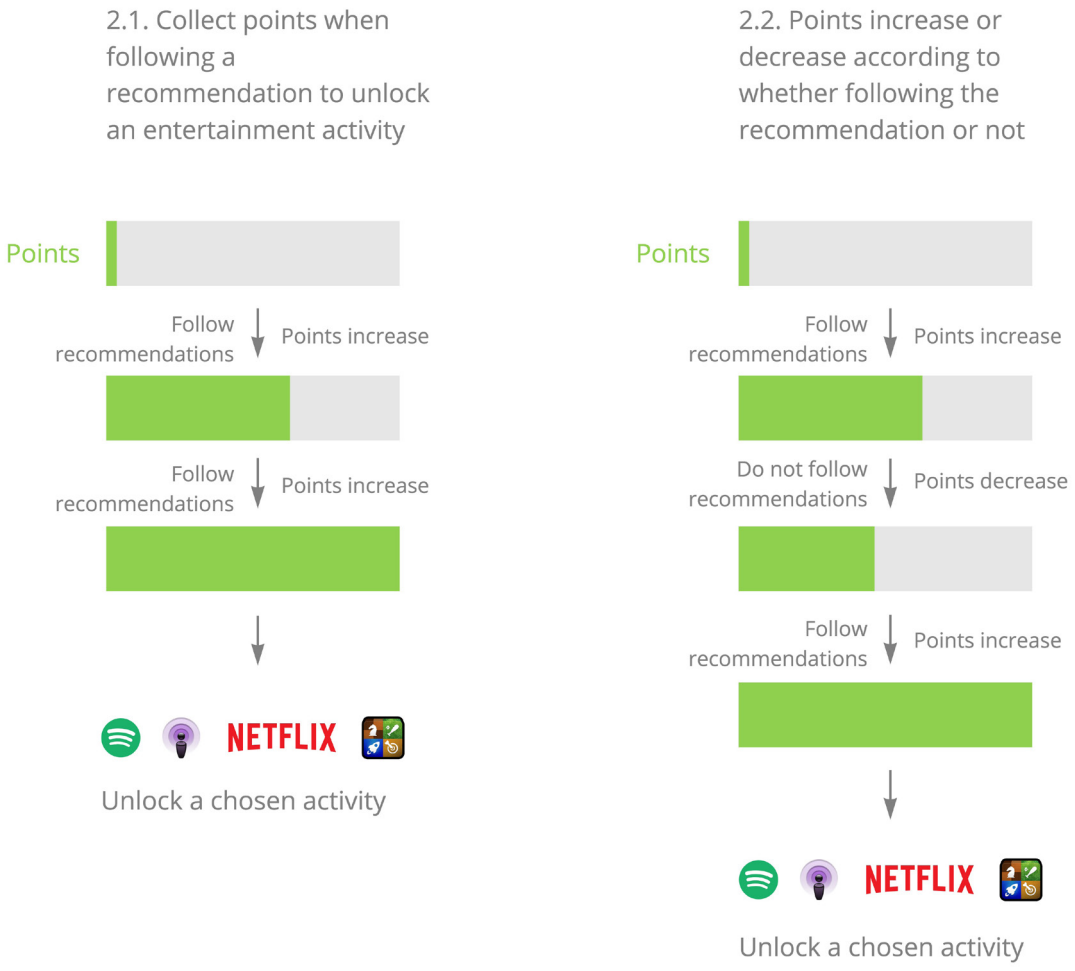


Figure56. Two variations of idea 2.

IDEA 3: DESIGN FOR INTELLECTUAL CHALLENGES

What is it?

A rewarding feature to make drivers enjoy taking intellectual challenges after taking over.

How does it work?

When the driver follows the Mediator's recommendation, he or she will be awarded with a (series of) quiz question that can be answered after the Piloted mode is turned on (or during preventive or corrective measurements). The driver can choose to compete with his or her friends by sending an invitation or asking a friend to answer on his or her behalf. The driver will receive a score for

correctly answering questions. The faster people select the correct answer, the more points they will get and the faster they will level up. The higher the level, the more complex the questions. There are two versions of this concept, where total scores (idea 3.1) or the percentage of right answers (idea 3.2) might be used to determine the level (see figure 57-58).

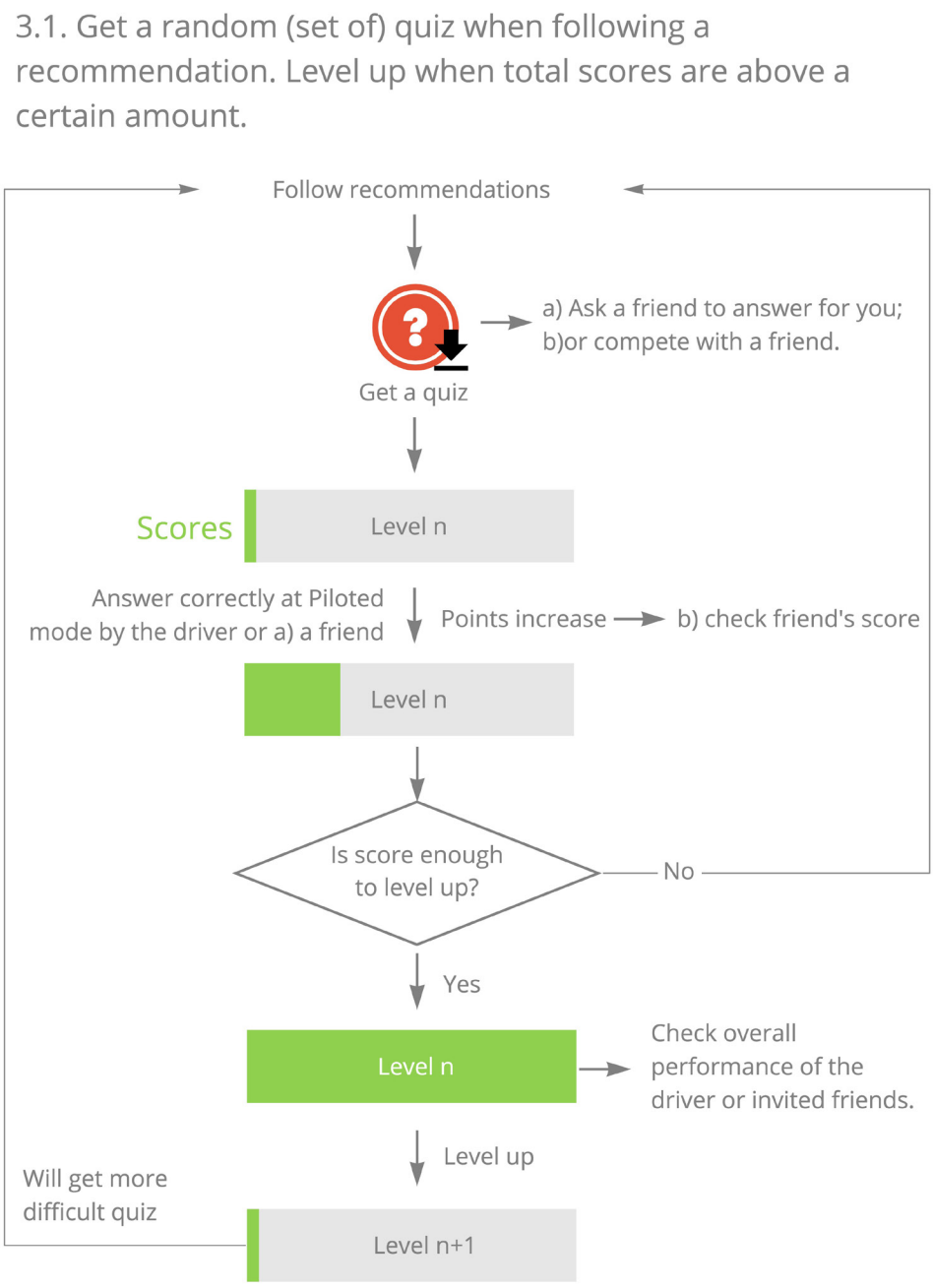


Figure57. The first variation of idea 3.

3.2. Get a (set of) quiz of interested topic when following a recommendation. Level up when the percentage of correct answers increases. Level down when the percentage of correct answers decreases.

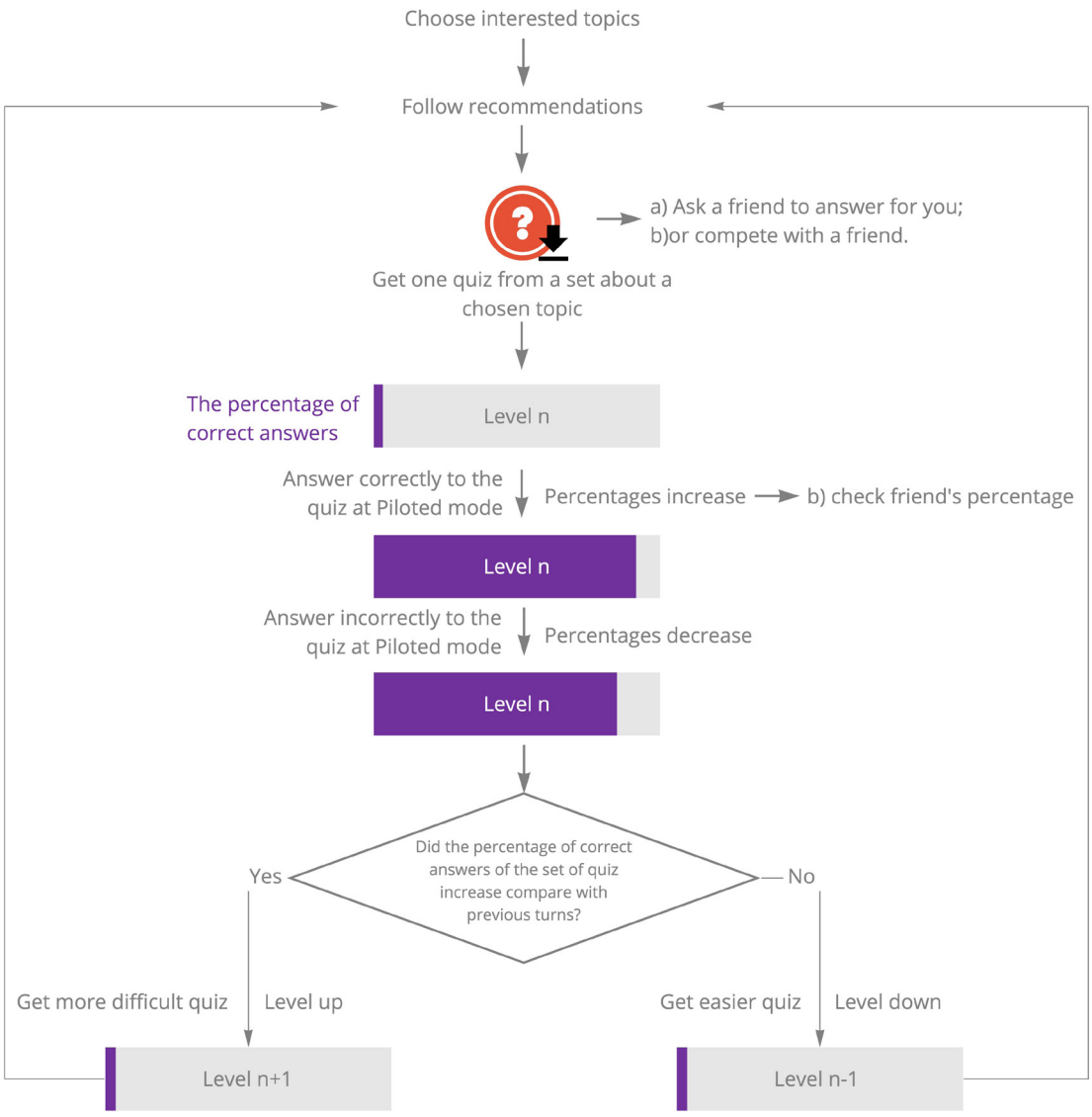


Figure58. The second variation of idea 3.

Why is this concept valuable?

This intervention may boost people's motivation to follow recommendations if they enjoy intellectual challenges. Because intellectual challenges have no limits, this intervention could be effective in the long run. Playing against some

friends could make it more challenging and interactive.

EVALUATION

Workflow:
It was unsure when seductive negotiation should be triggered during control transfer. Therefore, an initial workflow of use case 1 (see figure 59) was created through discussion with a Mediator member. It provided a framework to test ideas in this design iteration. When the driver disagrees with a forced takeover in which the shifter switches on its own, seductive negotiation is triggered. The rewarding feature will be activated whenever the driver turns to agree with the car. Appendix V shows a more thorough version of the workflow of figure 59.

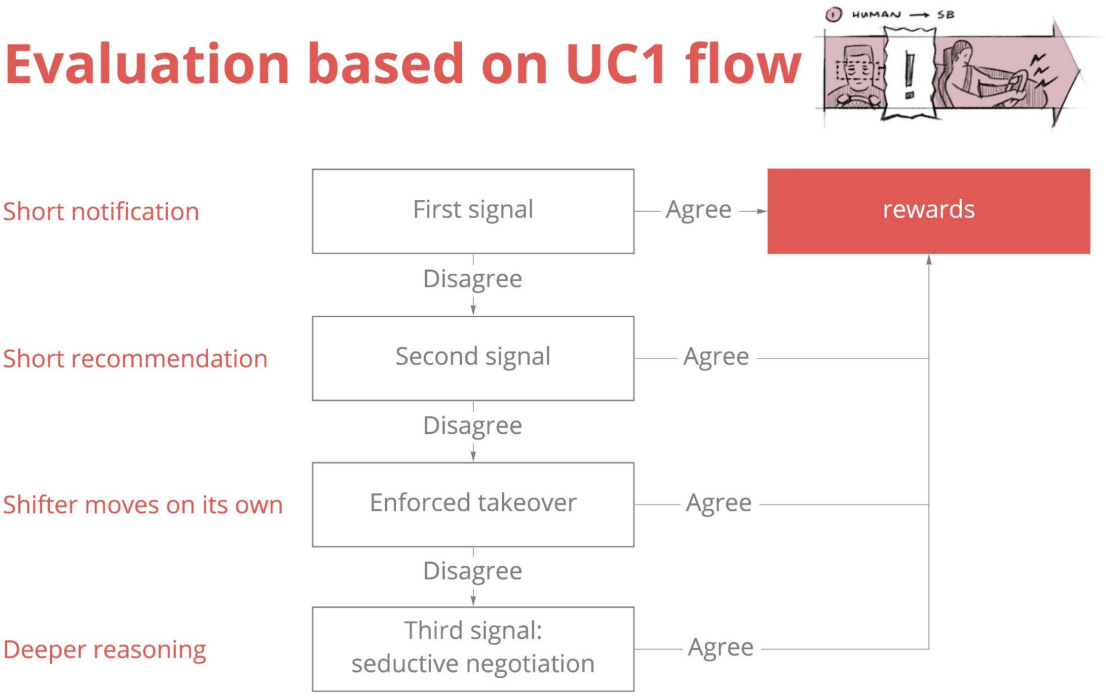


Figure 59. An initial workflow of use case 1 for testing iterated ideas.

Goal:
The purpose of this concept evaluation was to determine the pros and cons of rewarding features, as well as the user acceptance of workflow of use case 1. Experiments were conducted to determine which rewarding aspects were (weren't) helpful in getting drivers to follow recommendations and why (not).

Participants:
Three Master's students participated in the experiments after signing the

consent form. They were asked to enact drivers who care about safety but are skeptical about technology in use case 1 and use case 5a. In use case 1, the car detected human drowsiness and recommended participants to switch from manual mode to piloted mode. The participants were asked to disagree with the recommendation until a point the car triggered an enforced takeover. It aims to test participan's reaction towards the enforced takeover. The participant was asked to disagree with the enforced takeover by switching back the shifter, which would trigger seductive negotiation. After the car gave participants more explanation in a seductive negotiation, the motivation of participants to follow recommendations were investigated. In use case 5a, the car recommended the driver to take over at Drive mode in a persuasive negotiation where the motivation of participants to follow recommendations were investigated.

Methods:
In Unity, seven scenarios (or setups) were created to test a total of seven variations of three ideas in three tests. After testing each set-up of experiments, students were requested to fill out a survey. Because of unexpected technological difficulties (e.g., unable to send data from Unity to the VR headset), scenarios created in Unity were played to participants on a laptop rather than in VR. The test was completed by one participant remotely (see figure 60) and two participants in person.

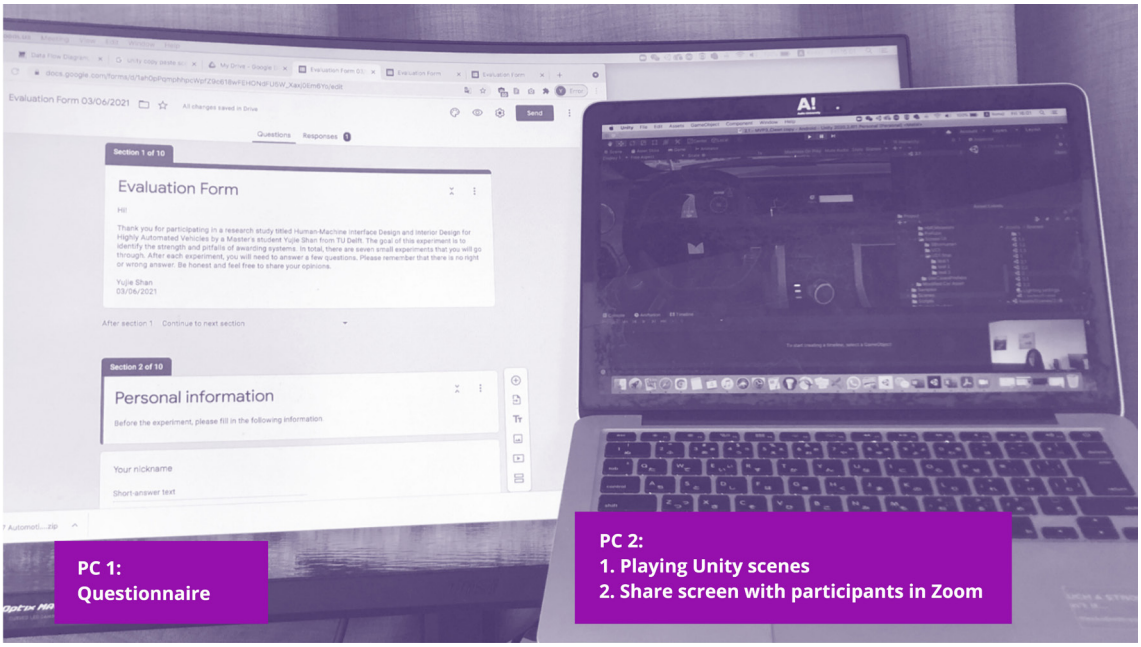
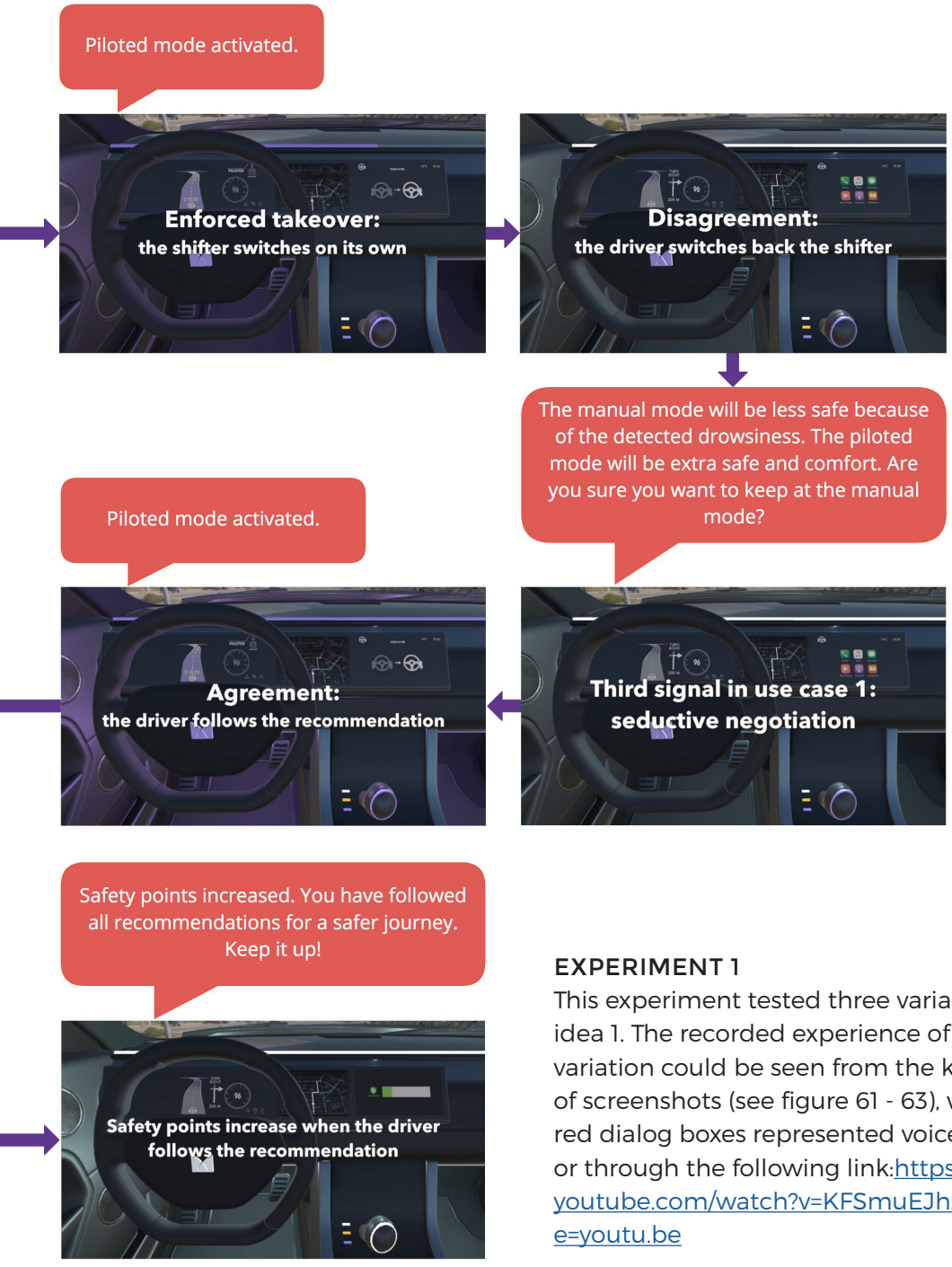


Figure 60. A set-up for remote testing.


Degraded human fitness detected. Piloted mode is available.
First signal in use case 1
The driver Ignores voice messages
Piloted mode is recommended.
Second signal in use case 1
The driver Ignores voice messages
We are approaching highway exit. Soon the current mode won't be available anymore. Manual mode is recommended.
Safety points increased.
Safety points increase when the driver follows the recommendation
The current mode won't be available in 30 seconds. Please take over with manual mode.
Manual mode activated.
The driver switches to manual mode



EXPERIMENT 1

This experiment tested three variations of idea 1. The recorded experience of each idea variation could be seen from the key frames of screenshots (see figure 61 - 63), where the red dialog boxes represented voice messages, or through the following link:https://www.youtube.com/watch?v=KFSmuEJhzzc&feature=youtu.be

Figure 61. Experience of the idea variation 1 in VR.

Degraded human fitness detected. Piloted mode is available.

Piloted mode is recommended.

We are approaching highway exit. Soon the current mode won't be available anymore. Manual mode is recommended.

Safety points increased.

The current mode won't be available in 30 seconds. Please take over with manual mode.

Manual mode activated.

Note:

The difference between this idea variation and the previous idea variation is highlighted in yellow frames.

Figure 62. Experience of the idea variation 2 in VR.

Note:

The difference between this idea variation and the previous idea variation is highlighted in yellow frames. The experience after the second signal was shortened, because it had already been tested.

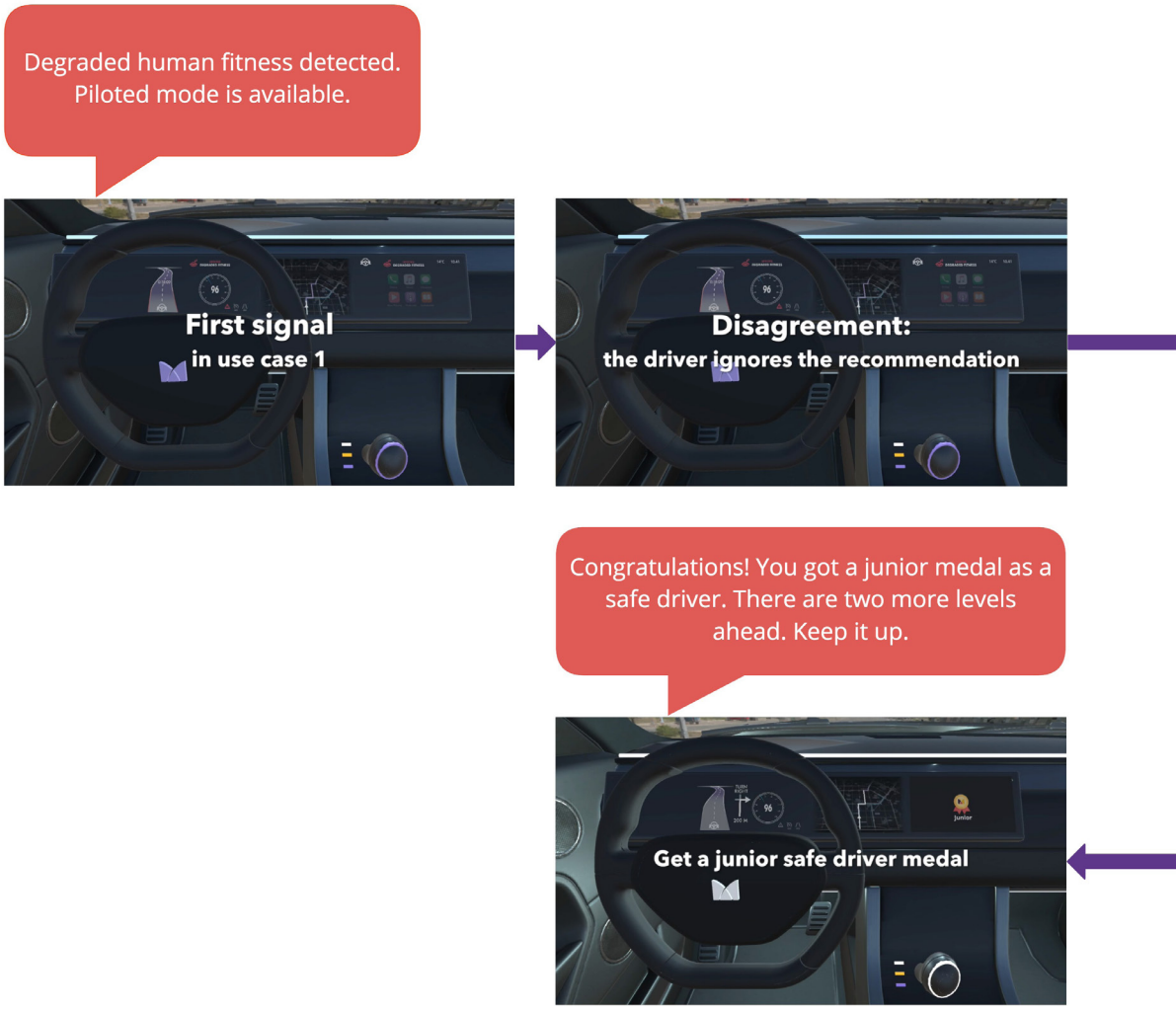
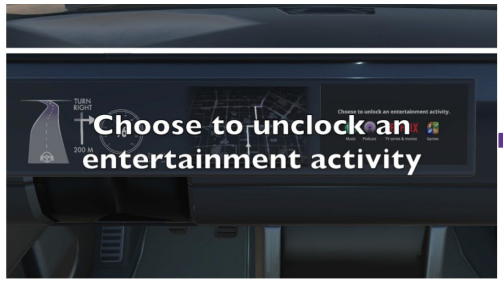
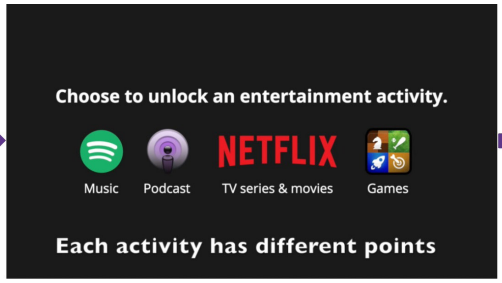


Figure63. Experience of the idea variation 3 in VR.

EXPERIMENT 2

This experiment tested two variations of idea 2. The recorded experience of each idea variation could be seen from the key frames of screenshots (see figure 64 - 65), where the red dialog boxes represented voice messages, or through the following link:https://www.youtube.com/watch?v=fEn4uWrM3rs





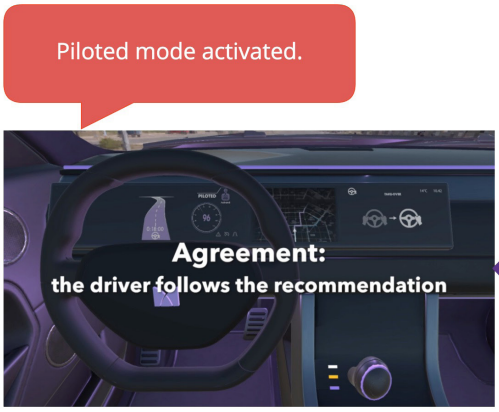
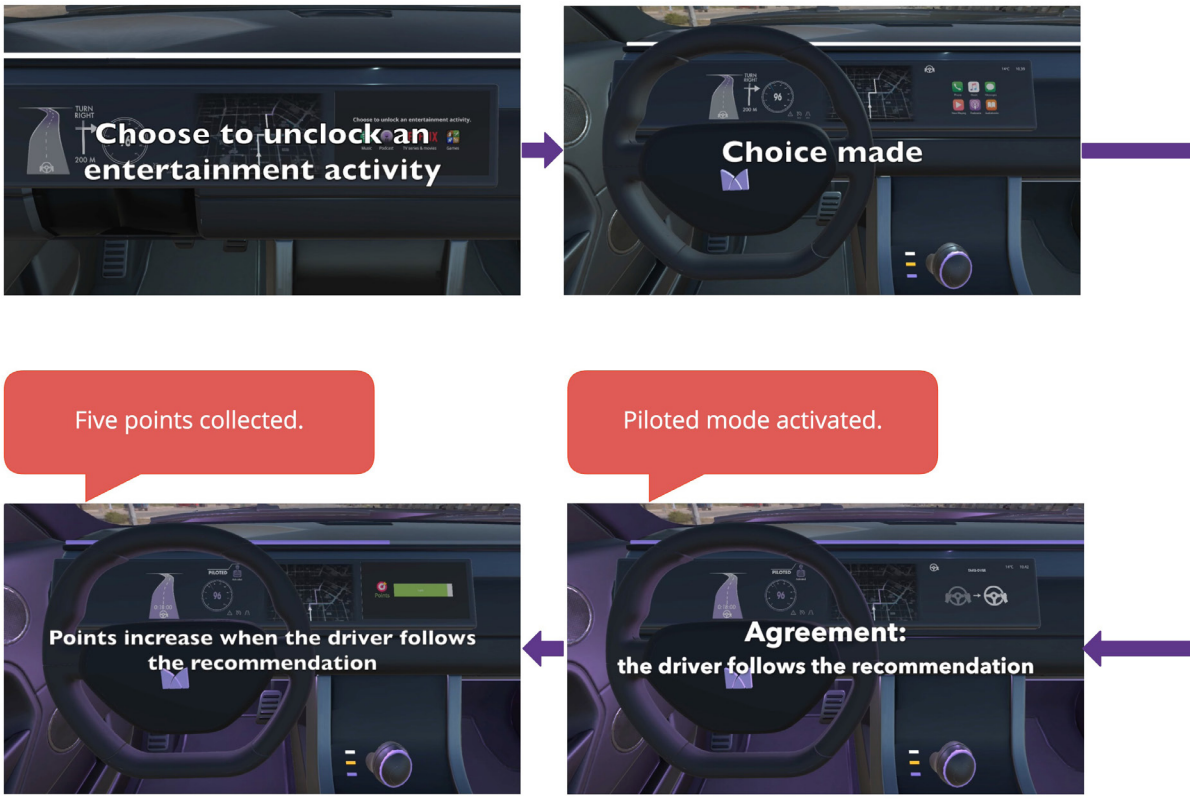


Figure 64. Experience of the idea variation 1 in VR.

Note:

The difference between this idea variation and the previous idea variation is highlighted in yellow frames. The experience after the second signal was shortened, because it had already been tested.



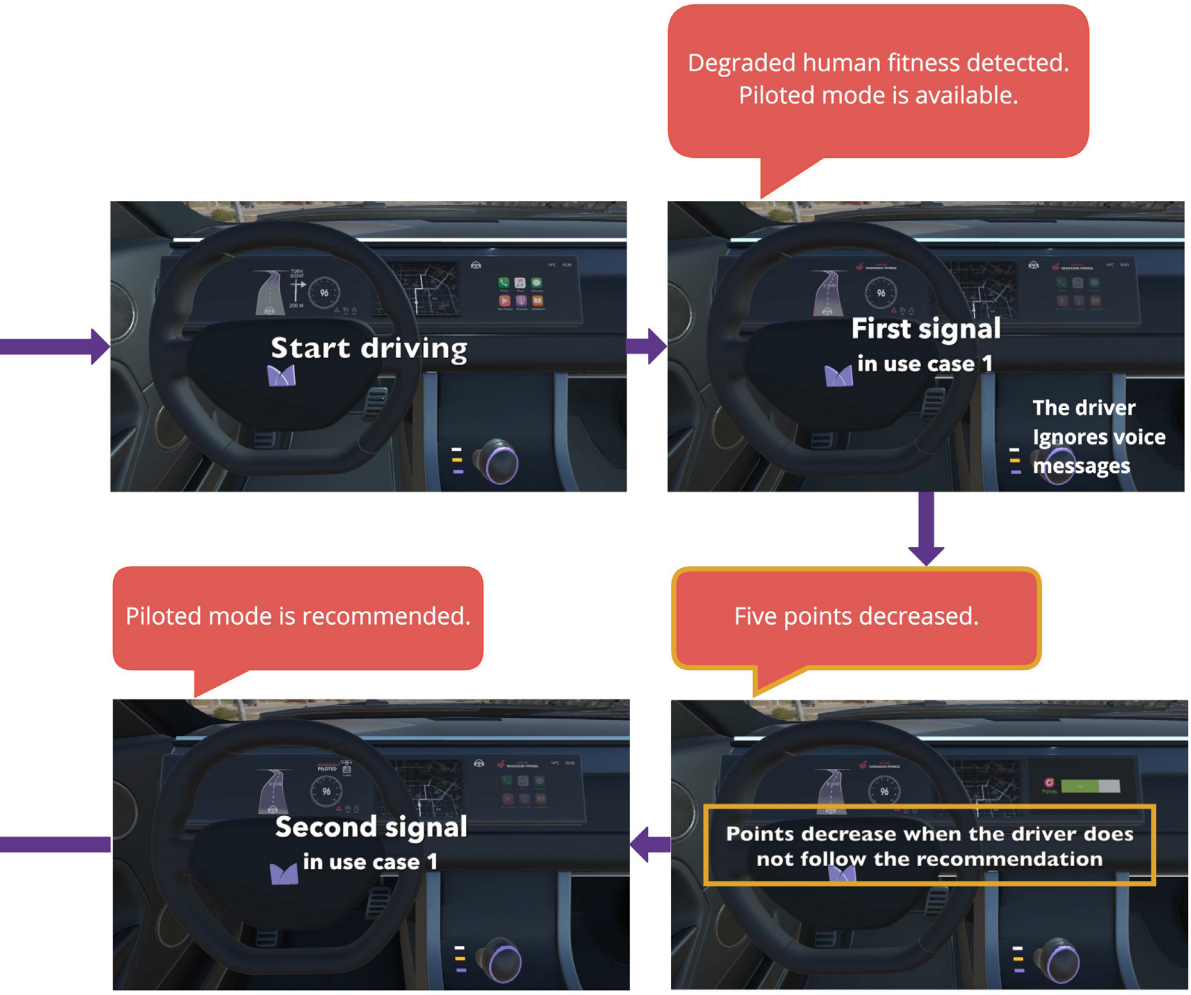


Figure65. Experience of the idea variation 2 in VR.

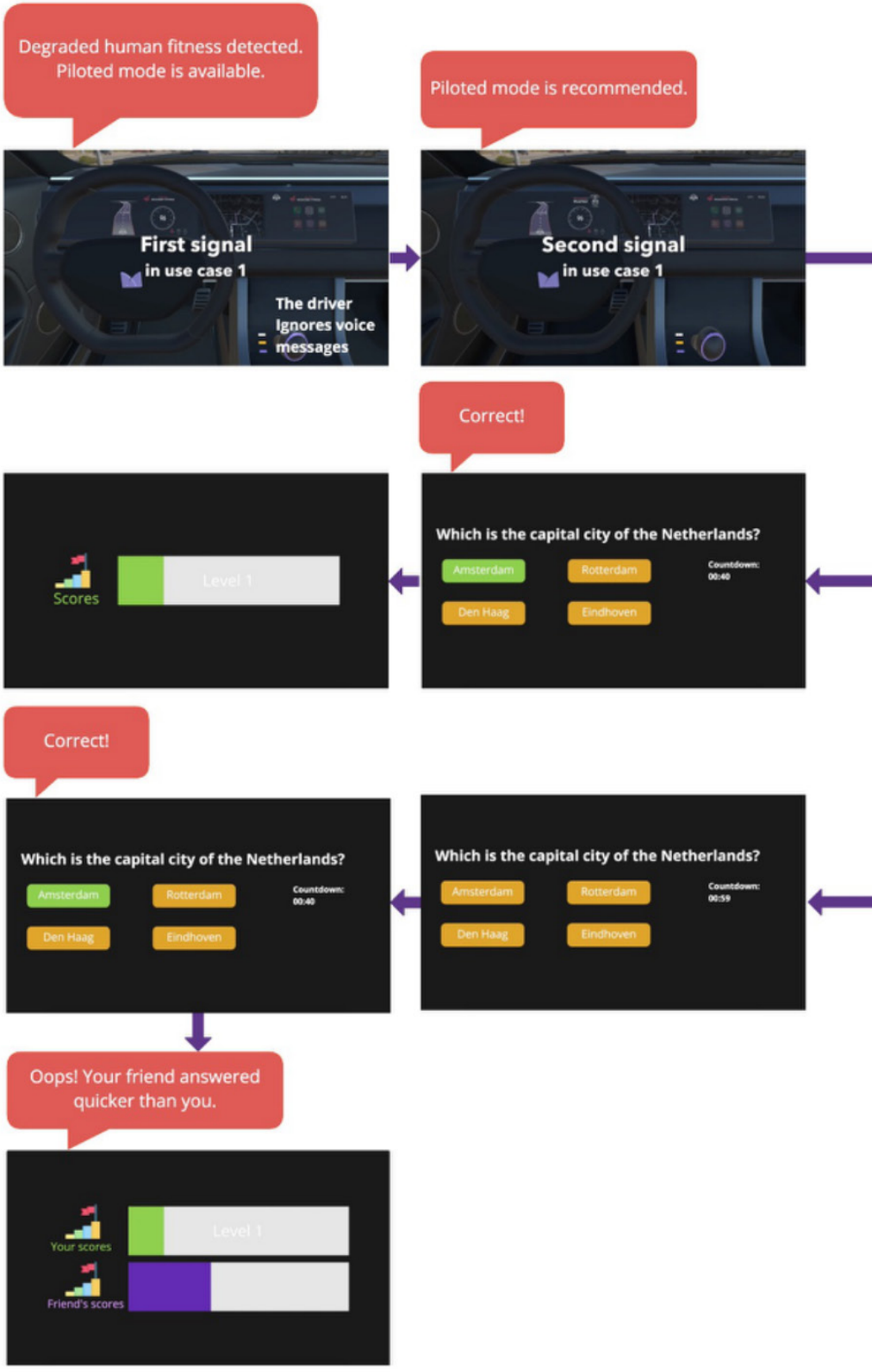
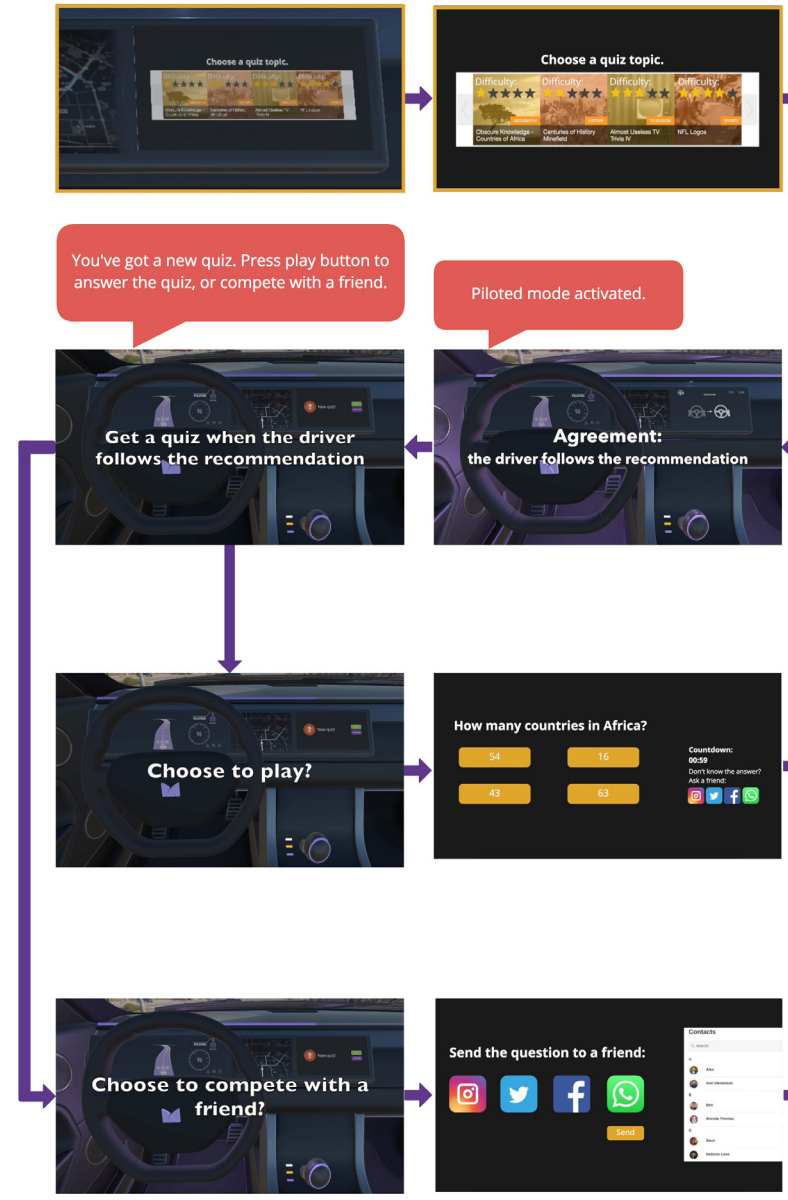

Degraded human fitness detected.
Piloted mode is available.
First signal
in use case 1
The driver
Ignores voice
messages
Piloted mode is recommended.
Second signal
in use case 1
Correct!
Which is the capital city of the Netherlands?
Amsterdam
Rotterdam
Den Haag
Eindhoven
Countdown:
00:40
Scores
Level 1
Correct!
Which is the capital city of the Netherlands?
Amsterdam
Rotterdam
Den Haag
Eindhoven
Countdown:
00:40
Which is the capital city of the Netherlands?
Amsterdam
Rotterdam
Den Haag
Eindhoven
Countdown:
00:59
Oops! Your friend answered
quicker than you.
Your scores
Friend's scores
Level 1

Figure66. Experience of the idea variation 1 in VR.

EXPERIMENT 3

This experiment tested two variations of idea 3. The recorded experience of each idea variation could be seen from the key frames of screenshots (see figure 66 - 67), where the red dialog boxes represented voice messages, or through the following link:
https://www.youtube.com/watch?v=qTdPGZmZe-8&feature=youtu.be



Note:

The difference between this idea variation and the previous idea variation is highlighted in yellow frames

Figure67. Experience of the idea variation 2 in VR.

RESULTS

The following are the summarized findings about the user experience of the use case 1 workflow, as well as the effectiveness of three rewarding ideas for motivating drivers to follow the car's recommendations.

The questions and detailed results of questionnaire could be seen through this link: https://docs.google.com/forms/u/1/d/1ah0pPqmphhpcWpfZ9c618wFEHONdFU5W_Xaxj0Em6Yo/viewanalytics

1.User experience of use case 1 workflow.
Participants (comparable to new users) were first unmotivated to follow the recommendation since they didn't understand why the system advised Piloted mode despite the fact that it claimed "degraded fitness detected." It was difficult for them to comprehend that the Piloted mode would be safer. Giving a more detailed explanation to make the association more obvious could help to motivate participants.

Regarding the enforced takeover feature (i.e. shifter switched on its own), participants felt annoyed or scared because of not being in control of the car. Thus, for new users of the Mediator system, it is recommended that the shifter should only move on its own when the driver is extremely drowsy or inform the driver beforehand of this feature. For users who trust in the Mediator system and have experience with this feature, it may not be a problem.

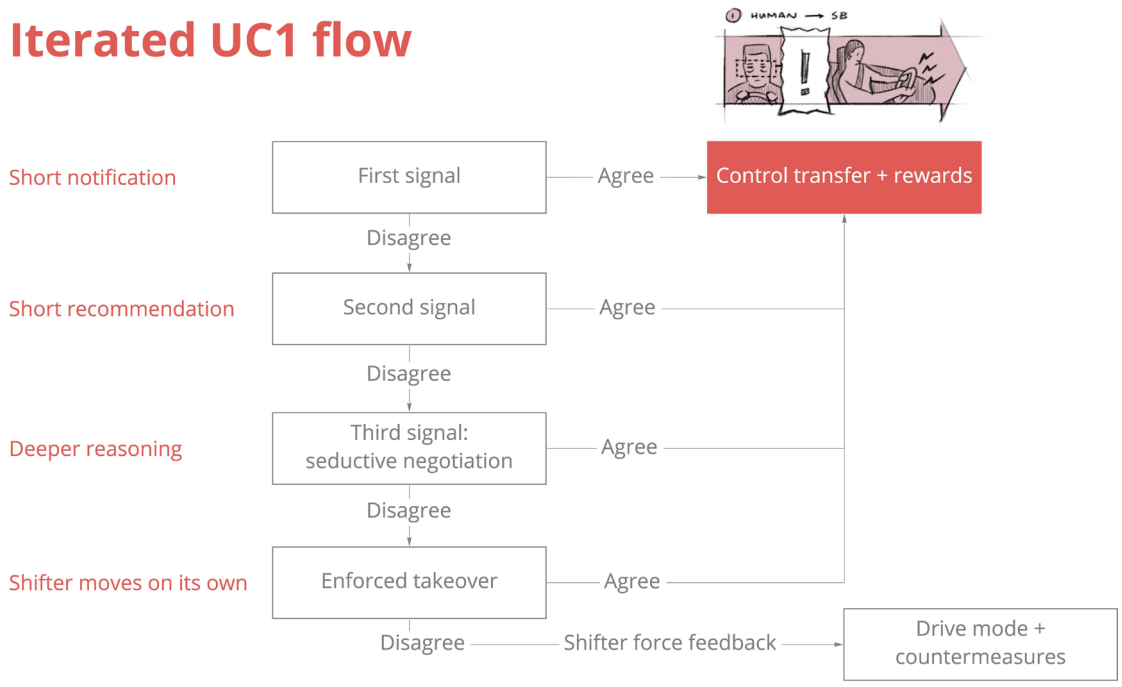


Figure 68. An iterated flow of use case 1.

After making the decision to transfer modes, and especially after exerting effort to do so, a participant was irritated by seductive negotiation. To minimize such annoyance, seductive negotiation should take place before enforced takeover. If the driver does not agree with the seductive negotiation, the vehicle may be compelled to switch from Drive to Piloted mode. After enforced takeover, if the driver still wants to return to Drive mode, it's best to use force feedback on the shifter and implement countermeasures (such as not exceeding a particular speed) without rewarding them. According to the suggestions, Figure 68 illustrated an iterated workflow.

2.Test result of idea 1.
Motivation levels of participants to follow recommendations in each variation of idea 1 could be seen in figure 69.

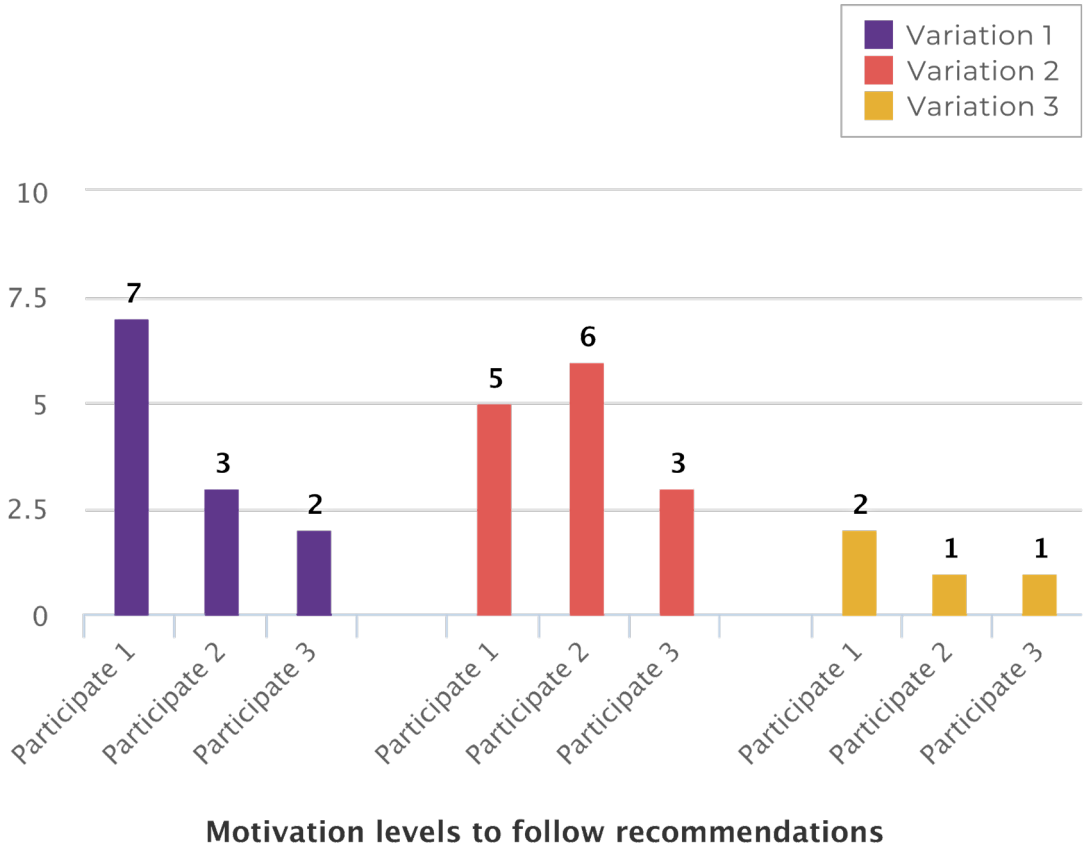


Figure 69. Participant's motivation levels of following recommendations for each variation of idea 1 (1 = not at all, 10 = very much).

Variation 1:
Only one participant said safety points made her feel good and she was very motivated to follow recommendations. Other two participants did not see the value of safety points if they could not compare the data with data from previous journeys to see personal growth. Additionally, one participant prefers different forms than points to make a clear association between safety and following advice. Another participant prefers showing her identity as a safe driver on the car's exterior (e.g. by rewarded stickers). If it influences her social identity, she will have more motivation.

Variation 2:
Having a goal or a milestone (i.e. getting a medal) made two participants more motivated to follow recommendations compared with variation 1.

Variation 3:
Reducing scores provided the least motivation to participants because it added additional stress, annoyance, and upsets. Participants felt compelled to accept recommendations, which they disliked. They can take machine advice, but they don't appreciate being rejected by it.

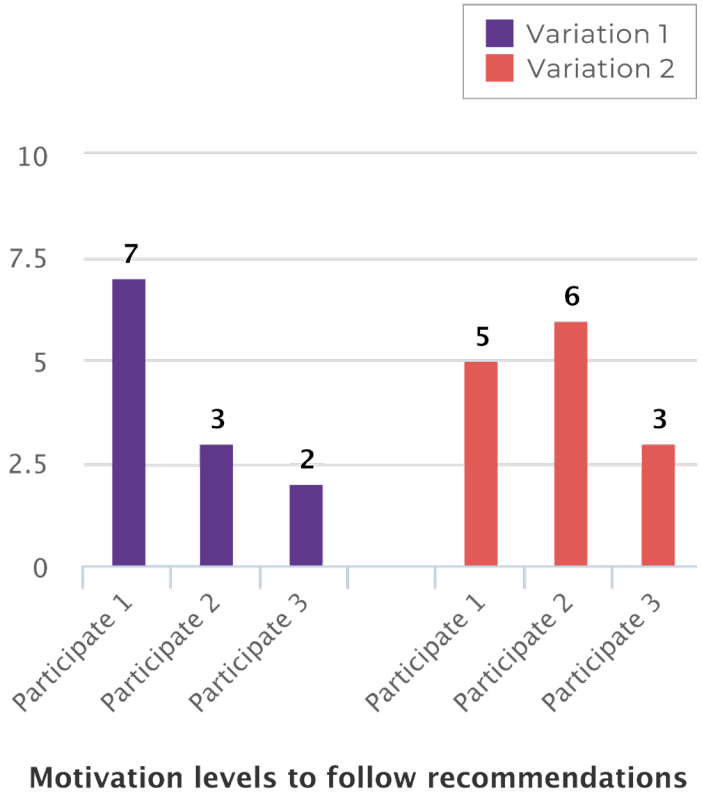


Figure70. Participant's motivation levels of following recommendations for each variation of idea 2 (1 = not at all, 10 = very much).

3.Test result of idea 2.
Motivation levels of participants to follow recommendations in each variation of idea 2 could be seen in figure 70.

Variation 1:
It would be good to offer some exclusive entertainment content or activities that people can only experience with this car. Or else, participants would prefer to just bring their own entertainment devices, bypassing the need to wait for points to accumulate. Furthermore, in the views of the participants, receiving rewards was not directly linked to the motivation of following advice. However, the safety considerations in provided takeover recommendations can effectively increase incentive.

Variation 2:
Same results as variation 3 of idea 1 regarding punishment.

4.Test result of idea 3.
Motivation levels of participants to follow recommendations in each variation of idea 3 could be seen in figure 71.

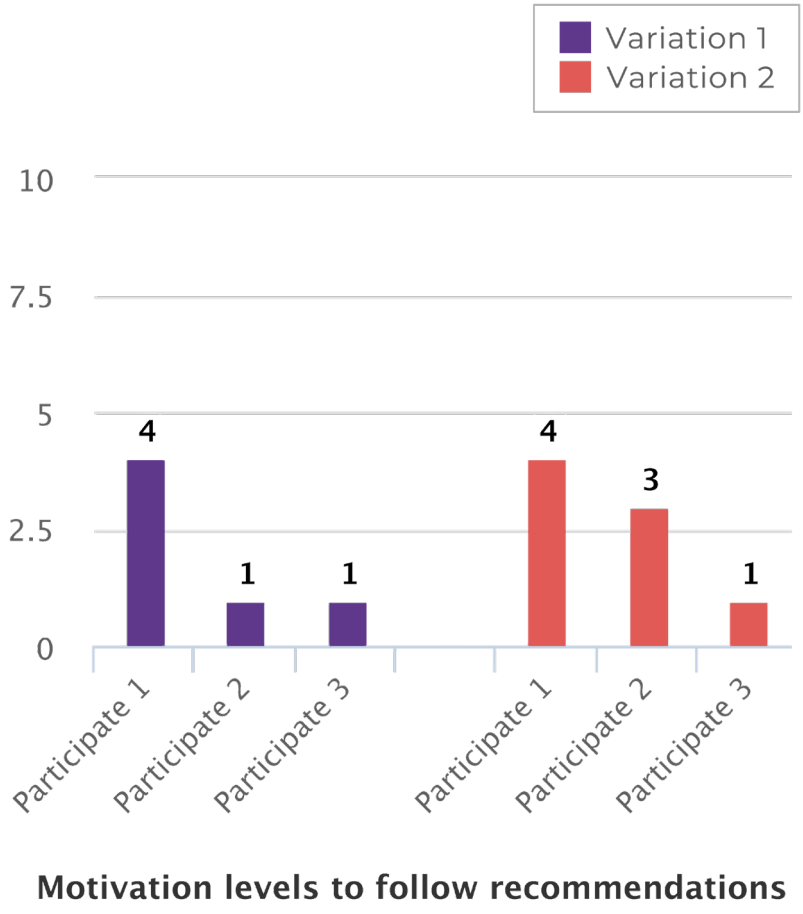


Figure71. Participant's motivation levels of following recommendations for each variation of idea 3 (1 = not at all, 10 = very much).

Variation 1:
Rather than taking a quiz, all participants opted to play different types of games according to their preferences. Despite the fact that one participant wanted to learn new things, she disliked being tested by the quiz because it made her feel stressed. Furthermore, in order to maintain sufficient incentive, the quiz should be neither too easy nor too difficult. The social aspect of the quiz was disliked by all of the participants.

Variation 2:
The ability to choose an engaging quiz topic was more appealing to participants when compared to variation 1, albeit it did not make a significant difference in persuading them to follow recommendations.

SUMMARY

The rewarding feature will have a better effect on motivating drivers to follow recommendations when:

1.The driver can make a direct association between receiving rewards and following recommendations.

2.The driver receives positive feedback.

3.The rewards interest the driver.

Overall, the second variation of idea 1 (i.e. earning safety points to earn medals) performed the best in terms of motivating participants to follow recommendations among the three ideas. A persuasive explanation for why a taking over request was made, on the other hand, may be more motivating for participants. As a result, it is recommended that the negotiation process include enough time set out for explaining the reasons, if possible.

As a conclusion, a rewarding feature should play an additional role and persuasive reasoning in voice messages should play a main role when motivating drivers to follow recommendations.

5.Expert review

Three recommendations were offered during the presentation of the above findings to members of the Mediator consortium, which impacted the next design iteration and design space.

a)To validate ideas, a larger number of participants from Europe was required. Men and women with varying levels of driving experience should be included in the group.

b)More direct rewards should be given to drivers such as a parking system that allows safer drivers to park closer to the destination in the city center.

c)Through discussion, a framework that integrated the negotiation ritual into the control transfer flow was developed (see figure 72). It was noted that it was not feasible for the Mediator project to implement personalisation features at the moment, implying that the negotiation experience would be the same for all drivers, no matter how much experience they had with the Mediator system. However, negotiation may be more appropriate and pleasant if the user's learning curves were taken into account, according to past experiments. This was further discussed in the last chapter as a recommendation.

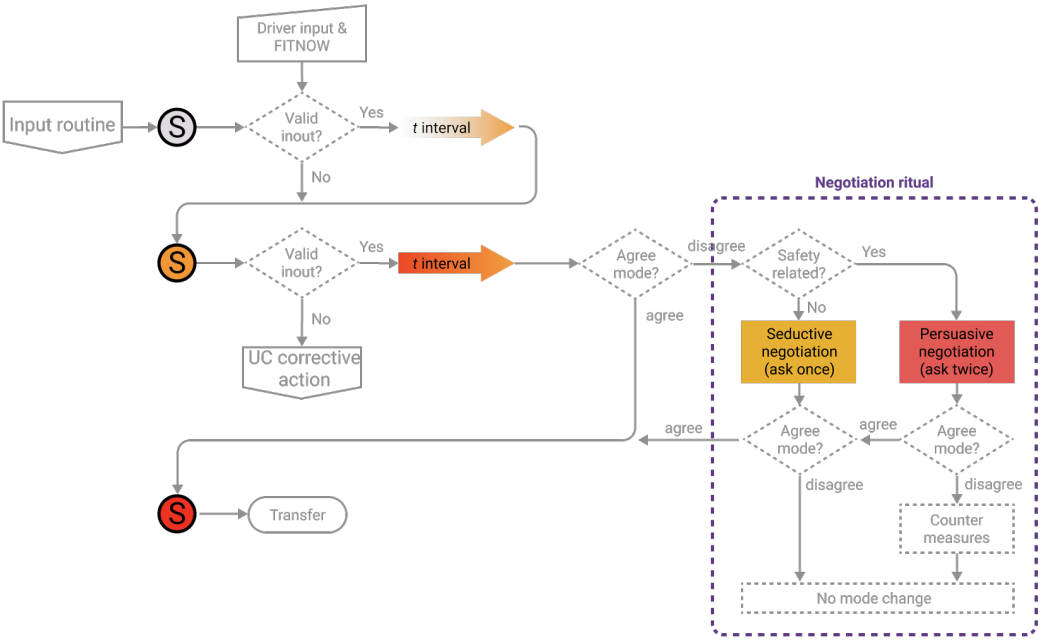


Figure 72. A framework of Mediator control transfer flow integrated with negotiation rituals.

Design iteration 2

The goal of this design iteration cycle was to iterate on the rewarding feature generated in the previous expert review. This cycle consists of design and evaluation.

Design

What is it?

A parking system that rewards safer drivers by allowing them to park closer to city center destinations. Safe drivers were defined as those who followed the Mediator system's recommendations during control transfer.

How does it work?

During the journey, the driver will get ratings after each recommendation from the car. The rating indicates the frequency of the driver listening to recommendations. It determines the driver's safety level from A to C, from the safest to the least. The ratings are displayed on the dashboard screen. There are two variations of this idea:

1)Variation 1: Parking restriction
The driver is only allowed to park in defined areas that correspond to their safety levels. When reaching the destination, a parking spot will be

suggested. Parking in an area that is not designated will result in a fine.

2)Variation 2: Parking benefits
According to the driver's safety levels at the time of departure, he or she can reserve a parking spot in the designated area. Parking at any other areas was allowed but no reservation can be made. The safety level at the end of the journey will have an impact on the parking benefits in the next journey.

Why is this concept valuable?

For most urban drivers, the reward is more direct and relevant, compared with ideas in the previous iteration. Thus, it was believed to be able to create stronger motivation to follow recommendations. In the evaluation, his hypothesis was put to the test.

EVALUATION

Goal:
validate the ideas of parking features as a motivating element to encourage drivers to follow the car's recommendations.

Participants:
12 people participated in the evaluation. They cover a diverse group as shown in figure 73. As suggested from the previous expert review, more european participants and people who have more driving experience were recruited to the evaluation. Furthermore, half of the participants consider themselves to be safety-oriented drivers, whereas the remaining quarter consider themselves to be autonomy-oriented drivers.

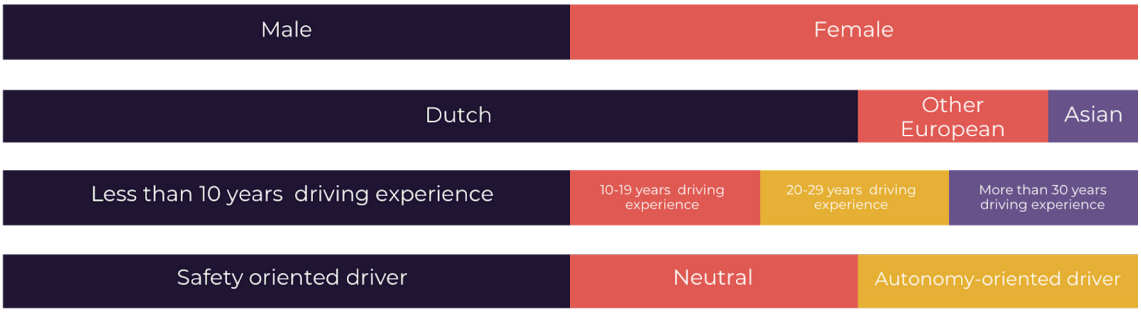


Figure 73. A diverse group of participants participated in the evaluation.

Methods:
In Unity, two scenarios were constructed to evaluate the iterated ideas in two separate tests. Each scenario features three branches that lead to distinct ends depending on the driver's choices. Each scenario covers use cases 1 (seductive negotiation) and 5 (persuasive negotiation). In this way, participants were able to choose when to take over on their own will. In addition, the prototype used shorter voice messages compared with previous designs.

Two experiments were conducted in which participants were invited to take over anytime they were motivated to do so based on the car's recommendations. Before the experiment, participants signed a consent form. After each experiment, they were asked to fill out a questionnaire with questions. Figure 74 shows the set-up of the devices for the test.

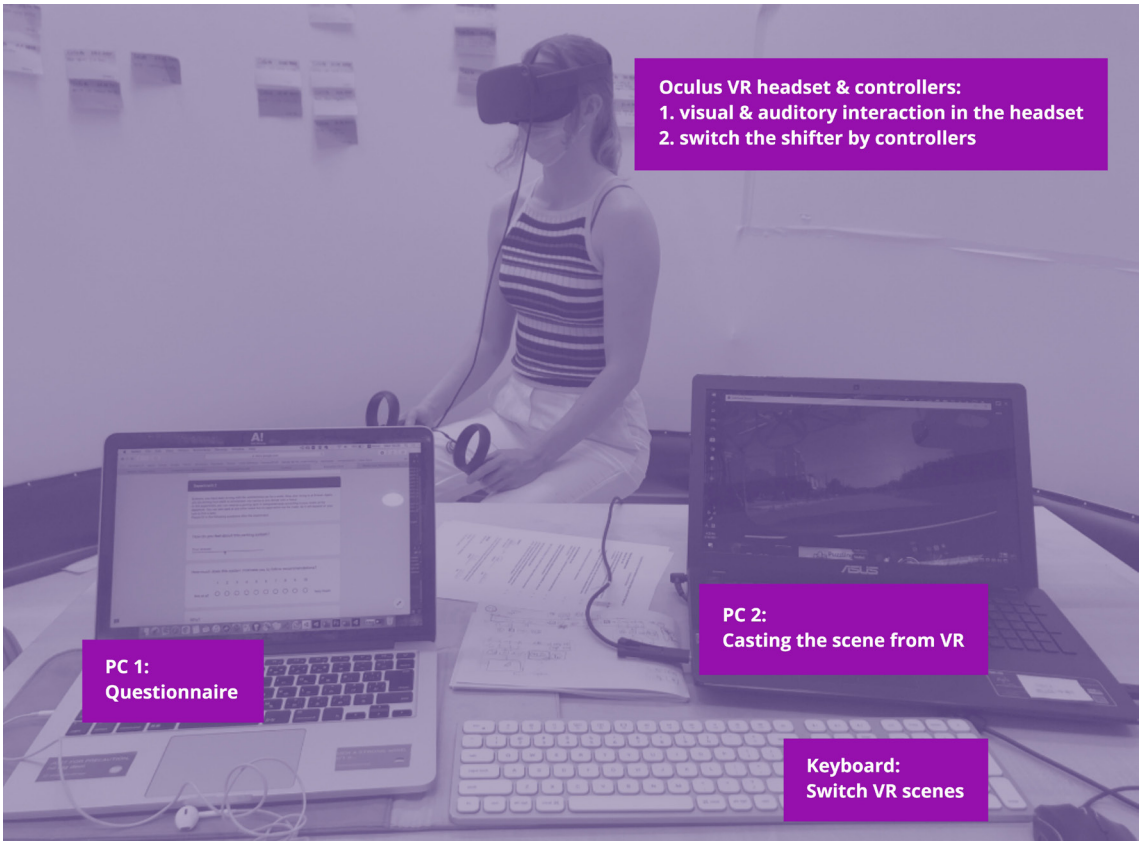
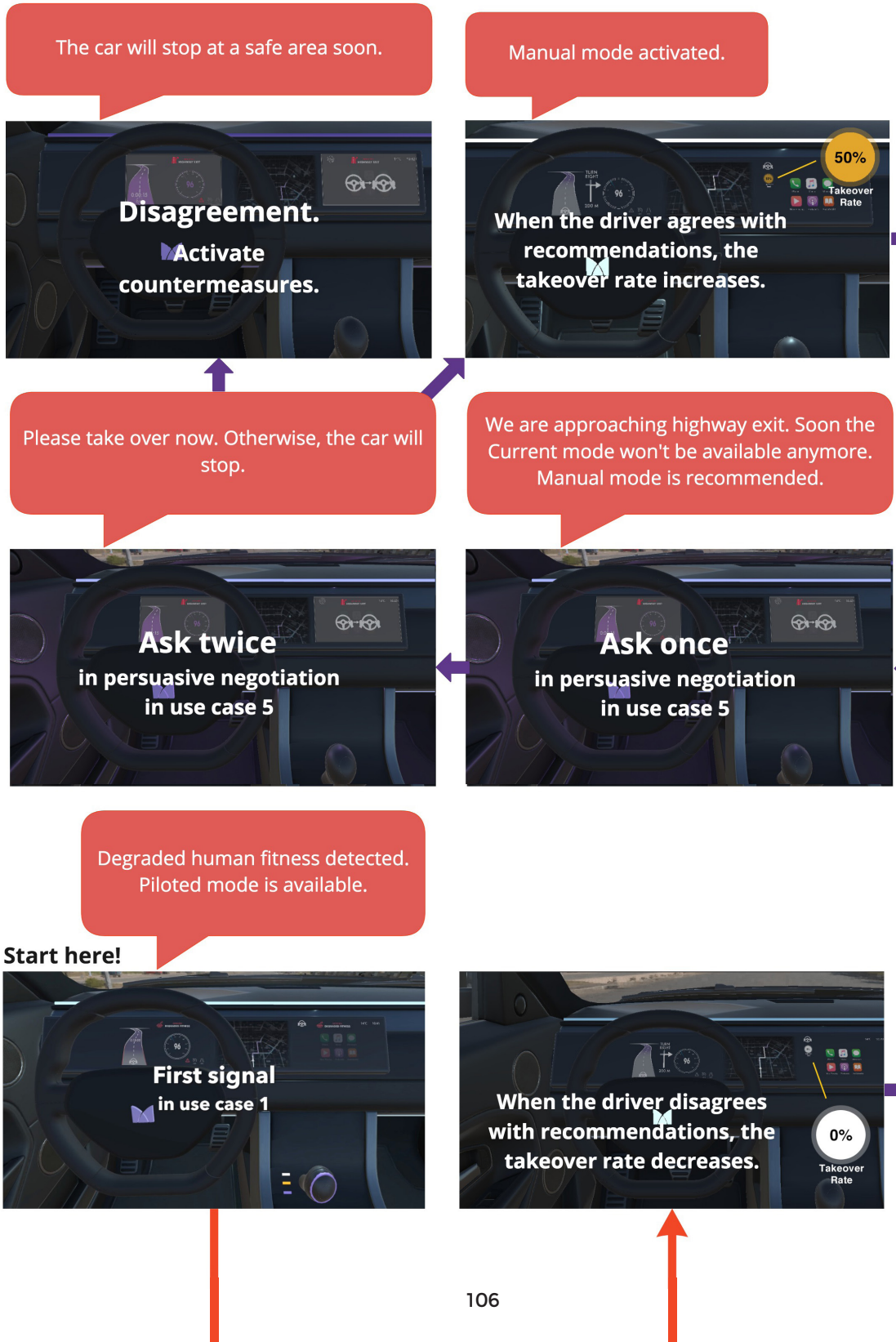


Figure 74. Test set-up.

EXPERIMENT 1 & 2

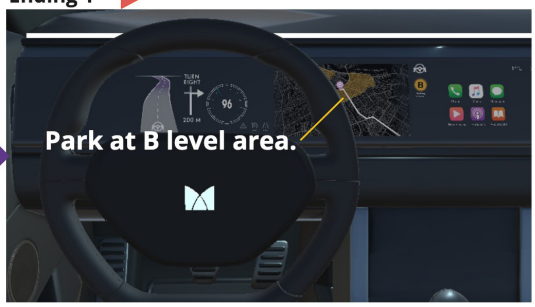
Experiment 1 tested the first idea variation, whereas experiment 2 tested the second variation. The experience of each experiment could be seen from the screenshots in figure 75 & 76 respectively, where the red dialog boxes represented voice messages. The differences between two variations are marked in yellow in figure 76. Red arrows indicate that the continuous journey is on the next page.

Figure 75. Experience of the idea variation 1 in VR, with three types of endings depending on participant's choices.



Approaching destination. You are qualified to park around the city center.

Ending 1



Manual mode is recommended.

Approaching highway exit.

Approaching destination. You are qualified to park outside the city center.

Ending 2

Figure 75. Experience of the idea variation 1 in VR, with three types of endings depending on participant's choices (continue).

Piloted mode activated.

Approaching highway exit.

Manual mode is recommended.

Approaching destination. You are qualified to park at the city center.

Ending 3

Note:

The difference between this idea variation and the previous idea variation is highlighted in yellow frames

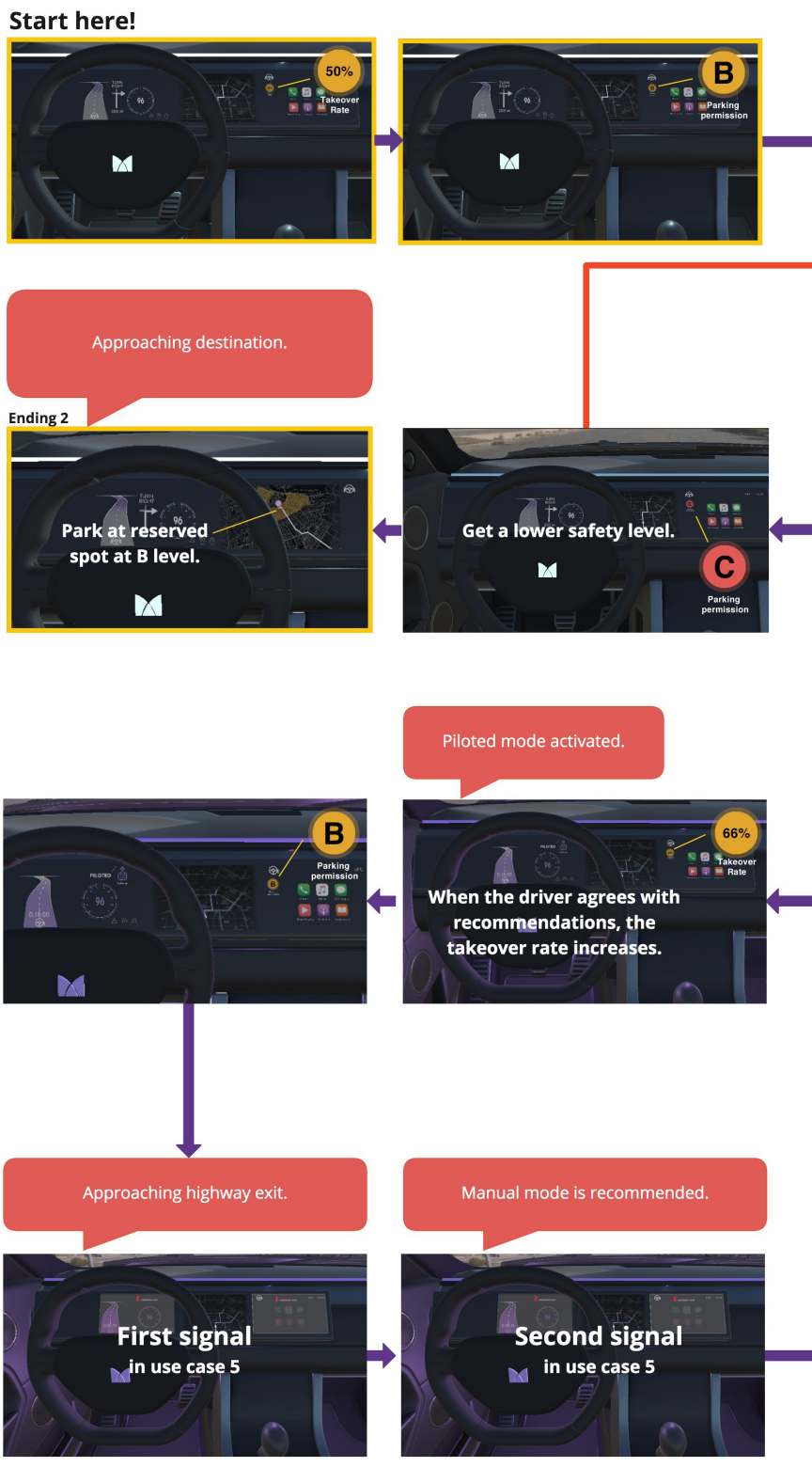


Figure 76. Experience of the idea variation 2 in VR.

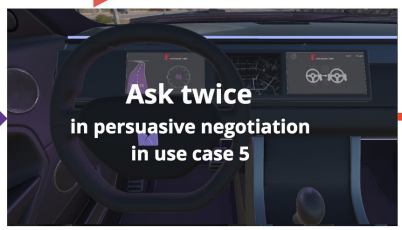
Choose to reserve a parking spot around center area at B level.

Degraded human fitness detected. Piloted mode is available.

Piloted mode is recommended.

Manual mode will be less safe because of the detected drowsiness. The piloted mode will be extra safe and comfort. Are you sure you want to keep at the Manual mode?

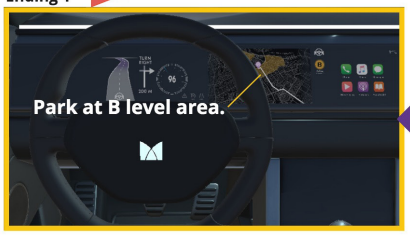
Please take over now. Otherwise, the car will stop.



We are approaching highway exit. Soon the Current mode won't be available anymore. Manual mode is recommended.

Approaching destination.

Ending 1

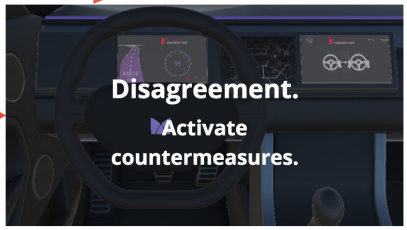


Approaching highway exit.

Manual mode is recommended.

Manual mode activated.

The car will stop at a safe area soon.



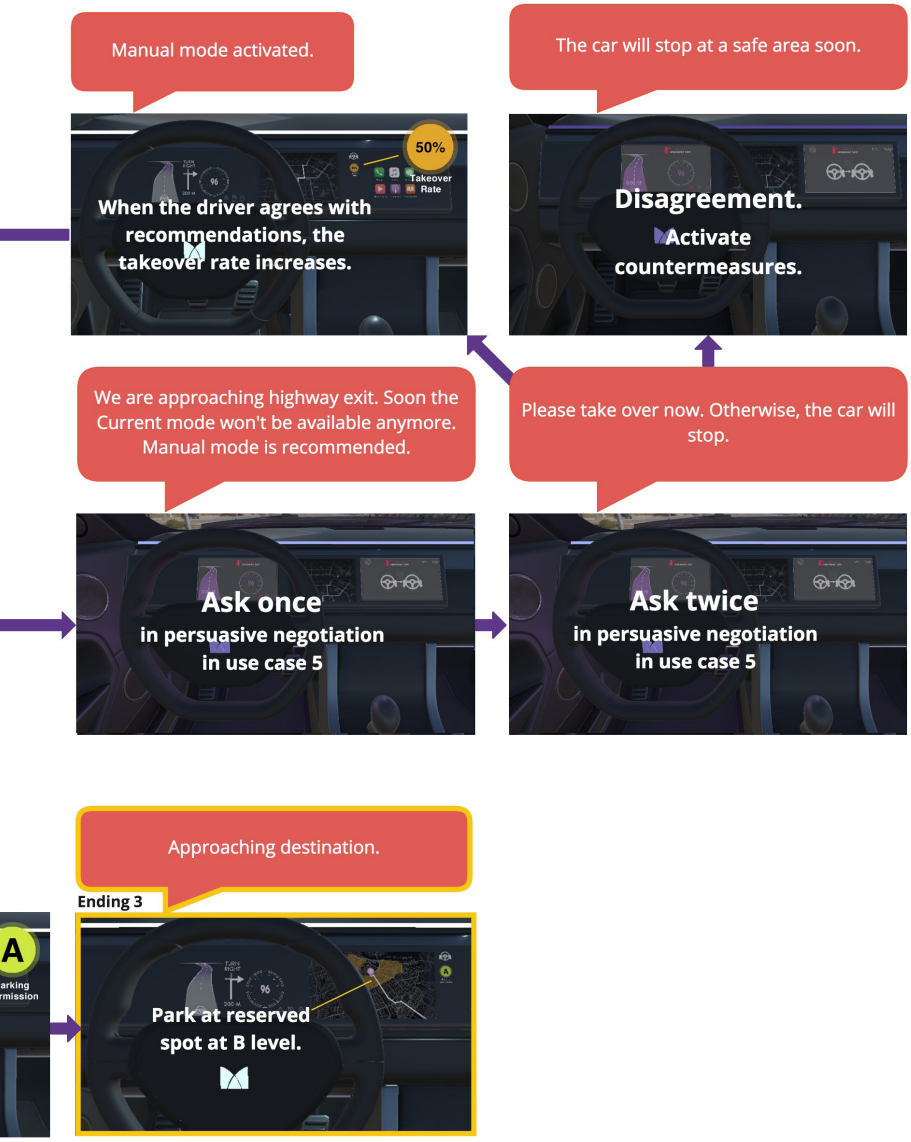


Figure 76. Experience of the idea variation 2 in VR (continue).

RESULTS

The second idea variation was preferred by the majority of participants over the first because they felt more rewarded in the second experiment and more restricted, forced, and punished in the first, especially for autonomy-oriented drivers. Therefore, the second idea variation provided slightly higher motivation to follow recommendations and slightly higher user values to participants (see figure 77 - 78). User value is the value that is satisfied when a user interacts with a product or service (Park, J., & Han, S. H., 2013)). It was considered that the higher the user value, the higher the user acceptance.

The rewarding feeling in the second variation indeed showed its positive effect on motivating participants to follow recommendations. However, some participants mentioned that the most effective motivating factors were voice messages, as well as the anticipation that taking over can bring more comfort. The reason was that the voice messages made them understand why taking over, which is more persuasive and directly linked to the driving behaviour compared with the parking benefits. It was undeniable that having rewards made people feel more pleasant through negotiation, which supplement the commanding voice messages in persuasive negotiation.

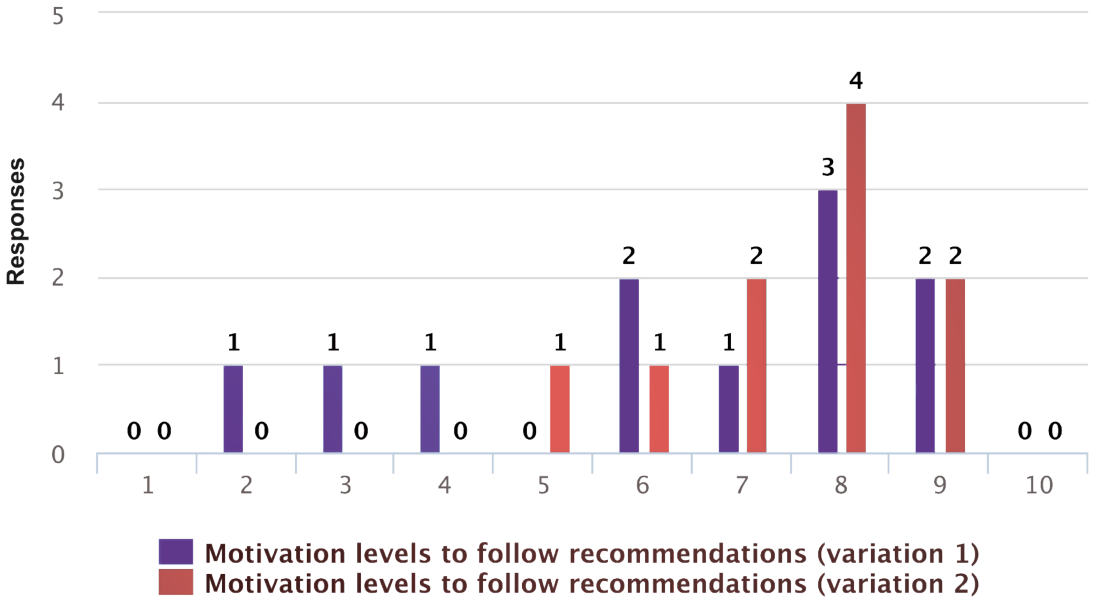


Figure 77. Participant's motivation level to follow recommendations (1 = not at all, 10 = very much).

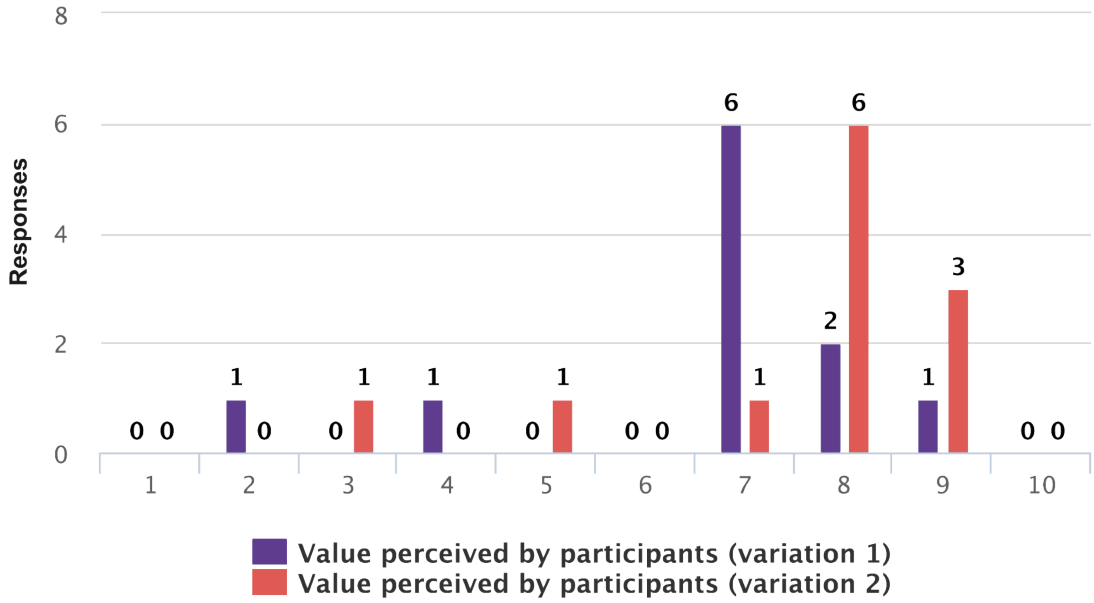


Figure 78. Value perceived by participants (1 = not at all, 10 = very much).

In addition, it was discovered that, despite having a general preference, participants can shift from safety-oriented to autonomy-oriented types depending on the situation (e.g. familiarity of the roads). As a result, it was necessary to meet both possible preferences of the same user throughout negotiations, regardless of how situations change.

The strength and weakness of each idea variation was summarized in the following chart. The questions and detailed results of questionnaire could be seen through this link: https://docs.google.com/forms/u/1/d/1KCUx6KFJyQqzZys1LT4N4As3tXUiYFQlPZojl6H5s9c/viewanalytics

Recommendations:

Idea variation 1		Idea variation 2	
Strength	Weakness	Strength	Weakness
1.Punishment could increase motivation effectively. 2.Participants liked to see that their behaviour had immediate consequences.	1.Punishment was not likable, especially for autonomy-oriented drivers and people who do not like their behaviours controlled by machines. 2.Lower user acceptance because of the parking limitation, compared with conventional cars. 3.Not able to know where to park beforehand (that could cause anxiety). 4.Not fair when the recommendation was inappropriate. 5.Not feasible if everybody follows recommendations and wants to park in the city center. 6.Not effective when the driver knew the destination well (so he or she wanted to park at a familiar place).	1.The reservation provided a sense of certainty to drivers. 2.Drivers can directly reserve a spot through the car's HMI. 3.Making the driver consider the future journey increased their motivation to follow the recommendations in this journey. 4.More pleasant because of the possibility to reserve a spot upfront and no punishment.	1.It requires the driver to think ahead for the next journey, which causes more mental effort.

Recommendations:

1 Discount as a reward

Getting a discount as a reward to park anywhere drivers want was more preferred by some participants. One Dutch participant (also a Mediator member) mentioned that this would work well in the Dutch culture, where discounts always provide consumers sufficient incentives. Furthermore, it will not leave consumers with a sense of inequity, unlike the idea variations.

2 Testing in traffic conditions

Although VR could create a relatively realistic interior simulation, participants tend to make takeover decisions according to the traffic conditions. Giving a realistic traffic condition outside the car in a virtual environment would create more trustworthy results.

3 Shorter voice messages

The voice messages should be further shortened so that it can be easily translated to other European languages, which was a requirement from the Mediator consortium.

SUMMARY

The experiment showed that the most persuasive motivating elements for following recommendations were the reasoning of the recommendations (in voice messages). The parking benefits could increase slightly more motivation to safety-oriented drivers and a lot more motivation for autonomy-oriented drivers, who regard the reward as a kind of compensation for their loss of autonomy. Rewards could also increase pleasant feelings in negotiation. Therefore, the combination of these two elements (voice messages & rewards) could maximas user acceptance for most drivers, even when they change preferences (between safety and autonomy) in different situations. Furthermore, recommendations were used to create the final concept design and improve the final evaluation.

Final concept & evaluation

The final concept was created based on findings and recommendations from previous design iterations (see figure 30). It was validated through high fidelity prototype testing and questionnaires.

What is it?

The final concept is a negotiation ritual consisting of voice messages and rewarding features to motivate drivers following recommendations from the car.

1.Voice messages: give short explanations of recommendations in collaborative or competing styles by wording and tones. In addition, drivers could select their preferred car voices.

2.Rewarding features: the privilege of reserving an affordable parking spot anywhere a driver wishes at the time of departure directly through HMI.

How does it work?

When there is a disagreement over who should take over, the negotiation ritual of either persuasive or seductive negotiation will be activated. In the persuasive negotiation ritual, the system will give takeover requests twice by voice

messages, emphasizing the urgency and consequences with a commanding tone and wording. In the seductive negotiation ritual, the system will only ask the driver once by voice messages, emphasizing the benefit of control transfer with a friendly tone and wording. Furthermore, during the journey, the driver will get ratings after each recommendation from the car. The rating indicates the frequency of the driver listening to recommendations, displayed on the dashboard screen. Drivers will get rewards such as parking discounts when following recommendations. The higher a driver's takeover rate is, the greater the discount for parking he or she receives as a reward.

Why is this concept valuable?

Voice messages were designed to improve intrinsic motivation (i.e., feeling safe or comfortable as for most participants) to follow recommendations, whereas rewarding features were designed to increase extrinsic motivation (i.e., getting affordable parking) for a pleasant negotiation experience. These two features work together to ensure that the Mediator system is widely accepted, regardless of the situation or the type of driver.

FINAL EVALUATION

Goal:
Validate the final concept by assessing how effective it is to motivate drivers to follow recommendations and how well it meets the HMI interaction qualities, design goal, and user acceptance criteria in Mediator use case conflict (see chapter 5.1).

Participants:
As shown in figure 79, the evaluation included 22 individuals who represented a varied demography. All of the participants were European residents, however they came from various countries. The majority of them were men with less than ten years of driving experience, drive less than once a week, and have no prior experience with the Mediator system.

Methods:
High fidelity prototypes were created in Unity and Figma for the final evaluation

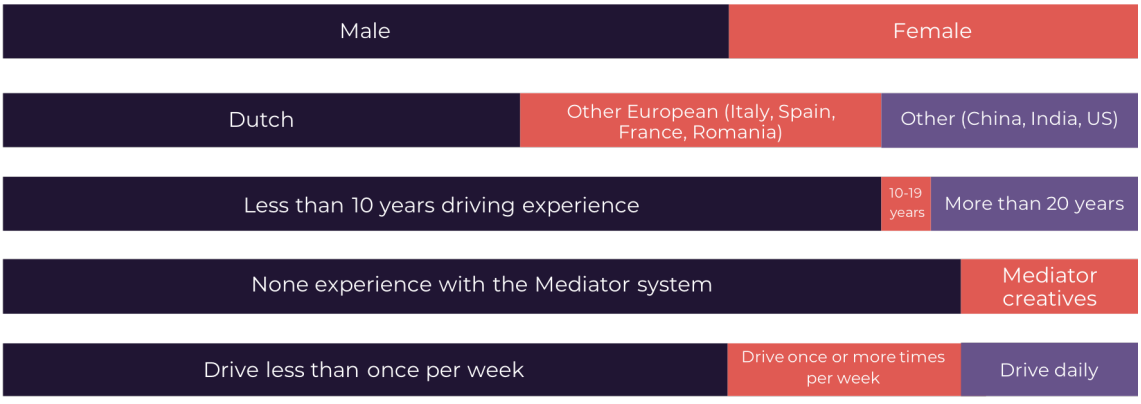


Figure 79. A diverse group of participants participated in the evaluation.

in VR. As a guide to assist in the creation of prototypes, a storyboard was created to illustrate the experience of the final concept for the evaluation (see figure 80). It covered conflict in use cases 1b, 5a & 3a. These use cases were chosen for the final evaluation since they could encompass all kinds of conflict and resolution: 1) conflict initiated by the car, 2) conflict initiated by the driver, 3) seductive negotiation, and 4) persuasive negotiation.
High fidelity visuals of the dashboard screens illustrated in the storyboard could be seen in appendix FIXME or through this Figma link: https://www.figma.com/file/rwE0uOM059hLHnAvX1OQD1/Mediator?node-id=0%3A1

The storyboard as well as the experience in the final evaluation contains six scenes from departure to parking:
1. Choosing favorite voices of the car on the (app screen) dashboard. There were four different voices to choose from during the experiment, including half female and half male. Samples of each voice type could be heard through this link: https://soundcloud.com/yujie-shan/sets/choose-cars-voices
Once a choice was made, the car would talk with that voice throughout the journey.

2. The driver could choose to reserve a parking spot with discount according to the safety level of the departure, directly through HMI on the (navigation screen) dashboard.

3. In use case 1b where the driver's phone rang that causes driver's distraction at Drive mode, a seductive negotiation ritual is activated after disagreements with recommendations of Piloted mode. Sound editing software was used to add a pause before the attractive keywords "extra comfort" and with a louder volume to those words as well as keyword "offers" to emphasize the benefit of Piloted mode. It could be heard from this link: https://soundcloud.com/yujie-shan/uc1
In prior iterations, the content of this voice message was tested in use case 1a (drowsiness) and found to be motivating since it sounded appealing. This time, it would be examined in use case 1b (distraction) to see if it was still effective.

4. Drive mode is recommended in use case 5a, where the system's reliability in Piloted mode has decreased due to changing road conditions. Persuasive negotiation ritual is activated after driver's disagreements. Takeover rate increases at any moment the driver follows recommendations.
Voice messages were processed by giving a pause before keywords "unavailable" and "now" and a louder volume to those words as well as keywords "5 seconds" and "must" to emphasize risks and the urgency in the persuasive negotiation. It could be heard from this link: https://soundcloud.com/yujie-shan/sets/persuasive-negotiation-in-uc5
Takeover rate increases at any moment the driver follows recommendations.

5. In use case 3a, the driver is no longer motivated to drive, thus he or she switches from Drive to Piloted mode. The driver experiences force feedback on the shifter, indicating Piloted mode is not recommended. Once the driver successfully switches the shifter to Piloted mode, a persuasive negotiation ritual is activated due to system unreliability,

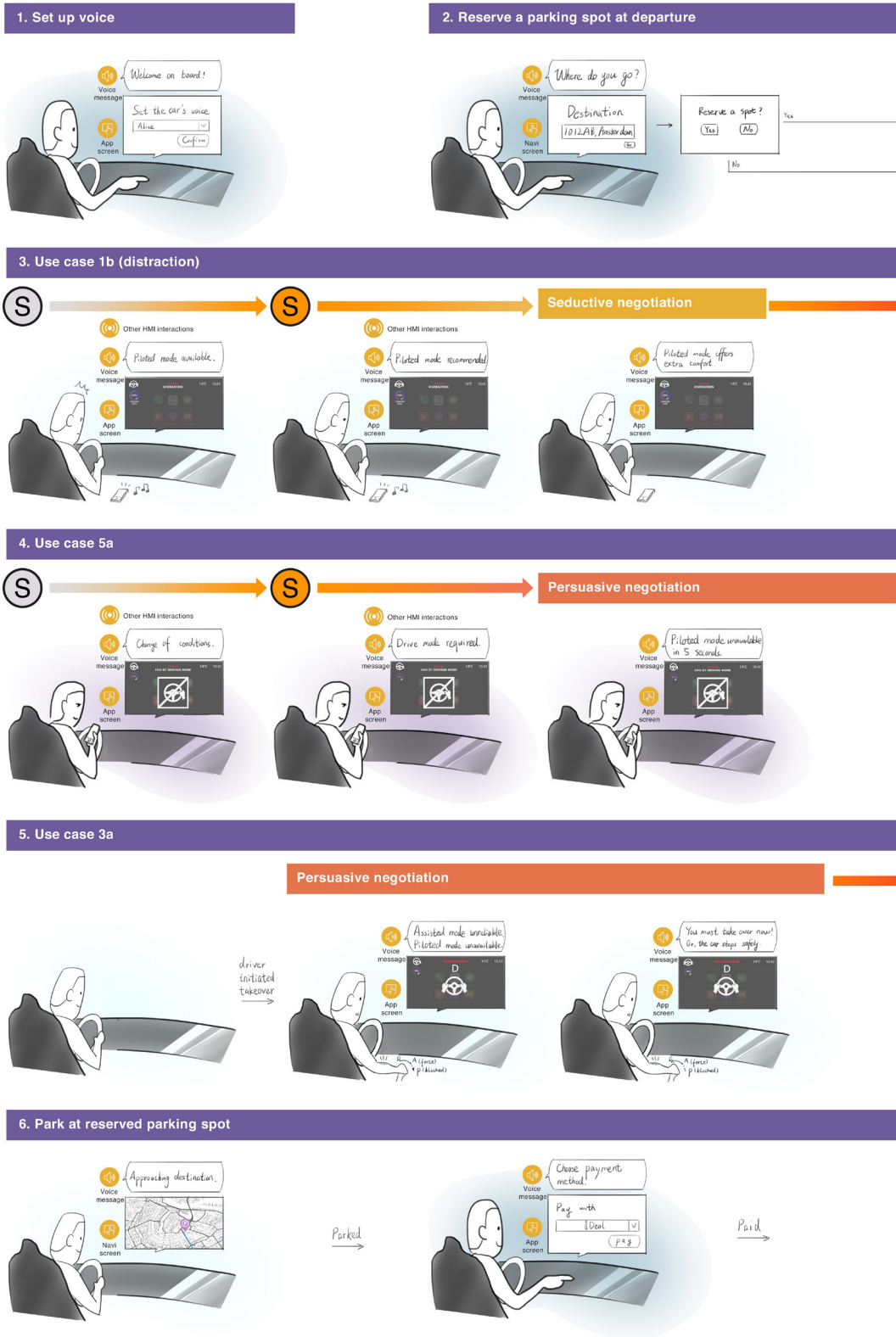
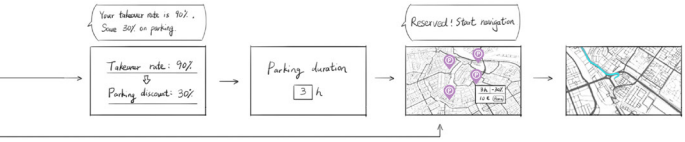
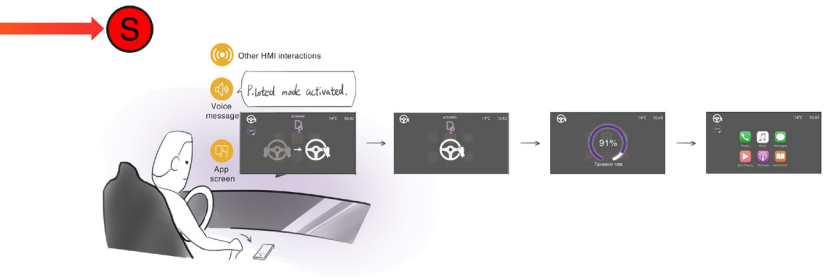
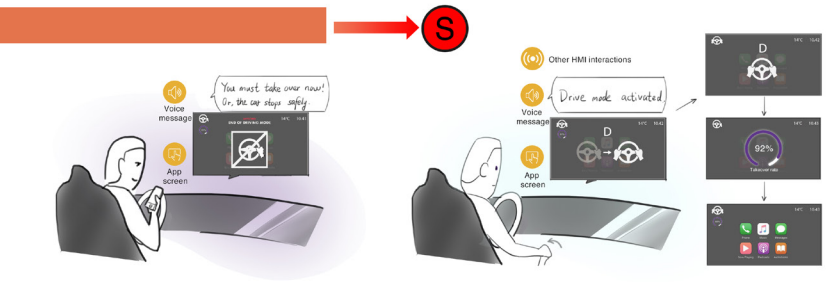
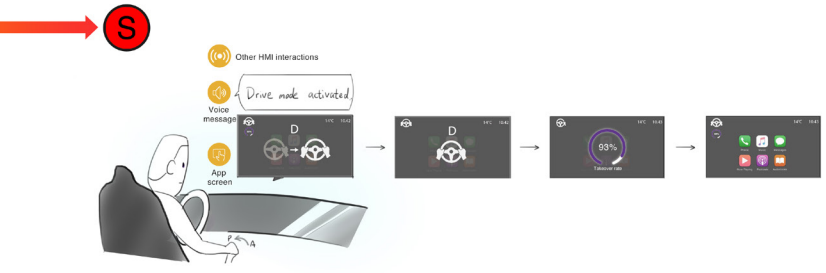


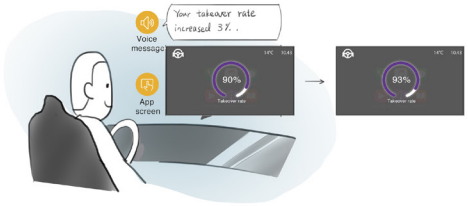
Figure 80. A storyboard was created to illustrate the experience of the final concept for the evaluation.











Ⓢ Control transfer - signal 1
Ⓢ Control transfer - signal 2
Ⓢ Control transfer - signal 3

where the app screen will show the recommended driving mode while playing the voice messages. Takeover rate increases at any moment the driver follows recommendations.
The voice messages were processed to emphasize keywords “unreliable” and “unavailable” and “now” by pausing and increasing the volume. They could be heard from this link: https://soundcloud.com/yujie-shan/sets/persuasive-negotiation-in-uc3a
Force feedback on the shifter was not used in this use case's experiment since it was difficult to do so in VR and the force feedback shifter had already been tested by other Mediator members who developed it in reality.

6. After parking at the reserved spot, the driver could pay for the parking fee with the discount directly through HMI and get an overview of the takeover rate changes throughout the journey on the (app screen) dashboard.

The focus of the final evaluation was on negotiation rituals, which would only be triggered after control transfer signals (see figure 80). Therefore, participants were asked not to react to any signals until all of them were given. Instead, they were asked to tell the researcher when they would already want to switch modes, despite the fact that they could not do so. A consent form and basic personal information were filled out prior to the experiment. Questionnaires regarding interaction qualities of HMI and motivation levels to follow recommendations as well as user acceptance of the concept were filled out after the experiment. Figure 81 shows the set-up of the devices for the test.

RESULTS

The following is a summary of the findings about the effectiveness of the final concept in motivating participants to follow the car's recommendations, and how well it meets the HMI interaction qualities, design goal, and user acceptance criteria. The questions and detailed results of the questionnaire could be seen through this link: https://docs.google.com/forms/u/1/d/1ua-Sl5AjaYkda9F0q7krTvq_VHotYlQOOf3DN7eqZ9M/viewanalytics

Driver’s motivation levels to follow recommendations:
1.Use case 1b
Results showed that in seductive negotiation of use case 1b, the voice message “piloted mode offers extra comfort” was effective to motivate the majority of participants to follow recommendation (see figure 82). However, to some participants, the content of the message was either too obvious and general, or inappropriate. For participants who already knew piloted mode would be more comfortable, this way of expression did not sound more appealing to them, which did not influence their motivation levels. Rather than giving such a general suggestion, they would love to get a more specific suggestion according to the context (i.e. phone rings). And for participants who thought the expression was inappropriate and therefore unappealing, because they could not associate distraction with comfort. Instead, they could associate it better with safety. Therefore, the voice

Figure 81. Test set-up.

message “piloted mode offers extra safety” in use case 1b might have better effects in motivating participants to listen to the car. Based on these insights found during the experiment, two questions were added up later on into the questionnaire to test with the rest of participants. The questions asked about motivation levels if the car says “you can take the call. Let me take over for you” (i.e. contextual recommendation) and “piloted mode offers extra safety” (i.e. safety recommendation). Figure 83 showed that both ways of expression were more effective to motivate participants to follow recommendations than mentioning comfort. Furthermore, contextual recommendation was most effective as well as likable by participants. Given that safety-related reasoning can make people feel uneasy, contextual recommendations are thought to be more appealing and appropriate for seductive negotiation in use case 1b.

2.Use case 5a

The majority of participants were motivated to follow recommendations by both voice messages in a persuasive negotiation ritual. Because the participants believed they had no choice but to obey this command due to the dangers they would face(see figure 84 & 85).

3.Use case 3a:

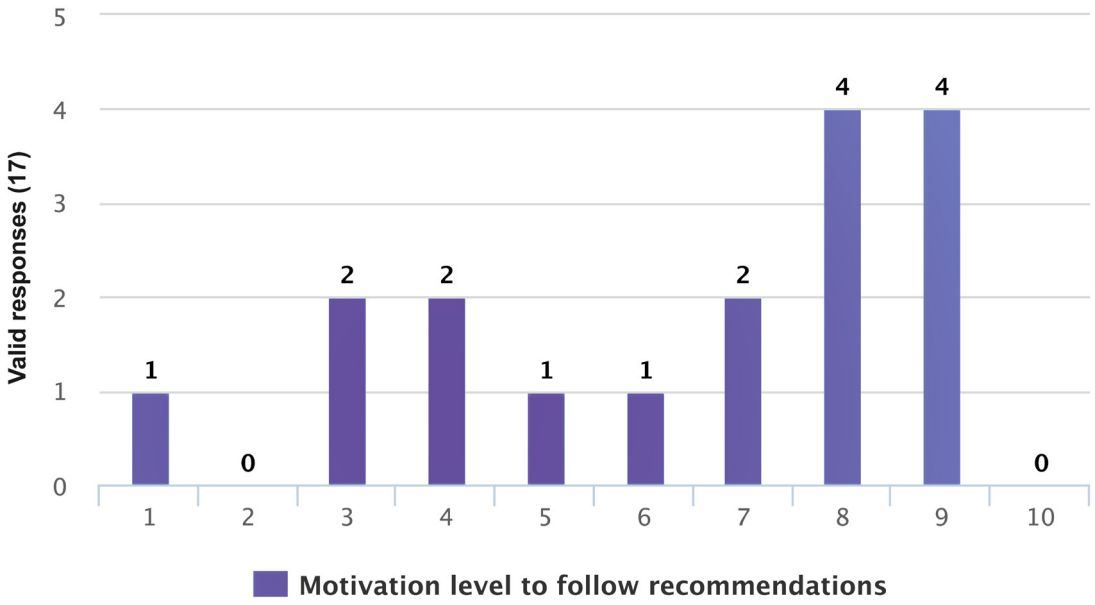


Figure 82. Motivation level to follow recommendations when the car said "piloted mode offers extra comfort" in seductive negotiation in use case 1b (1 = not at all, 10 = very much).

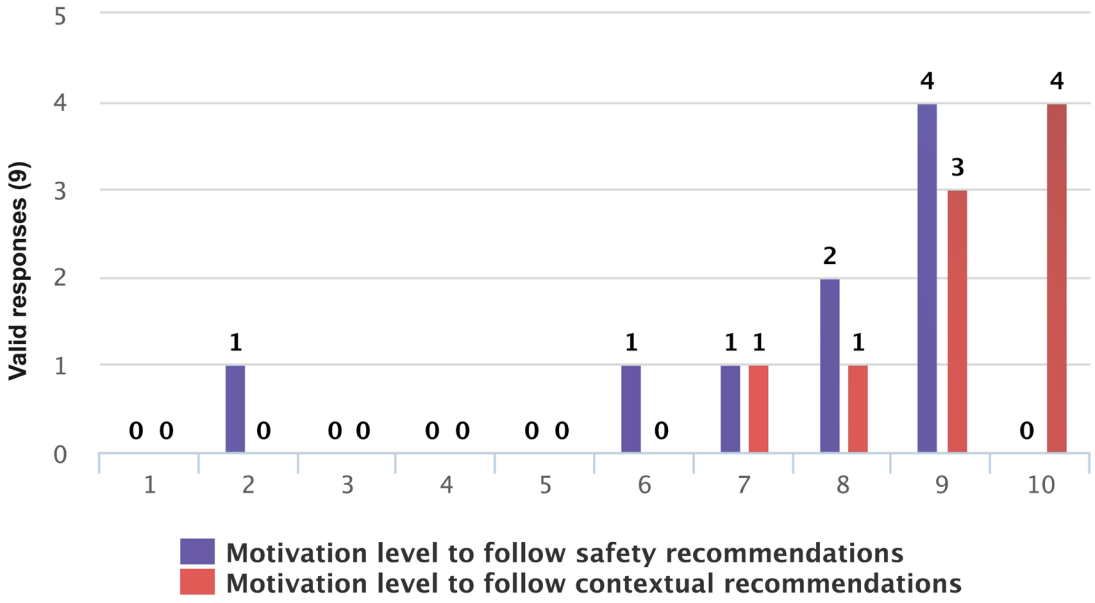


Figure 83. Motivation level to follow contextual and safety recommendations in seductive negotiation in use case 1b (1 = not at all, 10 = very much).

When the car stated "assisted mode unreliable, piloted mode unavailable" in the initial voice message of the persuasive negotiation ritual, all participants were highly motivated to follow recommendations(see figure 86). It proved that reasons that indicate the system's boundaries in persuasive negotiation are effective. The second voice message was the same message as

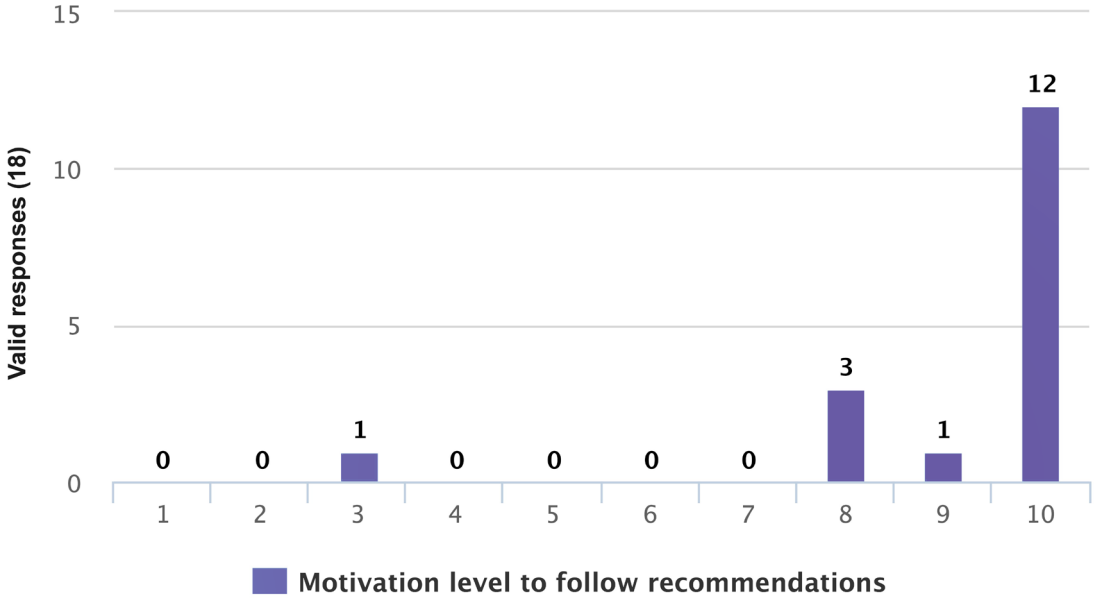


Figure 84. Motivation level to follow recommendations when the car said "piloted mode unavailable in 5 seconds" in persuasive negotiation in use case 5a (1 = not at all, 10 = very much).

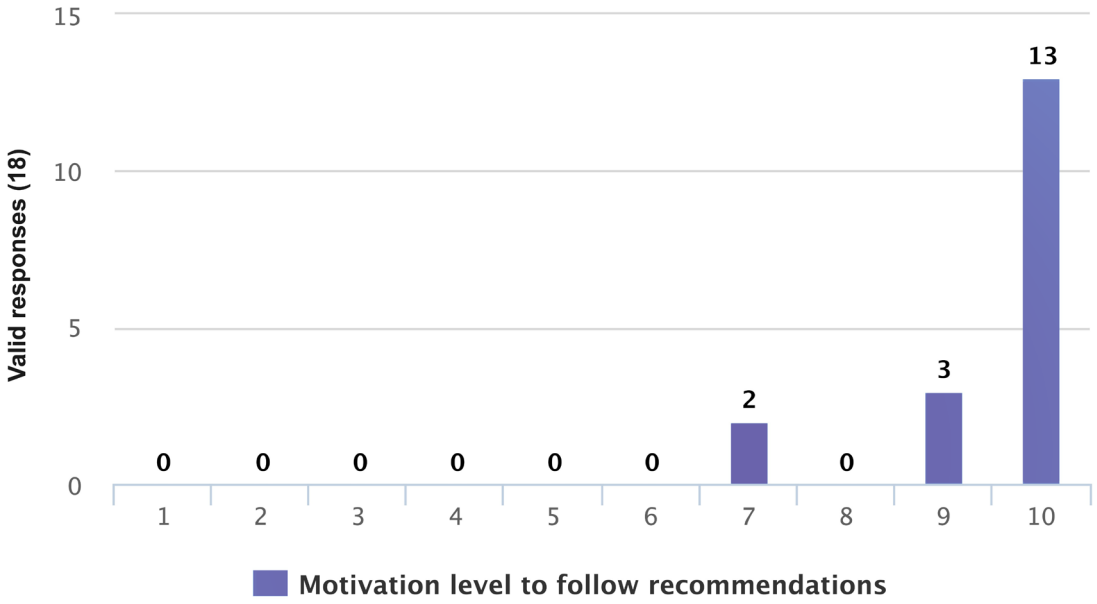


Figure 85. Motivation level to follow recommendations when the car said "you must take over now, or the car stops safely" in persuasive negotiation in use case 5a (1 = not at all, 10 = very much).

in use case 5a, addressed in the previous paragraph.

4.The choice of voices

The majority of participants' motivation levels were not influenced by the type of car's voices to follow the car's recommendations, as shown in Figure FIXME. It was discovered, however, that having the option of selecting a favorite voice could improve the pleasantness of negotiation through discussion with participants. This was because having a disagreeable voice telling them what to

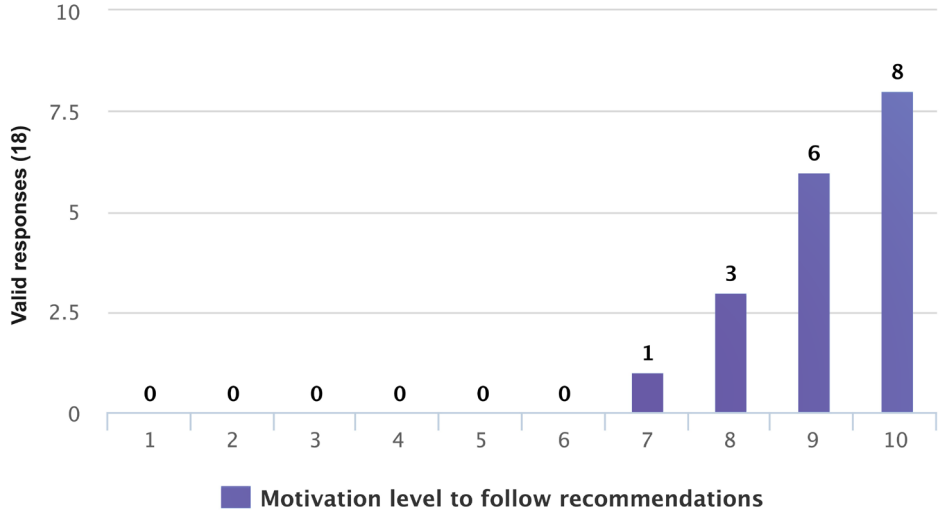


Figure 86. Motivation level to follow recommendations when the car said "assisted mode unreliable. Piloted mode unavailable" in persuasive negotiation in use case 3a (1 = not at all, 10 = very much).

do could be irritating.

5.Parking benefits & voice messages

Results showed that more than half of participants had a higher motivation level (>6) to follow recommendations because of the parking benefit. Additionally, a driver with a greater takeover rate has a higher motivation level, because he or she desires to retain the privilege. The rest of participants cared more about their safety than benefits, which voice messages alone would be motivating

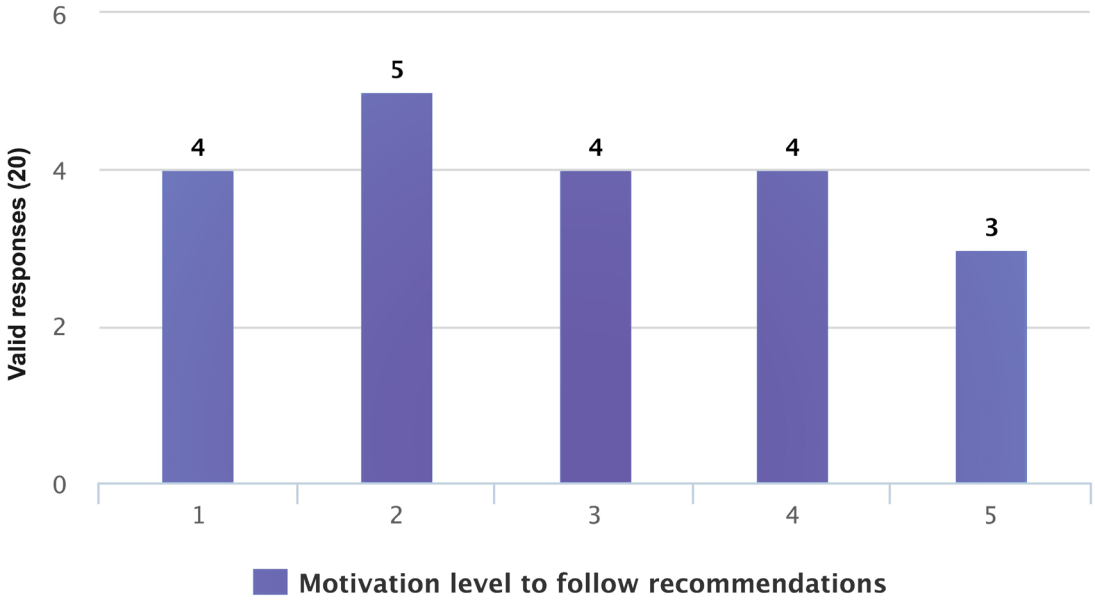


Figure 87. Motivation level to follow recommendations influenced by the choice of car's voices (1 = not at all, 5 = very much).

enough. In general, voice messages provide higher motivation levels for participants to follow recommendations (see figure 88). However, it was found that having parking benefits would make them feel more pleasant in persuasive negotiation and more appealing in seductive negotiations.

User acceptance:

The user acceptance of the Mediator system including the negotiation rituals and parking benefits of the final concepts was rather high as shown in figure 89. This concept successfully contributed to the achievement of user acceptance, which was one of the biggest challenges of this project.

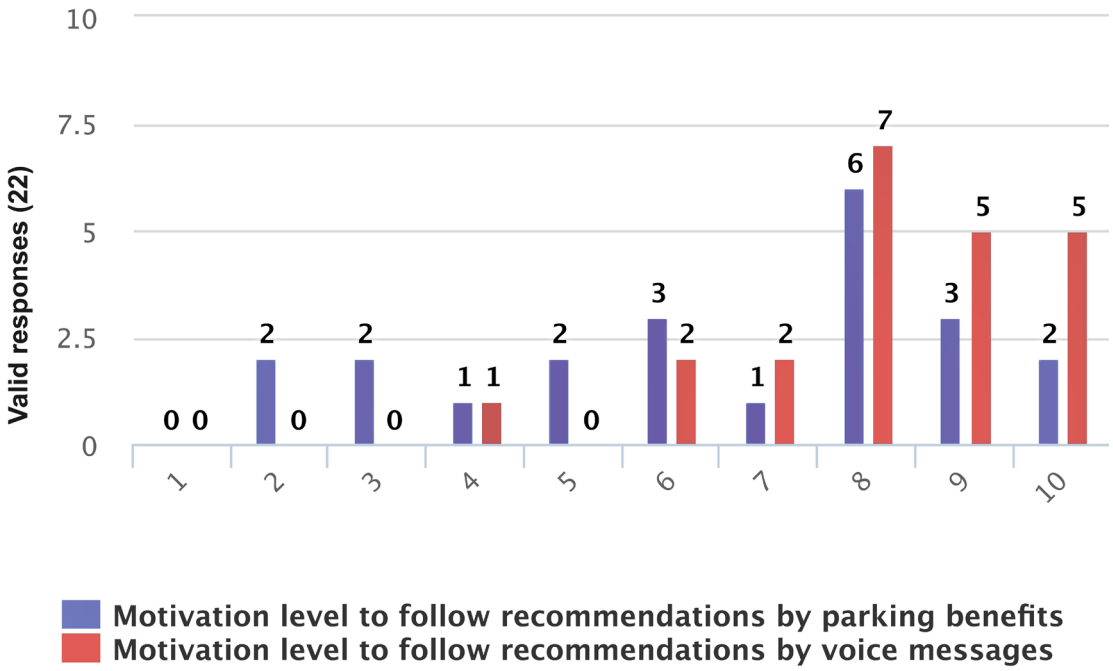


Figure 88. Motivation level to follow recommendations influenced by the parking benefits (1 = not at all, 10 = very much).

Design goal:

The design goal was to create a pleasant experience during negotiation through HMI within a highly automated vehicle. Most of the participants felt fairly pleasant (see figure 90). Some of the rest thought the first persuasive negotiation signal in use case 5a was given too late, which made them panic, and others felt the voice message was overly commanding. These factors highly depend on experience with the system and individual preferences. The results showed that the solution as a concept that had to be one-size-fits-all in the Mediator project was adequate to provide a pleasant experience for most participants.

The Mediator project aimed to ensure safety and comfort of the driver within highly automated vehicles. The negotiation experience aligned with these goals as well that most participants felt safe and comfortable, as shown in figure 91. However, evaluating these elements in reality is strongly recommended because participants may react differently than in virtual reality,

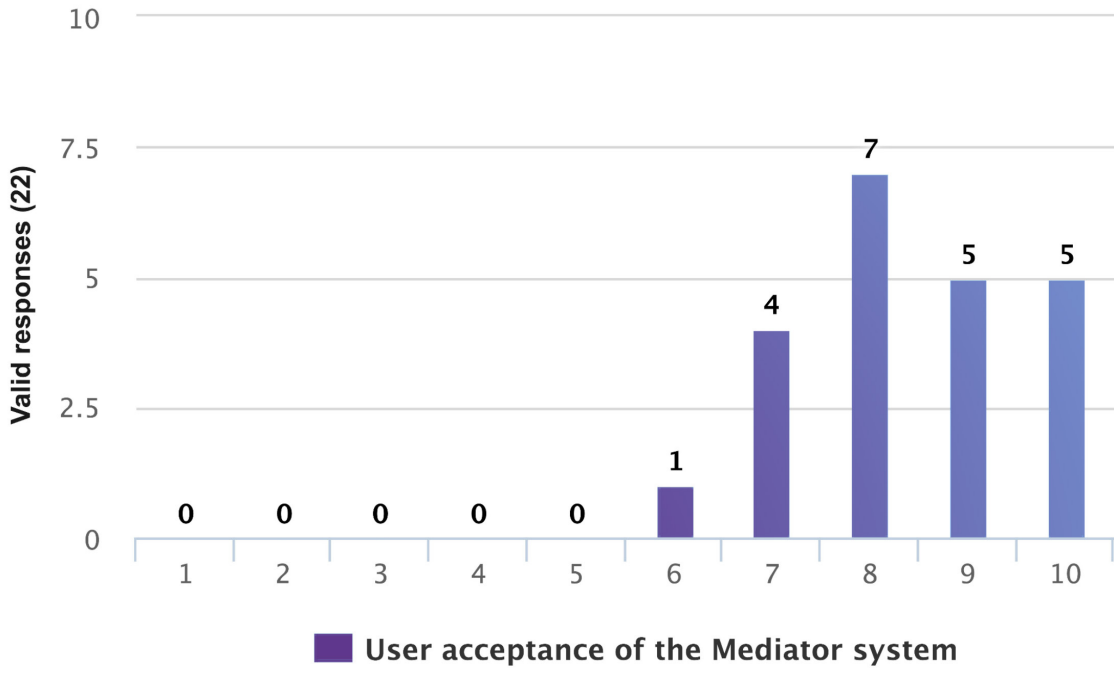


Figure 89. User acceptance of the Mediator system (1 = not at all, 10 = very much).

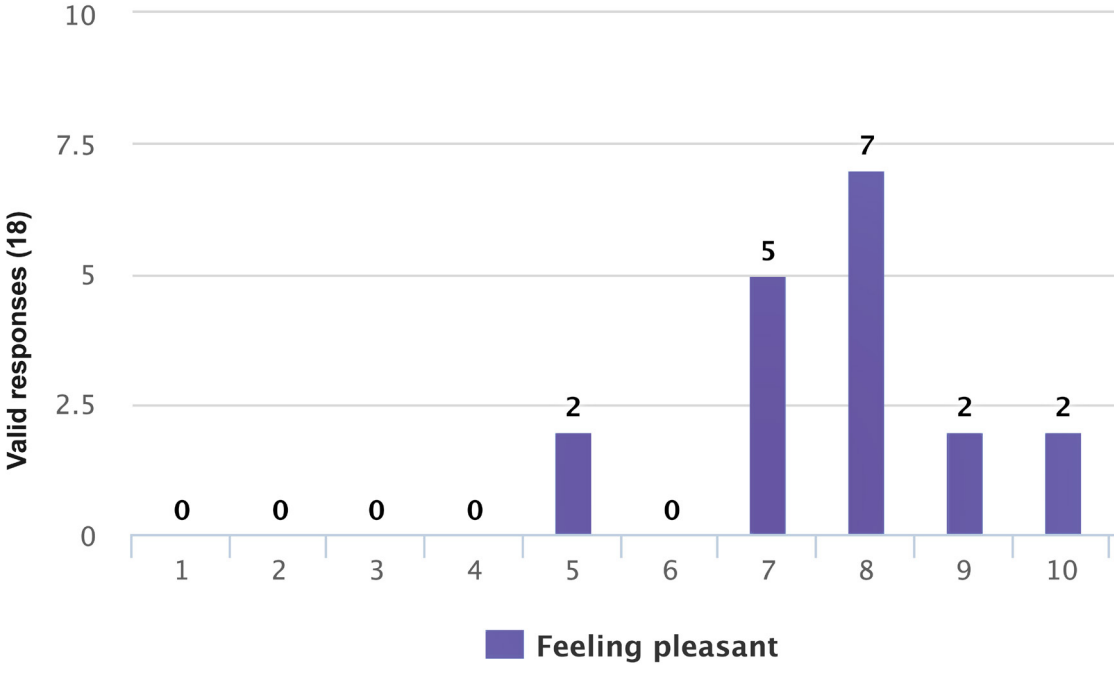


Figure 90. The pleasant feeling during the journey (1 = not at all, 10 = very much).

where they know they will be safe.

Interaction qualities:
Figure 92 showed the evaluation results of HMI interaction qualities that were defined in chapter 4.4. Most participants easily understood what the car wanted them to do because they thought the recommendations given in voice messages were clear and the overall interaction with HMI was simple enough. Most participants perceive

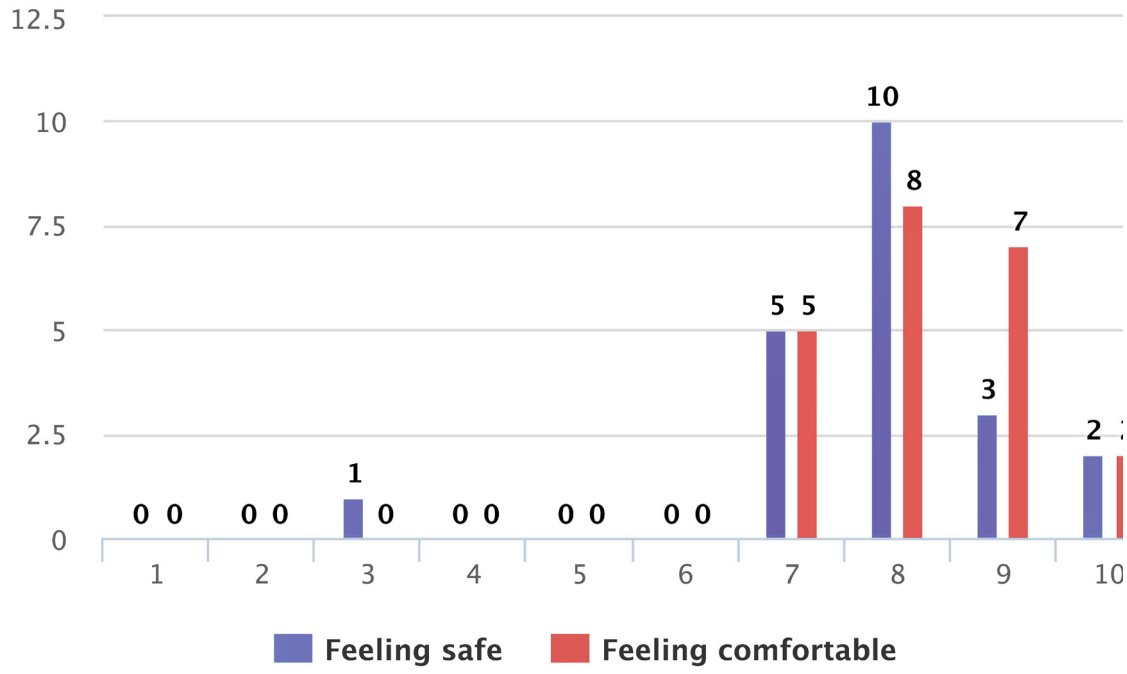


Figure 91. The safe and comfortable feeling during the journey (1 = not at all, 10 = very much).

the negotiation as efficient but a few participants thought the voice messages could be even shorter. This highly depended on participants' preferences and experience with the system.

Other findings:
1)The graphic representation of the takeover rate was clear. Despite the fact that it was designed in purple, the same colour as Piloted mode, none of the participants misunderstood it.

2)It was discovered that vocal negotiation (i.e. voice messages) was more acceptable and appropriate than

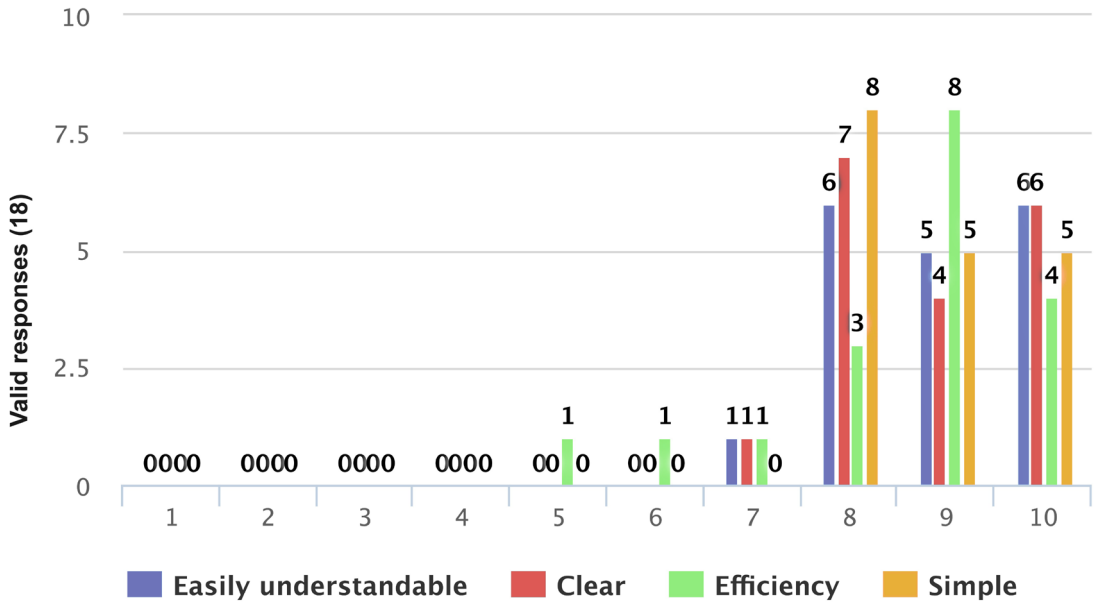


Figure 92. The safe and comfortable feeling during the journey (1 = not at all, 10 = very much).

visual communication since it was more human-like and comprehensible, and it did not require the driver to look at screens, which made participants feel safer because it did not divert their focus away from the road.

3)The timing of voice messages in the persuasive negotiation ritual has been proven to be critical for pleasantness. Some participants requested that the first voice message in negotiation be delivered significantly earlier in order to avoid panic. It was recommended that the car should be able to adjust the timing of the messages based on the driver's activity and experience with the system. Moreover, some participants stated that they would feel considerably better if they knew ahead of time that the car could safely stop even if they did not take control, despite their skepticism if it would be truly safe. Therefore, it is suggested to give prior knowledge about the countermeasures before the user uses the system. It could contribute to a pleasant experience in negotiation.

4)A participant preferred parking benefits above other benefits, such as automobile insurance discounts, because it involves less privacy concerns. Another participant, on the other hand, suggested that the amount of discount could be determined by how quickly the driver reacts to signs. This would encourage him to take on recommendations as soon as possible, lowering risks.

5)The voice messages should be

prioritised over navigation voices if they interfere with each other because it concerns safety so it was more important than missing a turn and taking a detour.

6)The pause and voice volumes were not always sensible to everyone, although it gave some participants a slightly different impression. However, even though these participants could sense the differences, the impressions received were highly subjective and varied greatly between individuals, making it difficult to say which was the best option. One exception was that most participants liked to have a pause when the car said "assisted mode [pause] unreliable, piloted mode [pause] unavailable," because it made it more clear and easier to understand. This insight was based on results from a questionnaire with 16 European participants. They were invited to listen to voice messages from each negotiation with a control group that did not have any pauses or volume changes, and an experimental group that did. Questions asked and detailed results could be reached from this link: https://docs.google.com/forms/u/1/d/1P1RmFAahbjC2VuYW1QRMrxqTYhaViBoeIxQKeAgthgI/viewanalytics
Sound files used for this questionnaire could be heard from this link: https://soundcloud.com/yujie-shan/sets/mediator-sound-evaluation

SUMMARY

Overall, the final concept sufficiently met the design goal and HMI interaction qualities. It was proven to be effective to motivate the majority of participants to follow recommendations. The concept achieved user acceptance as well as aligned the goal of the Mediator project, which is to ensure driver's safety and comfort.

06

CONCLUSION

Conclusion & recommendations
Discussion
Reflection

Conclusion & recommendations

Conclusion

The mission:
The goal of this graduation project was to create an HMI design for negotiation between the highly automated vehicle and the driver in conflict. The challenges of this project were to find appropriate ways to resolve conflict caused by different world views, and achieve user acceptance of this system by finding a balance between actual driver autonomy and automation dictated actions.

Interaction design opportunities:
Through desk research about the existing context, it was found that understanding all given information and the underlying reasoning of an automation decision can increase agreement. Voice messages can improve the driver's understanding of the situation, which supplement visual and sound signals, the most common interaction elements used in automotive HMI. Meanwhile, haptic feedback can reduce information overflow caused by visual and sound signals. Therefore, The most relevant components of the Mediator HMI in negotiation are the dashboard screen & heads-up display, sound systems, and the force feedback shifter, which involves driver's visual, auditory and haptic interaction.

User values & appropriate approach for negotiation:
Through conflict analysis, desk research and interviews, it was found that most participants wanted autonomy, comfort and/or pleasure, only when safety was secured. Therefore, regardless of what negotiation styles participants were diagnosed with, the competing style of the autonomous vehicle was most preferred in safety related situations and the collaborating style was most desireable in comfort scenarios. Most participants wanted autonomy, comfort and/or pleasure, only when safety was secured.

Design for specific contexts:
The HMI design should be able to resolve conflict within the Mediator use cases. Through analysis, it was found that the potential conflict in the Mediator project could be triggered by driver drowsiness and distraction, or the system's unreliability, which covered use cases 1 (a&b), 2, 5a, 3a, 6a. To resolve conflict caused by driver drowsiness and distraction, seductive negotiation should be employed, whereas persuasive negotiation should be used to resolve conflict caused by the system's unreliability.

Design goal & interaction qualities:
The HMI design should fit in a future context where the Mediator project will be delivered in 2023. Therefore, a future worldview was created through collected contextual factors. It envisioned a future trend towards hedonic experience while the vehicle handles any potential unpleasant experience. To achieve user acceptance in this future context, the design goal was defined as "**I want the driver to have a pleasant experience during negotiation through HMI within a highly automated vehicle.**" It led to the fundamental HMI qualities for negotiation that are **clear, simple,**

efficient, and easy to comprehend.

Conceptualization:
The final concept was created from three initial concepts and through two design iteration cycles, which focused on rewarding features and voice messages. Through experiments, it was concluded that persuasive reasoning in voice messages should play a main role in negotiation, while a rewarding feature should have an additional role to motivate drivers to follow recommendations. More direct rewards could be given to drivers such as a parking benefit without restrictions. The reward system could increase motivation slightly more to safety-oriented drivers and a lot more for autonomy-oriented drivers, who regard the reward as a kind of compensation for their loss of autonomy. Rewards could also increase pleasant feelings in negotiation. Therefore, the combination of these two elements (voice messages & rewards) could maximas user acceptance for most drivers.

Based on these insights, a final concept was created, which is a negotiation ritual consisting of 1) voice messages that gives short explanations of recommendations in collaborative or competing styles by wording and tones, and 2) a rewarding feature that is a parking discount to motivate drivers following recommendations from the car.

Validation:
Through final evaluation, it can be concluded that the final concept sufficiently met the design goal, which was to create a pleasant negotiation experience within a highly automated vehicle. It was proven to be effective to motivate the majority of participants to follow recommendations. The HMI interaction qualities were also achieved: the interactions were simple and offered efficient communication in clear and easy to understand voice messages. However, there is still improvement space for factors that are highly dependent on participants' preferences and experience with the system. Overall, the concept achieved user acceptance as well as aligned the vision of the Mediator project.

Recommendation

Through experiments, it was found that participant's preferences, experience with the Mediator system and prior knowledge highly influence some aspects of negotiation and have room for improvement. They are: 1) types of rewards, 2) personalized suggestion in seductive negotiation, 3) commanding levels in persuasive negotiation, 4) the timing of take-over requests in persuasive negotiation, 5) the length and frequency of voice messages, 6) persuasiveness.

1 Type of rewards

Although parking discounts were the most preferred benefit in design iterations when compared to a few other types of rewards, some people did not find it attractive, such as people who do not commute to the city center frequently. Therefore, it is highly recommended to provide a variety of options that drivers could choose from. For example, there could be perks related to automobile services such

as in-car entertainment, car insurance, maintenance, energy refill, and so on, or benefits related to travel, such as hotel booking, city tours, leisure activities, and so on. As a result, there will be a better chance of appealing to a wide variety of drivers, thereby creating higher extrinsic incentives to follow car's recommendations.
Furthermore, improvements to the final concept in terms of rewarding could include adjusting the amount of discount based on how quickly the driver reacts to the negotiation signals. In other words, the faster the driver reacts, the more discount he or she will get. This may increase driver motivation and reduce reaction time, resulting in a safer control transfer.

2) Personalized suggestions

Ideally, the seductive negotiation would be able to make personal recommendations or contextual recommendations that would benefit the driver. It should appeal to a driver depending on his or her particular interests. The system could use machine learning to learn from the driver's behaviour that could indicate his or her preferences to make personalized recommendations in a specific context. For example, if the system detects a behavioural trend in which the driver prefers to let the car take over in a traffic jam, the system may make a similar recommendation to this driver in the future. Another possibility would be using a log-in system to import a specific driver's profile, which would include his or her preferences. Even when in a shared vehicle, the vehicle's suggestions would differ from one to another.

3) Commanding levels

The commanding levels in persuasive negotiation should correspond to the risk or urgency. The car should use a more commanding style in a more critical situation. However, it was discovered that participants' tolerance limits of commanding approach vary from person to person. A car's commanding attitude could make a driver rebellious and irritated, resulting in a dead-end negotiation. Thus, it is highly recommended to implement a personalization option for voice messages, which could adjust the commanding levels of voice messages in its wording and tones for individual drivers.

4) Timing of take-over requests

The timing of take-over requests in persuasive negotiation should be able to adjust according to the driver's experience with the system and the driver's activities to make sure that the driver is able to take over within a given time. For example, if the driver was occupied with non-driving tasks (e.g. calling, eating, reading, etc), making it difficult to take over within a few seconds, the system should estimate the time driver needs for taking over and give recommendations upfront accordingly. This also depends on how familiar a driver is with the taking over process. If the driver is very experienced with the Mediator system, he or she might be able to switch tasks faster. Therefore, the timing should be adjustable depending

on these two human factors, which could be estimated through sensor detection and past historical data. The worst scenario would be giving too little time before the system activates countermeasures, which could cause panic to inexperienced drivers. This will lower the sense of safety and thereby user acceptance. Therefore, leaving as much time as possible for inexperienced drivers in persuasive negotiation is important.

5 Length & frequency of messages

The length and frequency of the voice messages should depend on the experience with and prior knowledge about the Mediator system. For inexperienced drivers who have non knowledge about the Mediator system, voice messages play an important role in explaining why a recommendation was made and based on what situation with longer messages. Some participants appreciated the patience shown by the car when it was willing to clarify itself, as it helped to create trust. However, for experienced drivers or people who have prior knowledge about the system, shorter messages are more preferred because they do not require explanations. Explanation could be an optional function of HMI. The frequency of messages should also be reduced, as this has the potential to irritate experienced drivers.

6 Persuasiveness

Persuasiveness highly depends on the prior knowledge of the mediator system. During experiments, a few participants (i.e. new users) were unmotivated to follow the first recommendation since they didn't understand why the system advised Piloted mode, despite the fact that it explained "degraded fitness detected." It was difficult for participants, within a few seconds, to comprehend that the Piloted mode would be safer, which could be critical when driving. Giving a more detailed explanation about how the system could detect drowsiness and what it means could create an association upfront, thereby increasing persuasiveness to motivate participants to follow recommendations. Therefore, a user menu or an introduction video that explains how the system works is suggested. This could also nurture trust toward automation technologies.

In this graduation project, none of the experiments were conducted in a real context of highly automated vehicles. Participants might react differently when driving autonomous vehicles on real roads with hazards. Therefore, it is highly recommended to test the final concept when there is a chance to conduct experiments in real cars on real roads in future experiments of the Mediator project.

Discussion

For autonomy-oriented drivers to adopt the Mediator system, the rewarding features are essential. It has been found that autonomy-oriented drivers are less likely to adopt this system if all they get are voice instructions. Without rewards, they are more likely to continue driving in conventional automobiles, which provide them with the most driving pleasure. In the highly competitive automobile

industry, incorporating such drivers would improve the Mediator's competitiveness, resulting in greater user acceptability. A feature that allows this type of driver to enjoy the pleasure of driving would improve the system's acceptability. For instance, a feature may advise the driver to race the vehicle in a specific region or to accelerate speed quickly in a short period of time only for pleasure. However, it may raise ethical concerns. The rewarding features that may raise ethical concerns should be thoroughly discussed with other stakeholders who will bear responsibility. However, the definition of responsibilities between stakeholders is still blurry in the transition of full automation. As a result, it was difficult to determine whether the idea was worth the risks for implementation.

Validating with a diverse group of people including users and stakeholders could help discover ethical issues more quickly. For example, a parking system was proposed in design iteration 2 that only allowed safer drivers to park in the city center. It made sense from a stakeholder perspective for the greater interest of society. Participants, on the other hand, felt compelled to follow the recommendations or else they would receive punishment. Some people did not appreciate the feeling of being controlled by a machine, and it was questionable who had the authority to judge what was the ethically correct thing to do. Implementing such a system in the Netherlands, a democratic country where people place a high value on autonomy, could be controversial. The final concept, on the other hand, just provides benefits and the freedom to park anywhere drivers want. It alleviated ethical issues and fit into Dutch culture, where discount usually works well for increasing incentives. In other cultures, this might not be effective, therefore, finding a reward that does not cause ethical issues and fit in local culture could be further explored.

Reflection

There are three things I learned from this project that I will apply in the future.

ViP method

The ViP method did not work so smoothly in this project as it intended to. It requires designers to gather value-free descriptions of world phenomena in cultural, technological, psychological, demographic, sociological fields. However, the choice of factors was largely influenced by the designer's values. Without a free and flexible mind, it is hard for the individual designer to look for data or create a cluster from a new perspective. Furthermore, this became harder if the domain was complex with many interrelated aspects and highly determined by or restricted to technologies. For example, the development of technologies (e.g. how accurately the car can detect the driver’s drowsiness and how well the car performs on its own compared with human driver’s operation) determined how much trust users have in the Mediator system, which influenced their motivation to follow recommendations. Therefore, the ViP method was only used as a source of inspiration for this project to find an interesting perspective.

For future projects, I will not choose to use the ViP method when I find that the project is restricted to technologies. Furthermore, if ViP can be used, I will plan extra time for clustering and constructing a world view. I would prefer to use it in a group project so that the ideas can be more flexible due to the diversity of viewpoints.

Design and democracy

As a human-centred designer, I thought design should be based on what users need and want. However, through this project, I learned that design is not democracy. First of all, users may not 100% know what they want. Interview results in a self-reporting approach may differ from the participant's behaviour in reality. Secondly, the sample may not represent everybody. Thirdly, satisfying the user's needs will not lead to unique design solutions. Thus, I could not and should not fully rely on such data. I will need to filter it out by a certain design value. Designer's job is like a movie director and user data is like an actor or actress. The director needs to use his or her vision to compose an authentic story with the actor or actress. Without this vision, the designer will be no different than an engineer who develops solutions to provide basic functionalities when users need them. It will take some time for me to grow into a designer with this unique vision by experience, which I will gradually uncover on my professional journey as a designer.

Ambition management

As a highly ambitious person, I made the initial design statement very ambitious as well, which was inspired by the ViP worldview. The initial design statement was formulated as "I want the driver to have hedonic experience within the SAE level 4 autonomous vehicle through negotiation with HMI." During a workshop where participants were asked to rephrase the design statement so that they could empathize with it, all participants said making a negotiation hedonic was too ambitious, although they liked the positive intention. They preferred the words "pleasant" and "not disagreeable", making it more realistic and reasonable. It was thought that a negotiation is not necessary to be hedonic just to make drivers listen to the recommendations. Instead, making them safe should be more important. I agreed with this opinion since it was aligned with my research findings about persuasive negotiation. However, I wanted to make the design more interesting so I tried to follow the ViP method and came up with such a challenging design statement and did not even realize it as unrealistic. From this experience, I understood how a designer's ambition could influence a design statement. It would be nice for ambitious people like me to check if the goal is set too ambitious with other designers and stakeholders. It was nice to set some challenges but it had to be technologically feasible and doable within the planned project schedule.

07

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08

APPENDIX

Project brief
Consent form
Questionnaire
Scenarios
Persuasive negotiation findings
Seductive negotiation findings
Clusters and factors
Mediator use cases
Brainstorm and workshop results
Workflows
High fidelity visuals

I.Project Brief

DESIGN FOR our future

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy".
Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name	Shan
initials	Y
given name	Yujie
student number	5028086
street & no.	
zipcode & city	
country	
phone	
email	

Your master programme (only select the options that apply to you):

IDE master(s):	IPD / ★ DfI / SPD
2nd non-IDE master:	
individual programme:	- - (give date of approval)
honours programme:	Honours Programme Master
specialisation / annotation:	Medisign
	Tech. in Sustainable Design
	Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair	Grondelle, E.D. van	dept. / section:	DA
** mentor	Zeumeren, I. van	dept. / section:	DA
2nd mentor			
organisation:			
city:		country:	

comments (optional): The reason that my chair and mentor is chosen from the same department is that they are already a part of the Mediator project and they can offer different experitise for this Mediator project on the topic I work on.

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair Grondelle, E.D. van date - - signature

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: EC

Of which, taking the conditional requirements into account, can be part of the exam programme EC

List of electives obtained before the third semester without approval of the BoE

YES all 1st year master courses passed

NO missing 1st year master courses are:

name date - - signature

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **.
Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: APPROVED NOT APPROVED

Procedure: APPROVED NOT APPROVED

comments

name date - - signature

Human-Machine Interface Design and Interior Design for automated vehic

project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 22 - 02 - 2021

03 - 08 - 2021 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

Across all transport modes, automated transport technology is evolving rapidly, with tremendous potential to improve road safety. The Society of Automotive Engineers (SAE) defines the automation level from 0 to 5, ranging from fully manual to fully automated systems. However, the transition to level 5 automation introduces new dangers, such as mode confusion, overreliance, reduced situational awareness and misuse. A more supervisory role is shifted to the human driver from driving tasks. It requires effective communication between the human driver and the automated systems through the Human Machine Interface (HMI) to ensure safety during role switching.

To mediate between the driver and the automation based on both their strengths and weaknesses, the European Union has funded a project called MEDIATOR. It is a 4-year international project led by SWOV, the national institute for road safety research, in collaboration with research organizations, top universities including TU Delft, as well as manufacturers and suppliers. Within the Mediator consortium, TU Delft is in charge of HMI development and design.

This Master's graduation project will focus on designing an automotive HMI for the negotiation between the automation and the driver, in case of disagreement of the two parties relating to taking control. HMI assists persuasive and seductive negotiation when control conflicts occur on high and low necessity levels. The driver's autonomy needs to be taken care carefully during control conflicts so that they can feel in control, safe and confident in the Mediator system. In this project, I will explore how the driver's autonomy could be secured by taking care of the driver's preferences in the system through HMI for persuasive and seductive negotiation. The project will also take social dilemma into account that caused by the potential conflict between the preferences of drivers and societal goal of reducing the number of fatalities.

Several design challenges will be taken: designing for control conflict for both persuasive and seductive negotiation between the automation and the driver, anticipating different scenarios regarding their interaction, envisioning appropriate approaches of informing either party of a control transfer, investigating to what degree driver preferences should be taken care to secure driver autonomy and safe traffic during the conflict of control. The HMI design can be multimodal and potentially involves the entire interior of the vehicle. The project will also explore user acceptance and identify car manufacturers ' options to design an HMI that matches their brand value and identity.

Research has been done by partner institutions regarding the functional requirements of HMI. It is currently being translated to design requirements which this graduation project will build upon. Furthermore, a partner corporation Kongsberg has analyzed different scenarios in which conflict might occur, and 3 TU Delft students (B.Grazian, T.Mallon, X.Wang) had worked on HMI related topics for MEDIATOR which gives insights to kick off the graduation project.

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introduction (continued): space for images

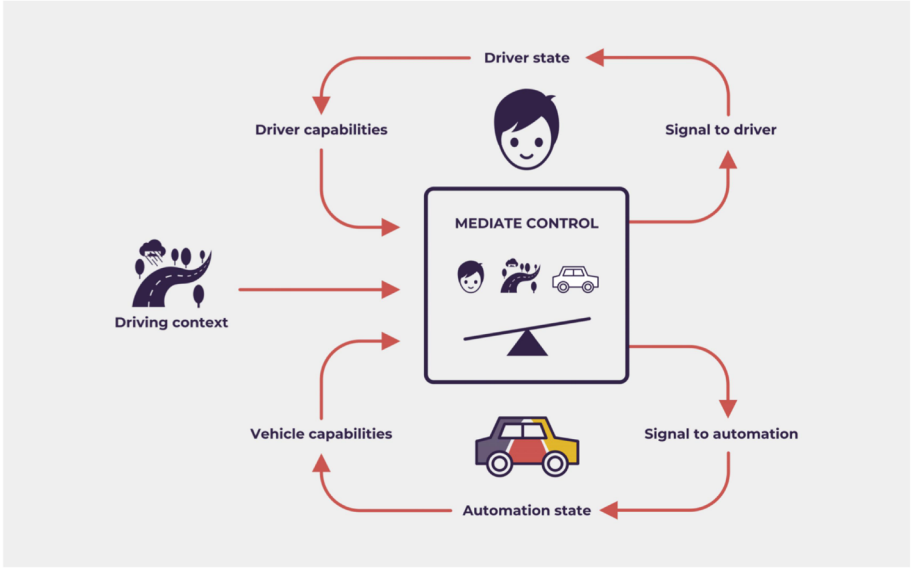


image / figure 1: The MEDIATOR system will weigh driving context, driver state and vehicle automation status.

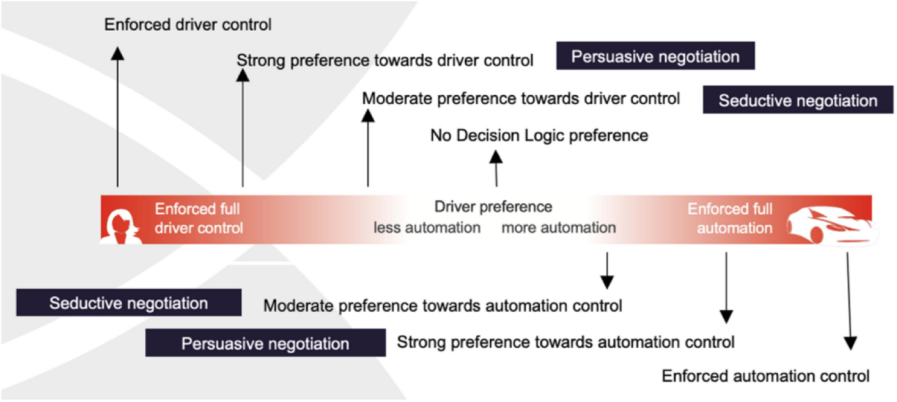


image / figure 2: An overview of the responsibilities of who is in control of an automatic vehicle.

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

This graduation project is given in scope within HMI design and interior design of autonomous cars. It will focus on use cases when role conflict happens between the automation and the driver. Currently, knowledge is missing on how to predict the occurrence of conflicts and how to resolve them.

Research shows that designing automated vehicles to act by the rule may not always be a good strategy. It is suggested to have expert understanding and behavior supplied by the driver in traffic decision making even at high automation levels. Customization and ad hoc intervention are two ways to influence the behaviour of the vehicle. (Terken, J., & Pfleging, B., 2020)

More specifically, the following research questions will be investigated.
• How to predict the occurrence of conflicts in different scenarios by using the interaction between the automation and the driver as a cue?
• How to resolve conflicts of control for both persuasive and seductive negotiation between driver and automation by a form of (multimodal) interface or interior?
• How may either the driver or the automation inform one another of a desired or necessary control transfer?
• How to secure user autonomy during a conflict of control? How customization and ad hoc intervention can help in this process?
• To what degree the preference of the driver should be taken care and still meets the social goal?

Reference: Terken, J., & Pfleging, B. (2020). Toward shared control between automated vehicles and users. Automotive Innovation, 3(1), 53-61.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

I will conduct literature reviews and small scale experiments on use cases when role conflict happens between the automation and the driver in a self-driving car. It will lead to new insights regarding conflict control that may contribute to the possible development of HMI for MEDIATOR. The result will be an HMI prototype that potentially involves car interior design.

The assignment consists of 6 phases which are research, define, ideation, conceptualization, prototyping, and user testing.
In the research phase, literature research will be conducted based on the existing knowledge sets of MEDIATOR and insights from previous graduation projects (B.Grazian, T.Mallon, X.Wang) at TU Delft. Topics relevant to conflict control from other literature will be extensively investigated. Furthermore, interviews with self-driving car drivers will be conducted to draw insights into the current state.
Design challenges, visions, and the concept direction will be defined in the define phase.
The ideation phase consists of creative sessions with target users and potential stakeholders. It aims to create ideas that could be potentially implemented into concepts.
In the conceptualization phase, 3 potential concepts will be generated based on the ideation phase that may have several aspects that need to be tested in the prototyping phase.
The prototyping phase consists of many small scale experiments by building and testing low-fidelity prototyping to evaluate several aspects of the concepts. Promising aspects will be included in the final concept which will be built in a high-fidelity prototype.
In the user testing phase, the final concept will be evaluated with a high-fidelity prototype in a driving simulator environment by target users and stakeholders.

Initials & Name		Student number	
Title of Project			

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 22 - 2 - 2021

3 - 8 - 2021 end date

The research phase aims to grasp the existing problems regarding control conflict in the current state. 3 weeks are reserved for the literature review. 1 week will be spent on interviews with 1 week of preparation ahead of the schedule. Another week will be spent on data analysis to get a problem overview.
Design challenge, design vision, and concept direction will be defined in the define phase with 3 times of iteration.
The ideation phase consists of 11 intensive working days for a creative session and data analysis, following 4 days of idea iteration combined with 4 times of lo-fi prototyping and testing on small scales. Each experiment will be focused on testing different aspects of the concepts.
The conceptualization phase is divided into 2 parts. The first part will be followed after the data analysis of the creative session to generate initial concepts. The second part is to create the final concept after 4 times idea iteration.
The prototyping phase includes 4 times of lo-fi prototyping for small experiments to iterate ideas and 1 time of hi-fi prototyping for the final evaluation and the showcase for graduation.
Accordingly, the user testing phase consists of 4 times of small scale testing and 1 time of final evaluation of the final concept.
Overall, the frequency of meetings with the supervisory team is planned based on different phases. In addition to breaks such as national holidays, every Thursday in the third quarter is taken to take a course called "Strategic Automotive" to facilitate this project. Almost every weekly task follows a full day of work on the report and reflection. When it gets close to the green light and graduation day, more days will be spent on the report and deliverables. Methods that will be used in this project are Vision in Product Design (VIP), interviews, journey mapping and storyboarding. More methods will be added on from the Delft Design Guide when it is needed according to the research findings throughout the project.

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

My objective in graduating from MSc Design for Interaction at TU Delft is to be able to design appropriate interaction between human users and advanced technologies through a human-centered approach. I believe technologies should play an assistant role in facilitating human users to have better performances in their daily lives. Thus, I want to bring this vision into my graduation project. Due to my dream job to be a UX designer who deals with interactions involved with advanced technologies and my interests in smart products and systems enabled by AI, the MEDIATOR project seems like a relevant project for my graduation and future career preparation.

Another reason that I want to join the MEDIATOR project is that I had done a similar project and gained valuable insights on the topic in another course called Interactive Technology Design (ITD). Unfortunately, that project could not carry on due to the Covid-19 situation. However, I did not want the insights to go wasted. Therefore, I looked for other opportunities to continue my exploration where I can build more knowledge on designing the interaction between the automation and the human driver, and most importantly sharing the insights with people who can make use of it and lead to real impact. The MEDIATOR project seems to be the perfect opportunity because it is tackling this challenge with stakeholders who can make use of the research findings to make a real impact. More specifically, MEDIATOR is carried out by a consortium of highly qualified research and industry experts who have rich resources and aims to maximize the exploitation of results after the project's end, leading to an innovative system that the European automotive industry will be eager to implement.

The emergence of self-driving cars opens a new era for interaction designers with more complex challenges. Thus, the complexity of the MEDIATOR project can indeed examine my research and design skills as well as knowledge gained at my Master's degree and further broaden my competencies. For example, I will learn and practice facilitating creative sessions on my own which will be valuable to my future career as well. I will also practice my visualization and storytelling skills to convey ideas and concepts appealingly and engagingly to stakeholders. Furthermore, I have done interface design in another course called Usability and User eXperience Assessment in Design (UXAD) and this graduation project can further sharpen my skills in interface design which I believe will be beneficial for my future job.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

Due to the ongoing Covid-19 situation, the project might need further adjustments which will be consulted with my supervisory team.

II.Consent form

Interview Consent Form

Hi!

You are being invited to participate in a research study titled Human-Machine Interface Design and Interior Design for Automated Vehicles. This study is being done by Yujie Shan for her graduation project for MSc Design for Interaction of Delft University of Technology. This project is a part of the 4-year Mediator project for the European Union.

The purpose of this interview is to find out how negotiation styles influence interactions with autonomous vehicles and will take you approximately 60 minutes to complete. When participating in this study I will ask you to fill in a questionnaire to diagnose your negotiation styles. Afterwards I will ask you questions regarding different conflict scenarios with autonomous vehicles. We will talk about your expectation, feelings and interactions with autonomous vehicles with an AI-based automation decision making system.

During the interview, personal information will be collected by means of questionnaires and audio recording. Also, notes will be taken during the interview. All this information will be collected, processed and stored safely and will be used to underpin the research output. Research output will be shared within the faculty of Industrial Design Engineering at TU Delft and with Mediator consortium.

There are no known risks associated with this research study. Your participation in this study is entirely voluntary and you can withdraw at any time. You are free to omit any question. When a participant withdraws from the study, all the recordings and notes which have been taken will be destroyed.

Thank you!

Consent Form for Human-Machine Interface Design and Interior Design for Automated Vehicles

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated 18/03/2021, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	□	□
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	□	□
I understand that taking part in the study involves a questionnaire and an audio-recorded interview. Audio recordings will be transcribed as text.	□	□
Use of the information in the study		
I understand that information I provide will be used for reports and presentation within the Mediator consortium.	□	□
I understand that personal information collected about me that can identify me, such as my name and negotiation styles, will not be shared beyond the Mediator consortium.	□	□
I agree that my information can be quoted in research outputs without my name presented.	□	□
Future use and reuse of the information by others		
I give permission for the audio recording and questionnaire database that I provide to be archived in the graduate student's hard drive so it can be used for future research and learning. The deposited data will be anonymised by given a nick name.	□	□

Signatures

_____	_____	_____
Name of participant	Signature	Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____	_____	_____
Researcher name	Signature	Date

Study contact details for further information:

Yujie Shan

Y.Shan-3@student.tudelft.nl

III.Questionnaire

This questionnaire was retrieved from the research paper that aimed to diagnose dynamic negotiation styles. (Schneider, A. K., & Brown, J. G., 2013).

Dynamic Negotiating Approach Diagnostic (DYNAD)

INSTRUCTIONS: Consider your response in situations where your wishes differ from those of another person. Note that statements A-J deal with your *initial* response to disagreement; statements K-T deal with your response *after the disagreement has gotten stronger*. If you find it easier, you may choose one particular conflict setting and use it as background for all the questions. Note that there are no "right" or "wrong" answers; your first impression is usually best.

Circle one number on the line below each statement for questions A through T.

A. WHEN I FIRST DISCOVER THAT DIFFERENCES EXIST,
I make sure that all views are out in the open and treated with equal consideration, even if there seems to be substantial disagreement.
Not at all Characteristic <----1--------2--------3--------4--------5--------6----> Very Characteristic

B. WHEN I FIRST DISCOVER THAT DIFFERENCES EXIST,
I devote more attention to making sure others understand the logic and benefits of my position than I do to pleasing them.
Not at all Characteristic <----1--------2--------3--------4--------5--------6----> Very Characteristic

C. WHEN I FIRST DISCOVER THAT DIFFERENCES EXIST,
I make my needs known, but I tone them down a bit and look for solutions somewhere in the middle.
Not at all Characteristic <----1--------2--------3--------4--------5--------6----> Very Characteristic

D. WHEN I FIRST DISCOVER THAT DIFFERENCES EXIST,
I delay talking about the issue until I have had time to think it over.
Not at all Characteristic <----1--------2--------3--------4--------5--------6----> Very Characteristic

E. WHEN I FIRST DISCOVER THAT DIFFERENCES EXIST,
I devote more attention to the feelings of others than to expressing my personal concerns.
Not at all Characteristic <----1--------2--------3--------4--------5--------6----> Very Characteristic

F. WHEN I FIRST DISCOVER THAT DIFFERENCES EXIST,
I am more concerned with goals I believe to be important than with how others feel about the issue.
Not at all Characteristic <----1--------2--------3--------4--------5--------6----> Very Characteristic

G. WHEN I FIRST DISCOVER THAT DIFFERENCES EXIST,
I often realize that trying to resolve the differences are not worth my effort.
Not at all Characteristic <----1--------2--------3--------4--------5--------6----> Very Characteristic

H. WHEN I FIRST DISCOVER THAT DIFFERENCES EXIST,

I make sure my goals do not get in the way of our relationship.
Not at all Characteristic <----1--------2--------3--------4--------5--------6----> Very Characteristic

I. WHEN I FIRST DISCOVER THAT DIFFERENCES EXIST,
I actively explain my ideas and just as actively take steps to understand others' ideas.
Not at all Characteristic <----1--------2--------3--------4--------5--------6----> Very Characteristic

J. WHEN I FIRST DISCOVER THAT DIFFERENCES EXIST,
I give up some points in exchange for others.
Not at all Characteristic <----1--------2--------3--------4--------5--------6----> Very Characteristic

K. IF DIFFERENCES PERSIST AND FEELINGS OF CONFLICT ESCALATE,
I set aside my own preferences and become more concerned with keeping the relationship comfortable.
Not at all Characteristic <----1--------2--------3--------4--------5--------6----> Very Characteristic

L. IF DIFFERENCES PERSIST AND FEELINGS OF CONFLICT ESCALATE,
I refocus discussions and hold out for ways to meet the needs of others as well as my own.
Not at all Characteristic <----1--------2--------3--------4--------5--------6----> Very Characteristic

M. IF DIFFERENCES PERSIST AND FEELINGS OF CONFLICT ESCALATE,
I let others handle the problem.
Not at all Characteristic <----1--------2--------3--------4--------5--------6----> Very Characteristic

N. IF DIFFERENCES PERSIST AND FEELINGS OF CONFLICT ESCALATE,
I try to be reasonable by not asking for my full preferences and I make sure I get some of what I want.
Not at all Characteristic <----1--------2--------3--------4--------5--------6----> Very Characteristic

O. IF DIFFERENCES PERSIST AND FEELINGS OF CONFLICT ESCALATE,
I put forth greater effort to make sure that the truth as I see it is recognized, and less on pleasing others.
Not at all Characteristic <----1--------2--------3--------4--------5--------6----> Very Characteristic

P. IF DIFFERENCES PERSIST AND FEELINGS OF CONFLICT ESCALATE,
I interact less with others and look for ways to find a safe distance.
Not at all Characteristic <----1--------2--------3--------4--------5--------6----> Very Characteristic

Q. IF DIFFERENCES PERSIST AND FEELINGS OF CONFLICT ESCALATE,
I press for moderation and compromise so we can make a decision and move on.
Not at all Characteristic <----1--------2--------3--------4--------5--------6----> Very Characteristic

R. IF DIFFERENCES PERSIST AND FEELINGS OF CONFLICT ESCALATE,
I do what needs to be done to resolve the conflict in my favor and hope we can mend feelings later.
Not at all Characteristic <----1--------2--------3--------4--------5--------6----> Very Characteristic

S. IF DIFFERENCES PERSIST AND FEELINGS OF CONFLICT ESCALATE,
I do what is necessary to soothe the other's feelings.
Not at all Characteristic <----1--------2--------3--------4--------5--------6----> Very Characteristic

T. IF DIFFERENCES PERSIST AND FEELINGS OF CONFLICT ESCALATE,
I pay close attention to the wishes of others but remain firm that they need to pay equal attention to my wishes.
Not at all Characteristic <----1--------2--------3--------4--------5--------6----> Very Characteristic

LEGEND: *Arrows read low to high:*

Vertical Arrow: ASSERTIVENESS: Getting your own needs met

Horizontal Arrow: EMPATHY: Maintaining the relationship between yourself and the other party

--------- > The relative amount of effort and creativity needed to use conflict management style

COMPETING STYLE
High Assertiveness/Low Empathy
"We're doing it my way …"

• **Strategies**: Make a strong case for your position, persuade, be firm, assertiveness, insist, take charge or control the discussion.
• **Source of Power**: From stating your position
• **Advantages**: Speed, decisiveness, preservation of important values, stability.
• **Disadvantages**: Destroyed or hierarchical relationships, loss of cooperation, diminished self-respect in others, and lack of input or feedback.

COLLABORATING STYLE
High Assertiveness/High Empathy
"My preference is … I'm also interested in your views."

• **Strategies**: Problem focused, assert your position while also inviting other views, welcome discussion of all viewpoints, creativity.
• **Source of Power**: From integrating solutions.
• **Advantages**: Builds trust in relationships, high cooperation, merges perspectives, high energy.
• **Disadvantages**: Fatigue, loss of motivation, time consuming, distraction from other more important tasks, analysis paralysis.

COMPROMISING STYLE
Medium Assertiveness/Medium Empathy
"Let's find some middle ground …"

•**Strategies**: Urge moderation, trade-offs, split the difference, find a little something for everyone, find middle ground.
•**Source of Power**: From moderation and reasonableness.
•**Advantages**: Relatively fast, enables the show to go on, provides a way out of stalemate, readily understood by most people, builds atmosphere of calmness and reason.
•**Disadvantages**: Mediocrity and blandness, possibly unprincipled agreements, likelihood of patching symptoms and ignoring causes.

AVOIDING STYLE
Low Assertiveness/Low Empathy
"Let's not make a big deal out of this …"

• **Strategies**: Withdraw, delay or avoid response, divert attention, suppress personal emotions, be inscrutable, conflict adverse.
• **Source of Power**: From calmness, silence, non-cooperation.
• **Advantages**: Freedom from entanglement in trivial issues or insignificant relationships, stability, preservation of status quo, ability to influence others without engaging.
• **Disadvantages**: Periodic explosions of pent-up anger, freeze-out – unable to build relationships, residue of negative feelings, stagnation and dullness, loss of accountability or participation.

ACCOMMODATING STYLE
Low Assertiveness/High Empathy
"OK, whatever you say …"

• **Strategies**: Agree, support, forego your perspective, placate, reasonable, creating goodwill.
• **Source of Power**: From relationships or approval of others
• **Advantages**: Maintains approval/appreciation of others, freedom from hassle and conflict (at least in the short-run), self-discipline of ego.
• **Disadvantages**: Don't get what you want, frustration for others who wish to collaborate, loss of respect, over-dependence on others, denies others benefit of healthy confrontation.

SCORING THE INSTRUMENT:

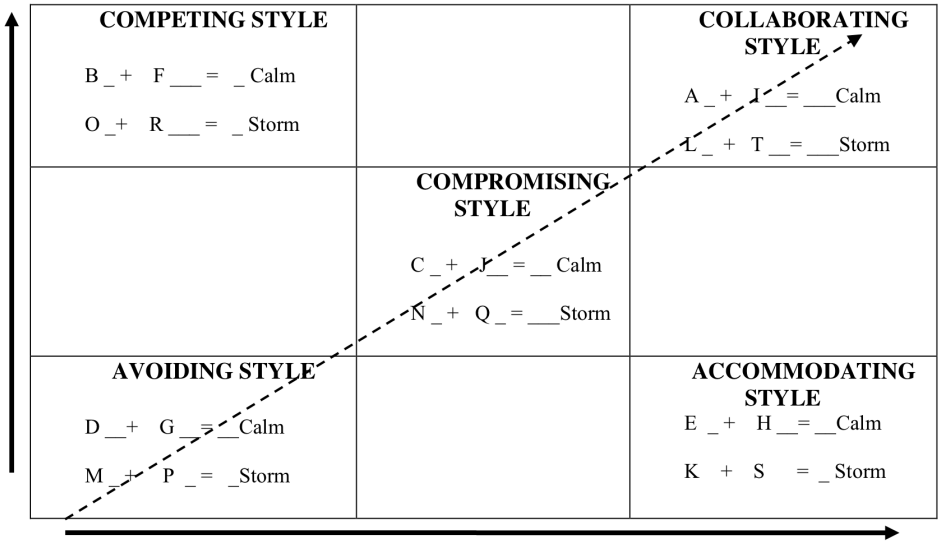
When you are finished**,** transfer the number from each item on the tally sheet. For example, on item A, if you selected number 6, write "6" on the line designated for item A on the tally sheet. Then add the numbers.

SAMPLE: B 1+ H 4= 5.

INTERPRETATION OF THE INSTRUMENT:

1. This instrument gives you two sets of scores. Calm scores apply to your response to conflict when disagreement first arises. Storm scores apply to your response if things are not easily resolved and emotions and feelings of conflict get stronger.
2. The scores indicate your *preference,* or inclination to use each style. The higher your score in a given style, the more likely you are to use this style in responding to conflict. You can develop skills in the appropriate use of each conflict management style and, as such, are not limited to using the style(s) that you prefer.

CONFLICT MANAGEMENT STYLE PREFERENCES - Tally Sheet



IV.Scenarios

It is considered more difficult to resolve conflict where both sides have the same strength of preferences, which is shown in figure 93. Thus, interviews were conducted within such a conflict. Four scenarios were created where scenario 1 and 2 were associated with persuasive negotiation and scenario 3/3.1 and 4 were associated with seductive negotiation.

Scenario 3.1 was an iterated variation of scenario 3 during the interview, which fit better within seductive negotiation based on the participants' differing reactions to scenarios that concerned safety versus scenarios that did not.

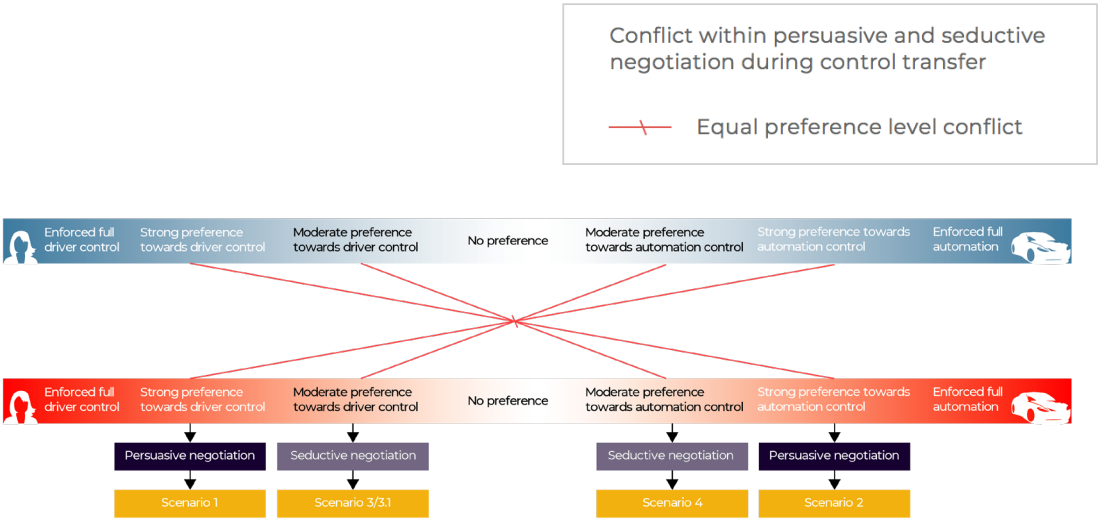


Figure 93. Interview scenarios were based on conflict where both sides have the same strength of preferences.

Scenario 1: You are having a fun video call with your friends when the period where automation level 4 can be activated is coming to an end. The car wants you to take over from level 4 to level 0. However, you are not finished with the call and you want to extend the period a little longer.

Scenario 2: You are driving in level 0. The car detects that you are drowsy. It decides to activate level 4 so that you can take a powernap. But you do not agree that you feel drowsy or see the need to take a nap. You want to keep driving on your own.

Scenario 3: You are driving on a highway with level 3. It starts to rain, so the car suggests you take over. But you have a moderate preference to keep driving on level 3.

Scenario 3.1: You are enjoying a relaxing time in the car that is driving with level

4 in the countryside. The car asks you if you would like to take over because the upcoming scenery is beautiful and it will be pleasant to drive.

Scenario 4: In a traffic jam, the car suggests you to activate level 3 from level 0 so the car could just follow the car in front automatically. But you are in a hurry and want to cut in other lanes, so you moderately prefer to drive manually.

V.Persuasive negotiation findings

a) Desirable interaction in persuasive negotiation

Results showed that no matter which dynamic negotiation styles the participants were diagnosed with, the most accepted negotiation style of the car by the majority of participants who were given persuasive negotiation scenarios was the competing style. Results showed that all these participants would prioritise the vehicle's (strong) preferences over their (strong or moderate) preferences. None of the participants would see the result of negotiation as a battle of winning or losing between the driver and the vehicle, instead they saw it as a win-win situation because the values of both parties were aligned and that was to secure safety.

Why competing style was most acceptable:

Compared with other negotiation styles, the competing style, which almost gave command to the driver, was the most **efficient** communication in a safety concerned situation. When the car made a take-over request that was related to safety, all participants chose to listen to the car because they knew that was for their sake and they trusted the expertise of the vehicle and thought that technology could secure their safety. They generally preferred a **firm and strong attitude** from the expert (i.e. vehicle). If the expert accommodated their opinions, then they would start to doubt its expertise and decrease trust in it. Collaborating style could spoil the driver and cause potential danger, although its friendly approach may make participants feel good. Participants said that the car should correct their improper behaviour (e.g. not hanging up a phone call before taking over) to ensure safety. Furthermore, collaborating style may give the illusion of choice that may not be true. For example, in a situation that was about to reach the limits of the vehicle, if the vehicle used collaborating style, it may make participants think that the vehicle could still do something on its own but that was not the case. This could cause potential danger and therefore decrease trust in the system.

b) User acceptance - emotional and rational acceptance

User acceptance consists of emotional acceptance and rational acceptance. Competing style from the vehicle may cause low emotional acceptance although it was highly dependent on the driver. Some drivers were more sensitive than others when dealing with aggressive attitudes. Besides, if the competing style was not designed well (through HMI), it could cause stress, panic or annoyance to the driver. Thus, the design space of the competing style needed to be further explored. Even though

the competing style could cause low emotional acceptance, it was rationally most acceptable in a safety related situation. Participants said they would regret not listening to the car if accidents happened. It could be concluded that the rational acceptance outweighs the emotional acceptance in a safety related situation.

c) Other factors - exception
Responsibility and driving experience: Very few participants preferred the collaborating style. Besides that they wanted to be treated nicely by the vehicle, some also thought they were responsible for their own behaviour rather than the car to secure their safety, so it was not necessary to receive a command from the car in a competing manner. Furthermore, the urgency of taking over and the experience with driving in autonomous vehicles also influenced the driver's preferences. Experienced participants preferred collaborating style in a not yet urgent situation and competing style in a very urgent situation.

Contextual influences:
Context may influence the driver's negotiation style in safety related situations, for example, when driving with other passengers, the driver may tend to drive more responsibly and become more willing to listen to suggestions of the vehicle in persuasive negotiation.

d) Desirable qualities in persuasive negotiation
Most participants preferred the vehicle to give **a short reason quickly, transparently and directly notifying the driver** why a suggestion was made and based upon which situation before giving a suggestion in a **calm** and **commanding** manner. In an urgent situation but not yet urgent enough to trigger enforced take-over, the vehicle could give a take-over request, then give an explanation after the driver responded to it. However, this interaction where a sudden request was given may cause panic to some participants and may decrease trust in the system. Thus, in a non-urgent situation, such interaction should be avoided.

Boundaries of the system's limits should be **clearly** and **straightforwardly** communicated to the driver so that the driver would know how large the negotiation space was. For example, a few participants wanted to know how **urgent** the situation was or how **necessary** it was to take over when a suggestion was made so they could make a decision accordingly.

e) Other factors worth considering
User expectation and requirements:
The assertiveness of take-over requests was assumed to be correlated to the urgency. The assertiveness should be stronger in an emergency but should not cause panic to the driver. The system must ensure enough take-over time and preferably capable of adjusting the duration to different drivers and situations. One experienced participant (with autonomous driving) mentioned that if the take-over request was given too early and with a competing style, he would feel annoyed and decrease trust in the system. In addition, the take-over request could be repetitive

in a situation where the driver has ignored or declined the request. Again, it should not annoy drivers. The strength of assertiveness correlated with the timing of giving take-over requests to various drivers and situations, as well as frequency of repetitive requests should be further explored. The HMI should allow participants to take **quick action** to respond to the request. In case the driver ignored or declined the request, s/he should be able to take over anytime if s/he wanted to, and with **minimum physical and mental effort.**

Learning curves:
One participant mentioned learning curves. She wanted the reason to be explained only in a new situation. In other words, she did not want the vehicle to repetitively explain the same reason in the same situation where she probably already knew the reason with growing experience with the vehicle.

Trust and interests:
Very few participants did not want to know the reason why a suggestion was made. Because they trusted the vehicle and they were not interested in knowing all of the information. However, they still wanted to have the possibility to get that information whenever they wanted to.

VI.Seductive negotiation findings

a) Desirable interaction in seductive negotiation

The relationship between the driver and the vehicle as **equal friends** are most desirable among participants who were given seductive negotiation scenarios. Among the three negotiation styles of the vehicle, the **collaborating** style was mostly preferred, no matter which dynamic negotiation styles the participants were diagnosed with.
The vehicle could make suggestions to the driver who remained as the decision maker. Results showed that all participants provided with seductive negotiation scenarios would **prioritise their (strong or moderate) preferences over the vehicle's (moderate) preferences.** Again, they would not see the result of negotiation as a battle of winning or losing between the driver and the vehicle, because they understood that the vehicle made suggestions for their sake and they were in charge of the final decision anyway.

Why collaborating style was most acceptable:
In a non-safety related scenario, the vehicle would not be regarded as an expert anymore. Thus, it was unnecessary of the vehicle to use a competing style, which was most unacceptable. That was because participants wanted **autonomy** and did not like to be asked what to do when it was not necessary. Some participants mentioned that it could trigger them to rebel against the vehicle. Instead, collaborating style took an interest in participants and made them **feel respected and cared for** in a **friendly and calm manner.** Most participants were also interested in the vehicle's preferences, so they did not like the accommodating style of the vehicle although it was acceptable. Some mentioned that it would be fun if the vehicle had a character. A few

participants were totally fine with the accommodating style since they did not expect the vehicle to have any opinion.

b) Emotional and rational acceptance
In a seductive negotiation, apparently emotional acceptance outweighs rational acceptance since the situation does not concern safety. Therefore, there is a larger room for emotional design to enhance user experience than persuasive negotiation.

c) Desirable qualities of seductive negotiation
Participants preferred a **friendly two-way communication.** The suggestion should **align the values** of the driver. It should explain why it is making this **personalised suggestion** for this driver. The **reason** given by the vehicle should **show a vision** of what the driver could get out of it (**benefit**).

d) Other factors worth considering
User expectation and requirements:
Participants expected the vehicle to know what they like (and dislike) and make suggestions accordingly. Personal suggestion is essential in a seductive negotiation. For example, if the vehicle knew that the driver would like to drive in curves, it could suggest how many curves were ahead and even inform who drove the best and then invite the driver to take the challenge. If the suggestion was based on big data of other users, it would be fine but not so exciting. In addition, unlike persuasive negotiation, participants did not want the same suggestion to be repetitive.

Technological opportunities:
The system could use machine learning to learn from the driver's behaviour that indicates preferences and make suggestions accordingly. For example, if the system detects a behavioural pattern that the driver usually chooses to let the vehicle take over in a traffic jam, then the system could make such a suggestion to this driver in such a situation next time. The vehicle should make specific suggestions to individual drivers. To achieve it, there could be a log-in system to import a specific driver's profile that consists of his or her preferences. The vehicle could be shared with others but the suggestion made by the vehicle would be different from one to another.

VII.Clusters and factors

1.Safety as a main benefit to travel with autonomous

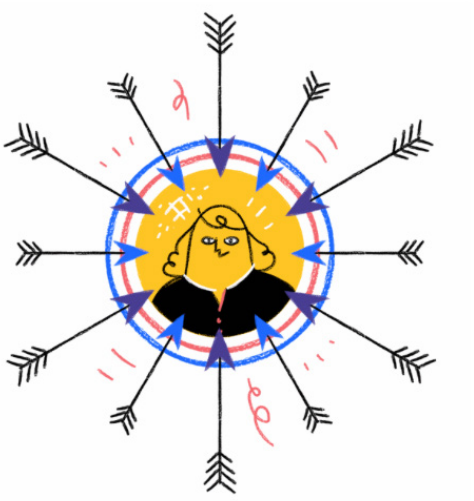
Cluster description:
People want to drive with autonomous vehicles primarily because they feel it will make them safer. Some people believe that the automobile is responsible for their safety.

Factors:
1.If a safety (autonomy) oriented driver (does not) thinks the autonomous vehicle has responsibility to secure the driver's safety, then they would prefer the vehicle to be (cooperative) assertive in safety related situations.

2.Those who thought self-driving cars and their automated responses safer would prefer to travel with autonomous cars.

3.Safety is the most valued benefit of AVs by (84% of) UK, US, and Australian consumers. (Schoettle and Shivak (2014b)) In another survey conducted by Howard and Dai (2014), 75% of respondents stated that safety was the most attractive feature of AVs.

2.Egoism



Cluster description:
Self-interested people may confront social dilemmas and liability concerns. AVs should refrain from making unethical decisions.

Factors:
1.Liability concerns about automated vehicles' responsibilities would lead vehicle manufacturers to design vehicles that are conservative, posing a severe challenge when mixed vehicles (automated and conventional) are on the road.

2.The societal goal of lowering the number of fatalities faces a social dilemma between driver preferences and the goal.

3.Liability: To decide who is held

accountable, most of these regimes use the concept of causality of the accident. However, when more automation is being used, determining the actual reason of an accident (i.e., whether it was caused by a hardware defect, a software malfunction, or inadequate driver behavior) will become more difficult.

4.People would prefer to buy and ride in a car that protects its passengers at any costs, rather than a utilitarian solution, such as a self-driving car that would sacrifice its own passenger in order to save two or more pedestrians. Furthermore, Mercedes-Benz stated that the safety of the driver and passengers of the vehicle would always be prioritized. (Taylor, 2016).

5.There is a moral distinction between killing and letting die, according to Philippa Foot's "Trolley Problem" (Thomson, 1985). Doing something that causes someone to die seems worse than allowing someone to die as a result of events that you were not responsible for.

6.Our society is requesting that AVs avoid making ethically incorrect decisions rather than mandating them to make ethically correct decisions since no choice is more acceptable than another. (Hars, 2016).

3.More valuable time for hedonic and productive benefits

Cluster description:
People desire more convenience and leisure to do hedonistic or productive activities. When technology can handle more inconvenient jobs, humans have

more opportunities to make their time more valuable.

Factors:
1.In Germany, younger urbanites with a high income do not place a great value on driving experience. 70% of them would rather not drive if it meant gaining convenience and time (Deloitte, 2017).

2.AI could cover more driving situations to free drivers from driving tasks.

3.In general, those who drive a lot expect the interior to adapt flexibly to current needs and activities.

4.Increased propensity of people who use active modes of transport to experience hedonic and productive benefits. (F, A. S., Aliaksandr, M., Patricia L., M., & Giovanni, C., 2019)

5.If drivers had an hour free from driving, they were most likely to pay for communication, entertainment, or higher productivity. (Hartwig, M. , 2020, May 14)

6.Globally, the number of video gamers

is rapidly increasing. (Clement, J., 2021, January 29).

4.Less responsibility, more benefits

Cluster description:
People desire to use objects as a means of gaining experience. They don't actually care about ownership because it means they'll have fewer responsibilities when it comes to maintaining the property.

Factors:
1.Users want experience instead of material things. (Momentum Worldwide, 2019)

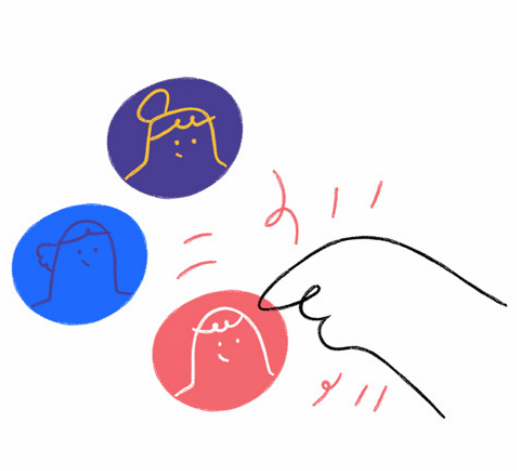
2.Accessing a car means users no longer have the responsibility and fixed costs of maintaining it – plus they get the chance to drive different vehicles as their needs (or wants) change. (M., 2018, November 8)

3.Millennial generations, who embrace openness and collaboration, social networking, and the sharing economy, are increasingly in need of shared living spaces. (M., 2018, November 8)

4.Fewer vehicles will be owned by individuals, and more vehicles will be shared actively.

5.It was found that Baby Boomers, Generation X, and Generation Y customers have distinct mobility needs and habits. In comparison to other generations, Generation Y customers are more likely to give up vehicle ownership. (Deloitte, 2014)

5.Living in cognitive bubbles



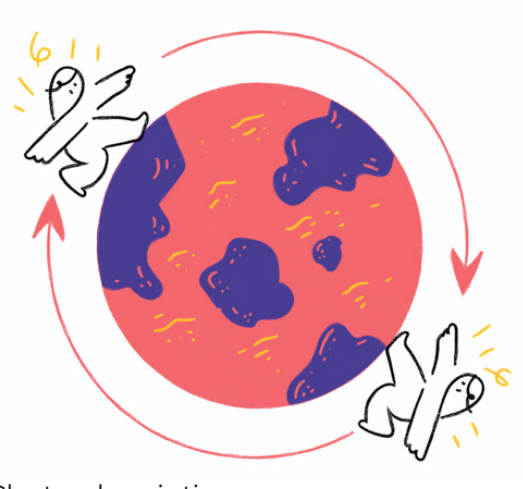
Cluster description:
People only see what they want to see on social media and its AI recommendation systems, rather than coming across those who have alternative beliefs. It reduces mutual understanding and encourages people to remain in their comfort zones.

Factors:
1.By increasing echo effects and allowing us to live in cognitive bubbles, social media actually increases divisions. We are fed what we already enjoy or what our like-minded peers enjoy. We actually get less connected in this way—except to individuals in our group. (Byrne, D., 2020).

2.While social media might bring us closer together, it can also make us feel isolated from society, envious of others, and have less tolerance and understanding of differences. (Byrne, D., 2020)

3.Humans are prone to overlook the difficult decision of tomorrow in favor of a simpler answer today. (Deloitte, 2020)

6.Living more flexibly



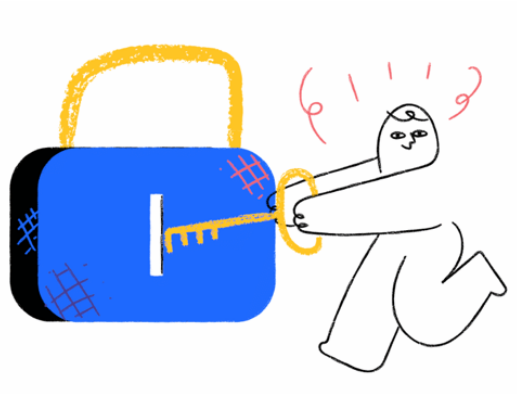
Cluster description:
A flexible lifestyle is becoming increasingly popular. People, particularly younger generations that use technology, are increasingly choosing and being able to work remotely.

Factors:
1.Remote working is on the rise, especially after COVID-19.

2.Digital nomads are an increasing trend of younger generations who utilize technology to make a career while migrating from one region to another. (M., 2018, November 8)

3.Over the last 35 years, home ownership has dropped, especially among so-called 'Millennials.' This is due in part to rising home prices and stagnant or declining wages. (M., 2018, November 8)

7.Needs of staying in control



Cluster description:
Humans, especially elderly persons, have a strong need to maintain control of their automobiles.

Factors:
1.Humans have a need to feel in control.

2.The majority of respondents from 11 European countries believe that humans should manage their vehicles (70 %) and that autonomous vehicles should include a steering wheel (80%). 41% said they would be uneasy driving alongside an autonomous vehicle (Tennant et al., 2016).

3.Older people prefer private conventional vehicles and are unconcerned about whether AVs are shared or privately owned. (Haboucha, C.J., Ishaq, R., Shiftan, Y., 2017)

Humans want machines to obey their wishes.

8.Needs of feeling free

Cluster description:
People have a need to do what they want. Giving them options could help them feel more in control.

Factors:
1.People are worried about losing autonomy in AVs.
2.User acceptance largely depends on user autonomy.
3.A number of choices could give humans a feeling of autonomy.

9.Autonomous vehicle drivers facing new safety risks

Cluster description:
When autonomous vehicles interact with conventional vehicles, they may introduce additional safety concerns. Accidents may occur as a result of reduced road capacity, for example. Equipment failures, liability issues, privacy concerns, ethical challenges, and cybersecurity are also concerns.

Factors:
1.AVs will make up a modest percentage of the vehicle fleet by 2030, coexisting with conventionally powered vehicles. There are still significant safety concerns. (Alonso Raposo et al, 2017)

2.Increased urban development, autonomous taxis, or a lesser usage of public transportation could all raise travel demand as a result of making road travel cheaper, more comfortable, and efficient for new user groups. Because traffic conditions are so tightly linked to transportation demand, they may even worsen. (Alonso Raposo et al, 2017)

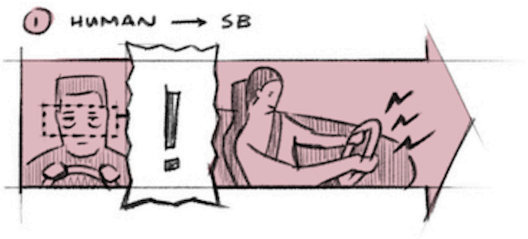
3.A study found that approximately 88% of the respondents were concerned about riding in AVs, 79% were worried about equipment failures, 59% were concerned about liability issues, and 52% were concerned about hacking issues (Seapine Software, 2014).

4.The majority of research also agreed on potential obstacles to AV adoption, such as legal liability and ethical problems, privacy concerns (such as the disclosure of trip data), cybersecurity, and hacking concerns. (Gkartzonikas, C., & Gkritza, K., 2019)

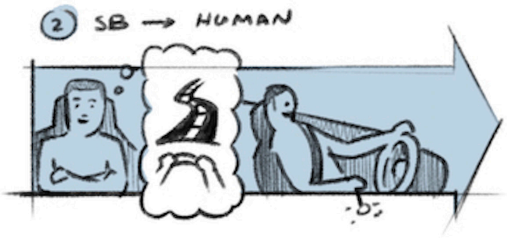
▲
Illustration from Simple illustrations

VIII.Mediator use cases

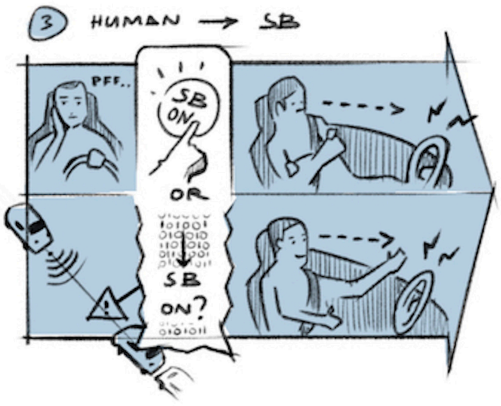
Use case 1:
MEDIATOR initiated take over Human -> Automation:
MEDIATOR detects degraded human fitness caused by A). drowsiness B). distraction, and initiates a forced take over to automation.



Use case 2:
Automation -> Human:
Driver takes back control: the human driver indicates a desire to take back control via the HMI.

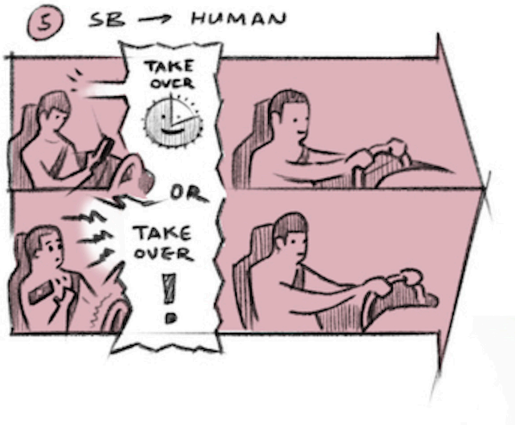


Use case 3:
Comfort take over Human -> Automation:
A). Driver initiated: driver is not motivated to drive and indicated a preference for automation to drive via the HMI.
B). Mediator initiated: Mediator detects an event (such as a text message or an upcoming traffic jam and uses historical data to conclude that the driver would likely want to hand over control. Mediator proposes the Human --> Automation take over.
Because whether taking over is beneficial or preferred depends on the driver, use case 3b does not result in a negotiating ritual. The car can only give one signal, and it is up to the driver to determine what to do with it.



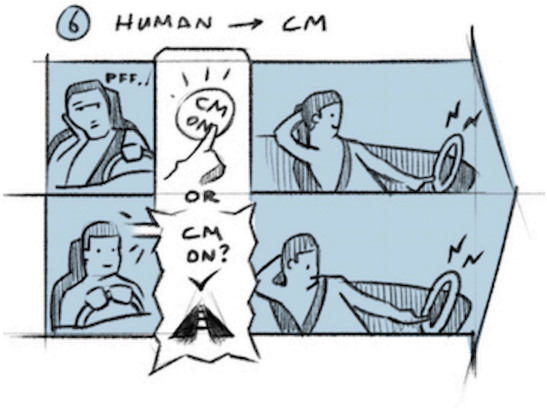
Use case 4:
Corrective Mediator action during standby: the human gets drowsy while expected to be on standby.
Mediator tries to improve the driver fitness and monitor the effect.

Use case 5:
Mediator initiated take over Automation -> Human:
A). Planned: the automation communicates that the current route will leave the Operational Design Domain (ODD) within the next seconds.
B). Unplanned: the automation communicates that its reliability is degrading rapidly and the human should take over within seconds. Mediator informs the human and guides an urgent take over.



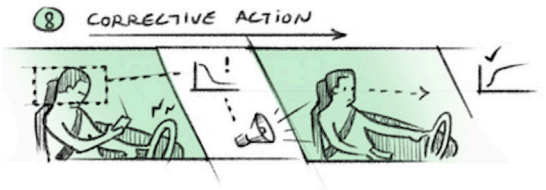
Use case 5b does not lead to a negotiation ritual because it is an urgent take over. The corrective measurement will occur when the driver does not respond to the car's takeover requests. If corrected measurement could not effectively activate the driver, the counter measurement (e.g. the car should stop at a safe area) should apply.

Use case 6:
Comfort CM switch on:
A). Driver initiated: Human is not motivated to drive fully manually and indicated this via the HMI.
B). Mediator initiated: Mediator detects reliable automation and uses historical data to conclude that the human likely preferes to activate partial automation.
Because whether taking over is beneficial or preferred depends on the driver, use case 6b does not result in a negotiating ritual. The car can only give one signal, and it is up to the driver to determine what to do with it.

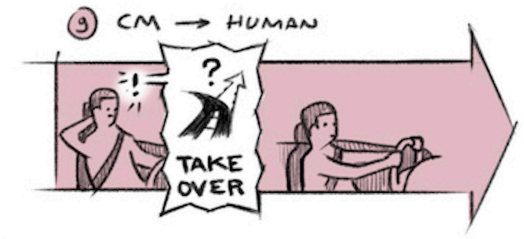


Use case 7:
Prevention – CM Keep the driver in the loop:
While driving with L2 automation, Mediator tries to prevent underload of the human drive and keep him/her in the loop by providing an active task. What this task will entail is one of the research questions.

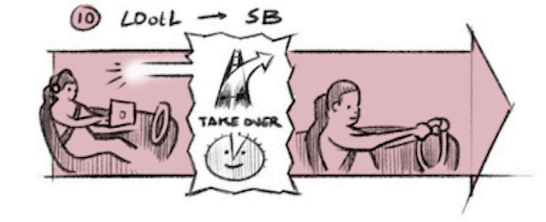
Use case 8:
Corrective – CM Get the driver back into the loop:
While driving with L2 automation drowsiness or distraction is detected. Mediator initiates a correction action such as a voice message to get the driver back in the loop.



Use case 9:
CM shuts off immediately:
While driving with L2 automation the road markings degrade and Mediator indicates L2 will shut off immediately.



Use case 10:
Smooth transition from Long Out of the Loop to Stand By:
The driver is fully out of the loop while driving on the highway with L4 automation when the route is approaching a highway exit. Mediator informs the drive that the standby mode (L3) will be switched on and monitors the driver fitness for this standby task.
Use case 10 does not result in a negotiating ritual since there is no negotiation space for human drivers when the system has to change from Time to Sleep mode to Standby mode.



IX.Brainstorm and workshops results

1.Brainstorm:

I facilitated a 10-minute brainstorm session with 2 other design students who are involved with the development of the force feedback shifter. I voted for the ideas during data analysis. Our ideas could be seen in figure 94.

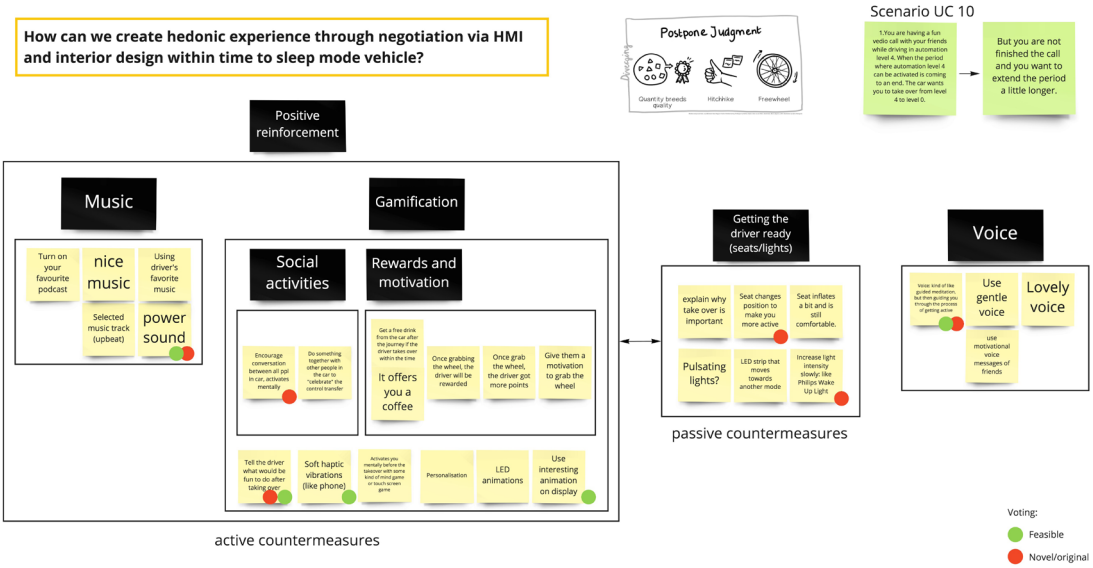


Figure 94. Brainstormed ideas with votes.

2.Workshop 1:

An online workshop was conducted with 3 design students and I played a role as a problem owner. The 2-hour workshop schedule could be seen in figure 95. The design question was rephrased as “how can we make an interface to let the driver feel safe and comfortable?” by the workshop members (see figure 96). Then, initial ideas (see figure 97) and more creative ideas (see figure 98) were generated through purge and brainwriting methods. The group arranged all ideas into similar categories (see figure 99) and voted for our favorite ideas that are feasible and novel in green and red dots (see figure 100). At the end of the workshop, a concept was generated according to the voted ideas(see figure 101). It was an interface that contained screens and voices for negotiation. Through screens, drivers could change modes and it could indicate emergent situations in red color to alert the driver. Voice messages will explain more about the situation and the driver could choose their favorite voice for the car.

Figure 95. The schedule of workshop 1.

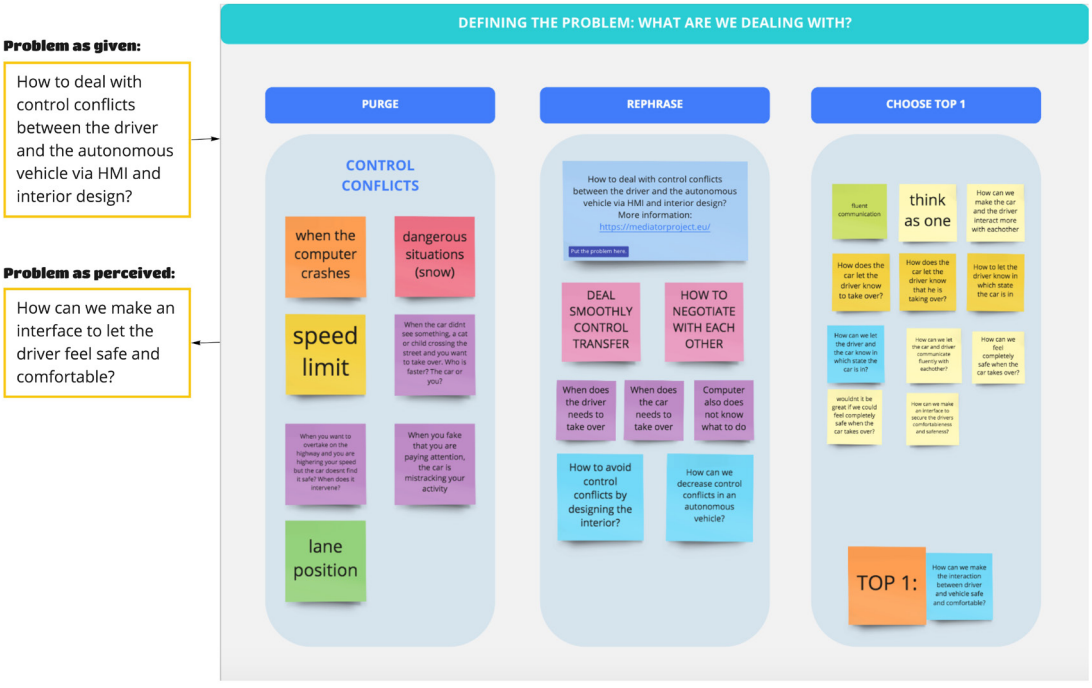


Figure 96. Rephrasing the design question.

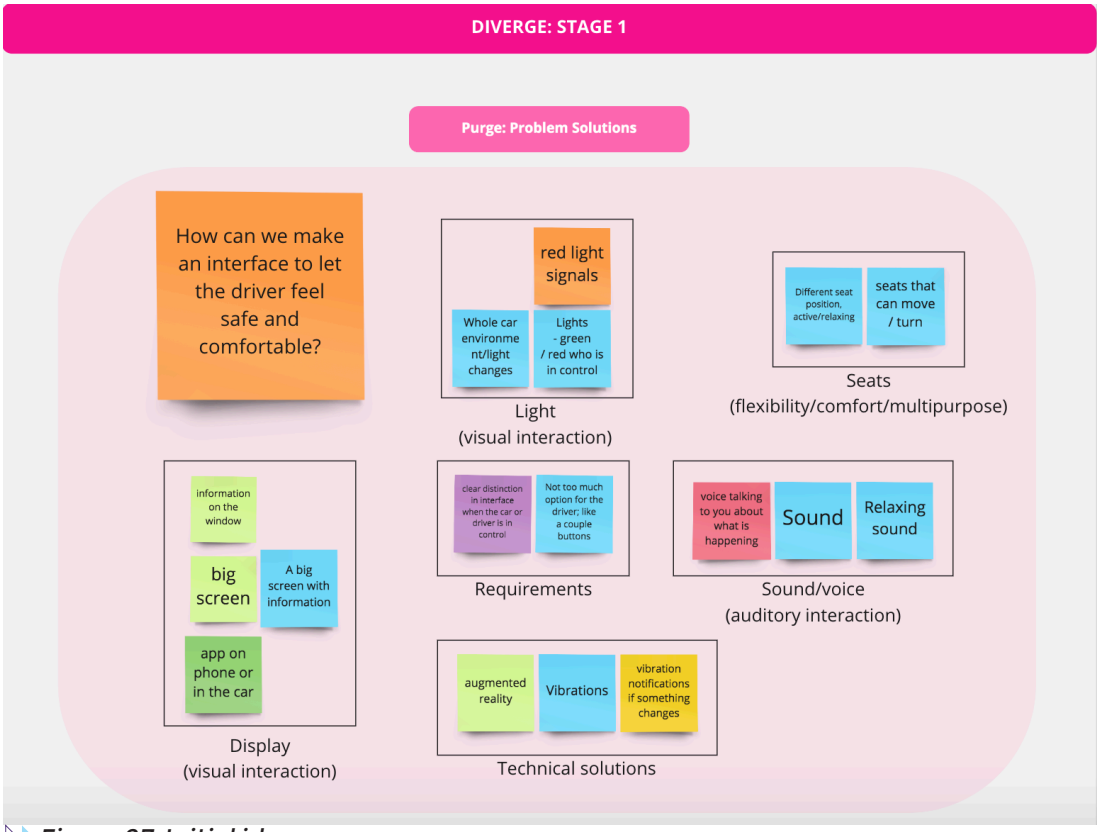


Figure 97. Initial ideas.

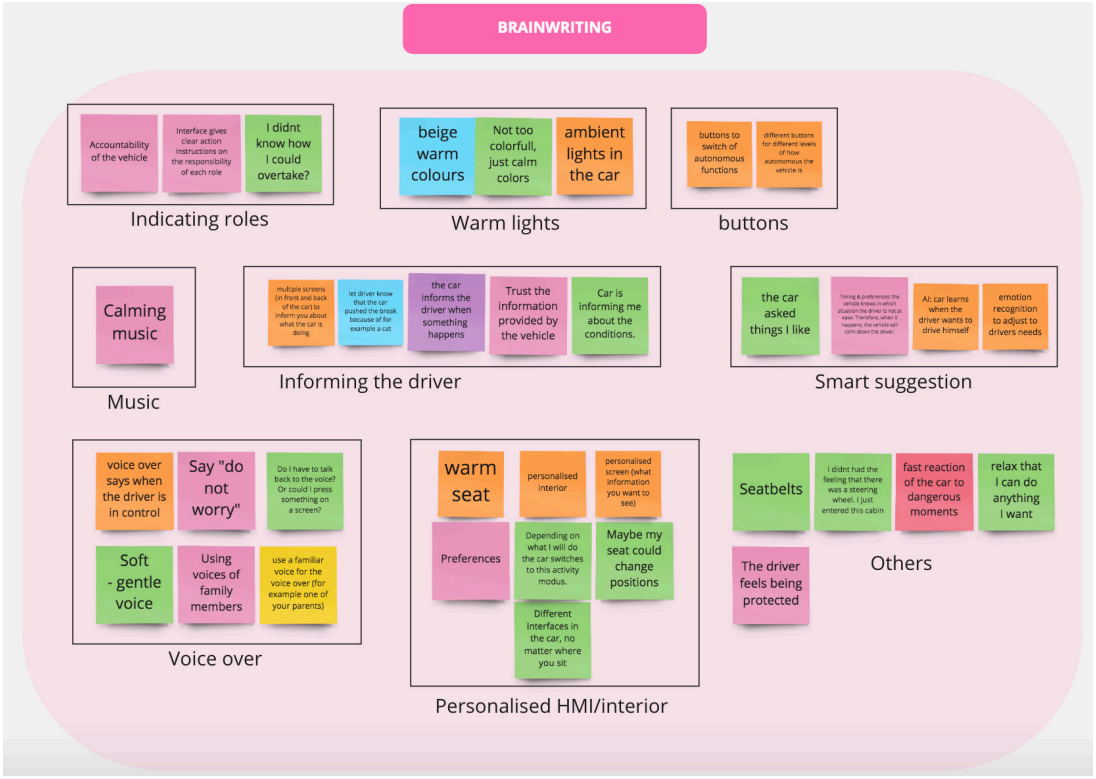


Figure 98. Creative ideas.

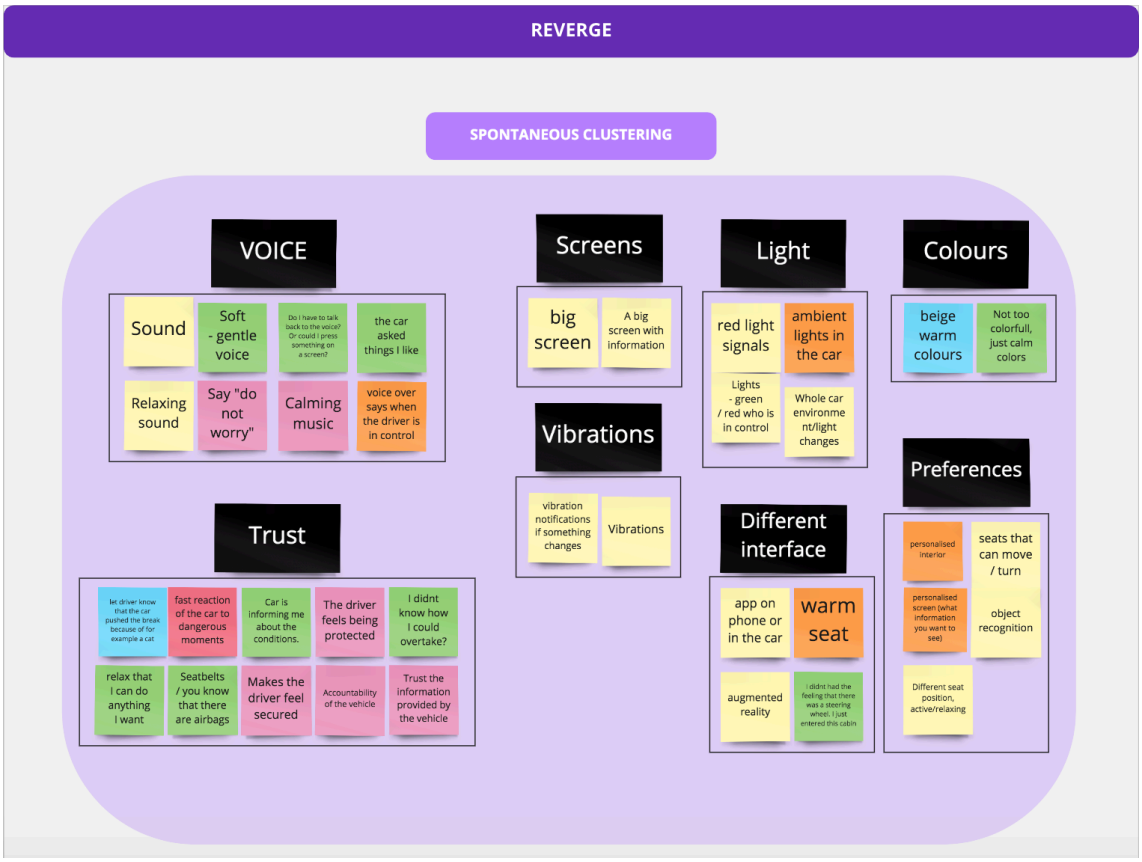


Figure 99. Clustering ideas.

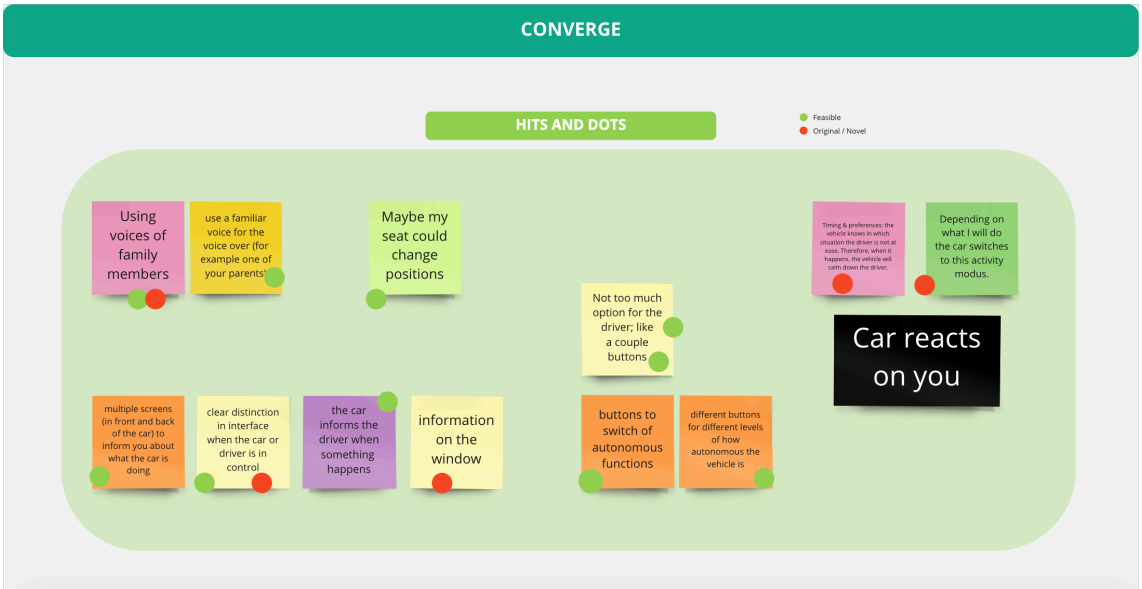


Figure 100. Voting for favorite ideas that are feasible and novel in green and red dots.

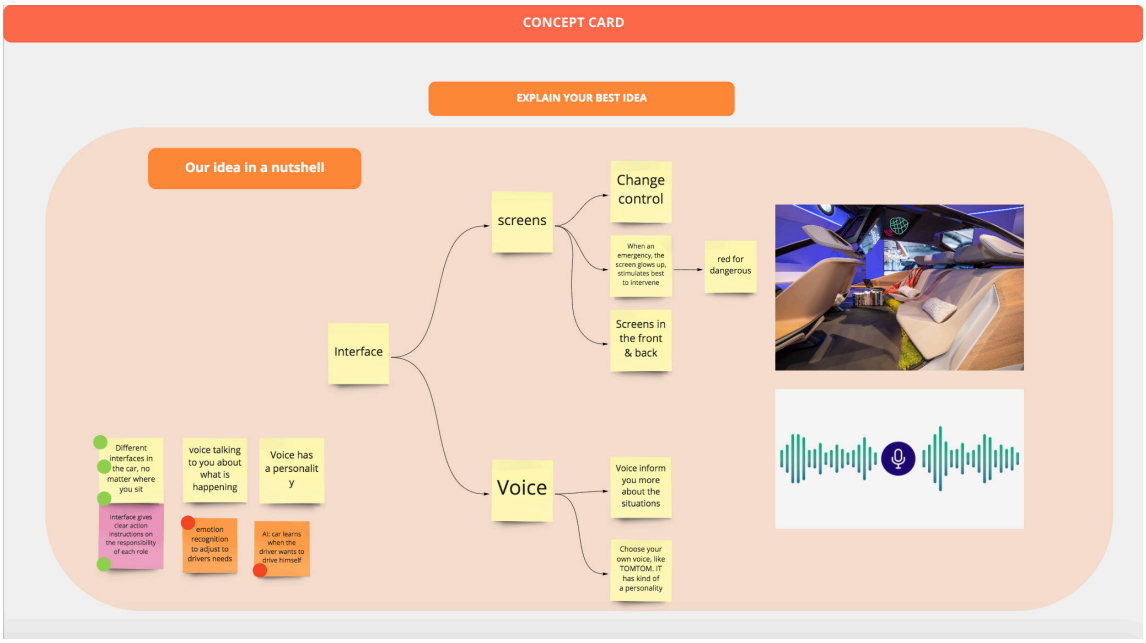


Figure 101. A concept that used screens and voices was generated.

3.Workshop 2:

I planned and facilitated the second workshop with 2 design students and 1 product designer within 70 minutes in person. It contains two phases: problem finding and idea finding. The process could be seen in figure 102. In the problem finding phase, participants wrote down initial ideas (i.e. purge) and then rephrased the original design question to a question that they could emphasize with (see figure 102). In the idea finding phase, participants generated their initial ideas (i.e. purge) and had more creative ideas (i.e. brainwriting) after getting inspiration from a guided fantasy that tells a story based on use case 5a. I categorized the ideas and gave my votes according to feasibility and novelty of the ideas during data analysis. Initial ideas could be seen in figure 103 and more creative ideas could be seen in figure 104. The idea of offering entertainment activities inspired me to do a research on the most popular in-car activities (Carnegie Mellon University College of Engineering. (n.d.)) and analyzed the most relevant HMI elements that support these activities in the context of autonomous vehicles (see figure 105). Accordingly, a sketch of potential interior design that could support these activities were created in figure 106. However, the seats could not turn around due to the narrow space inside the prototyping car that the Mediator project will use. After presenting the interior idea, the Mediator members shared the defined interior components, which helped me to redefine my design space within this framework (in chapter 2).

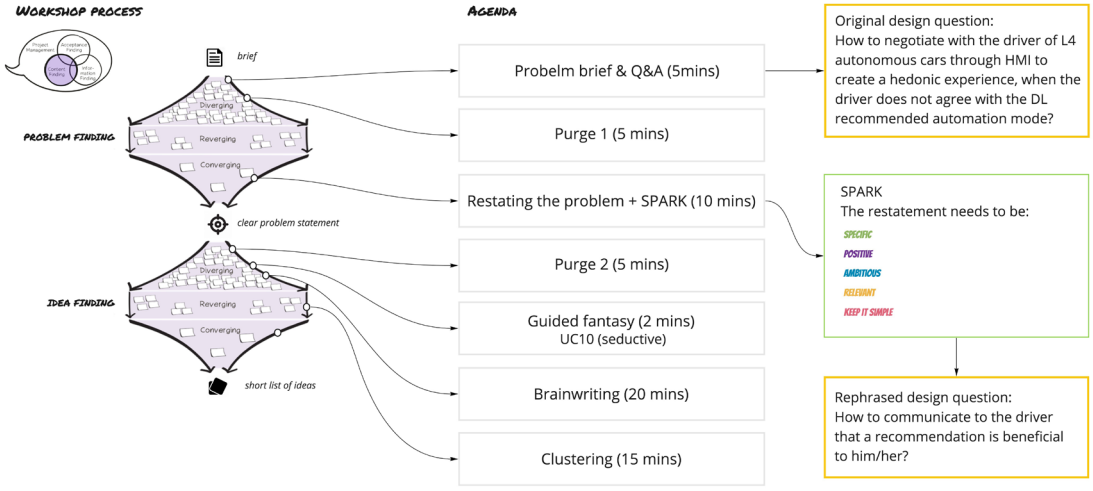


Figure 102. Process of the second workshop.

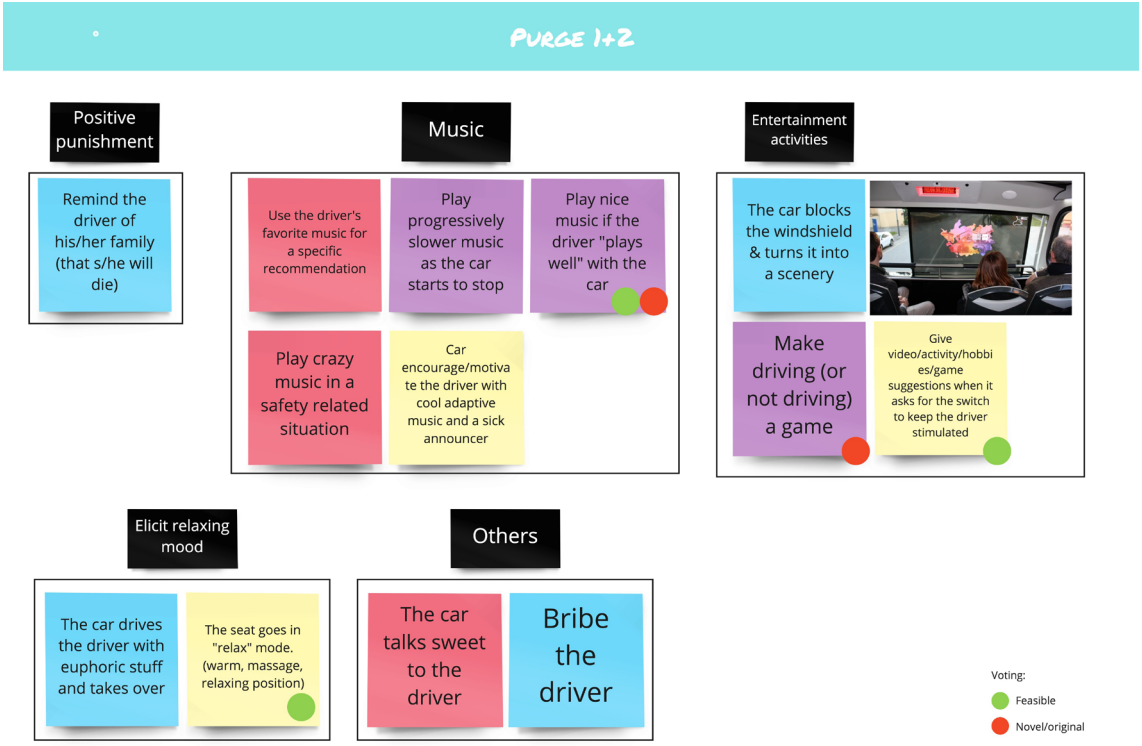


Figure 103. Categorized initial ideas with votes.

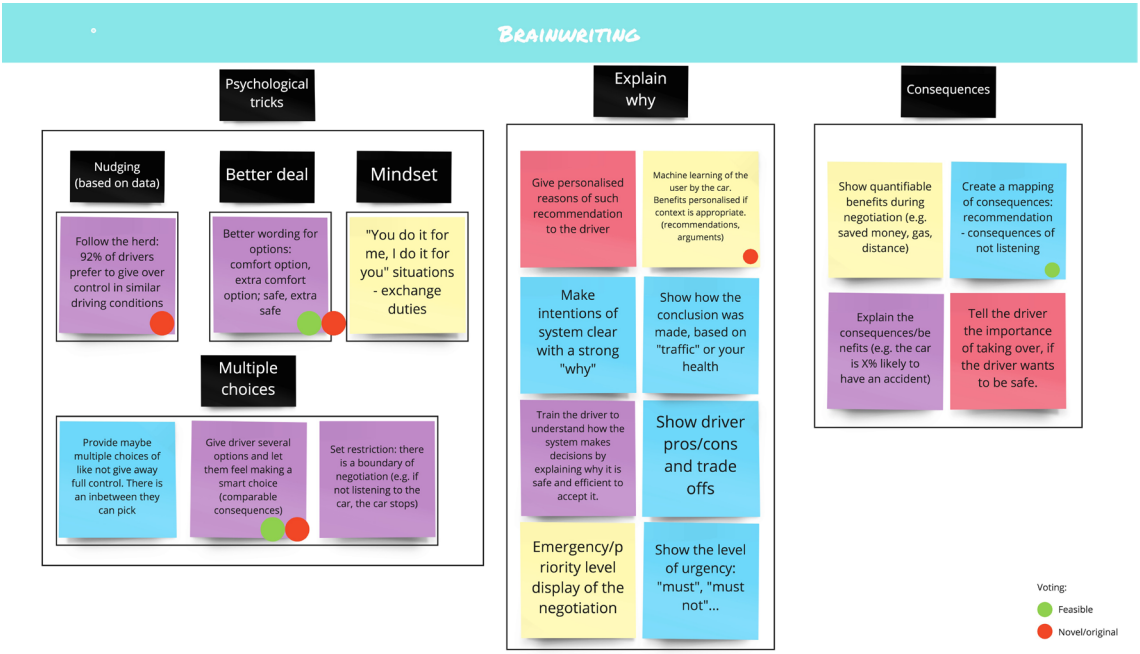


Figure 104. Categorized creative ideas with votes.

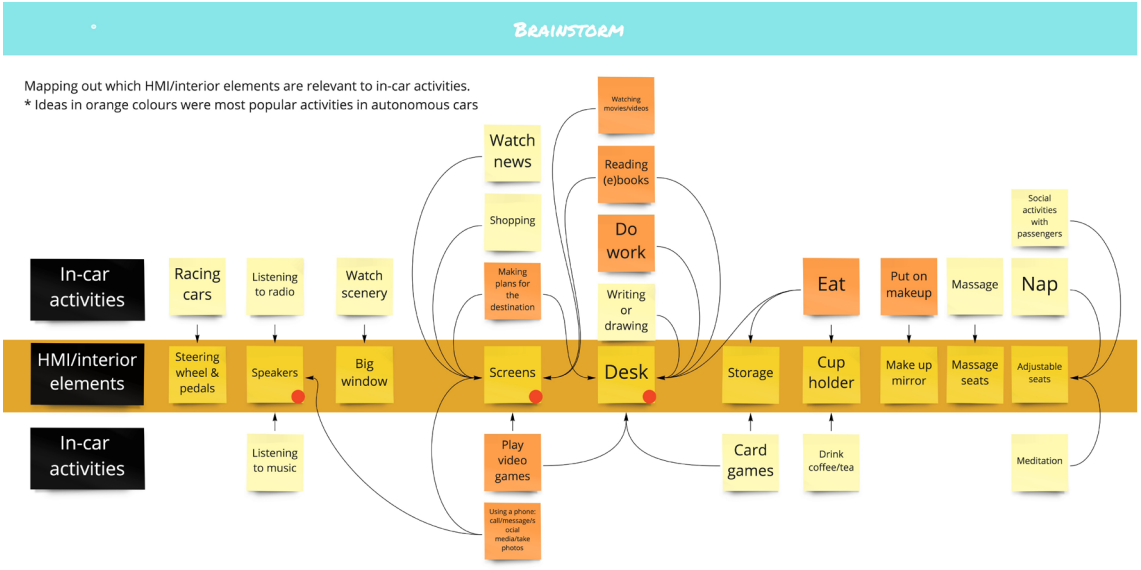


Figure 105. Brainstorm of HMI elements that support most popular in-car activities marked in orange post-its.

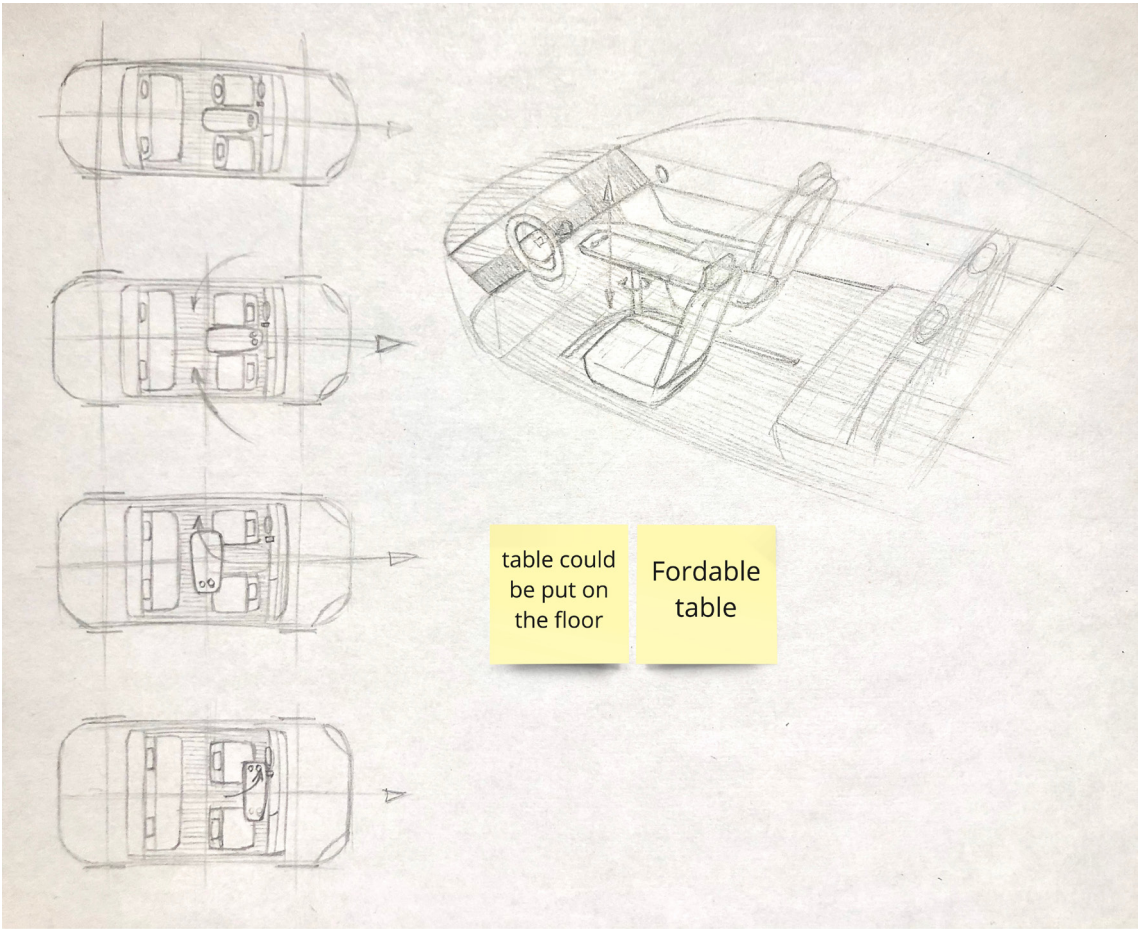


Figure 106. Sketch of potential interior that supports the most popular in-car activities.

X.Workflows

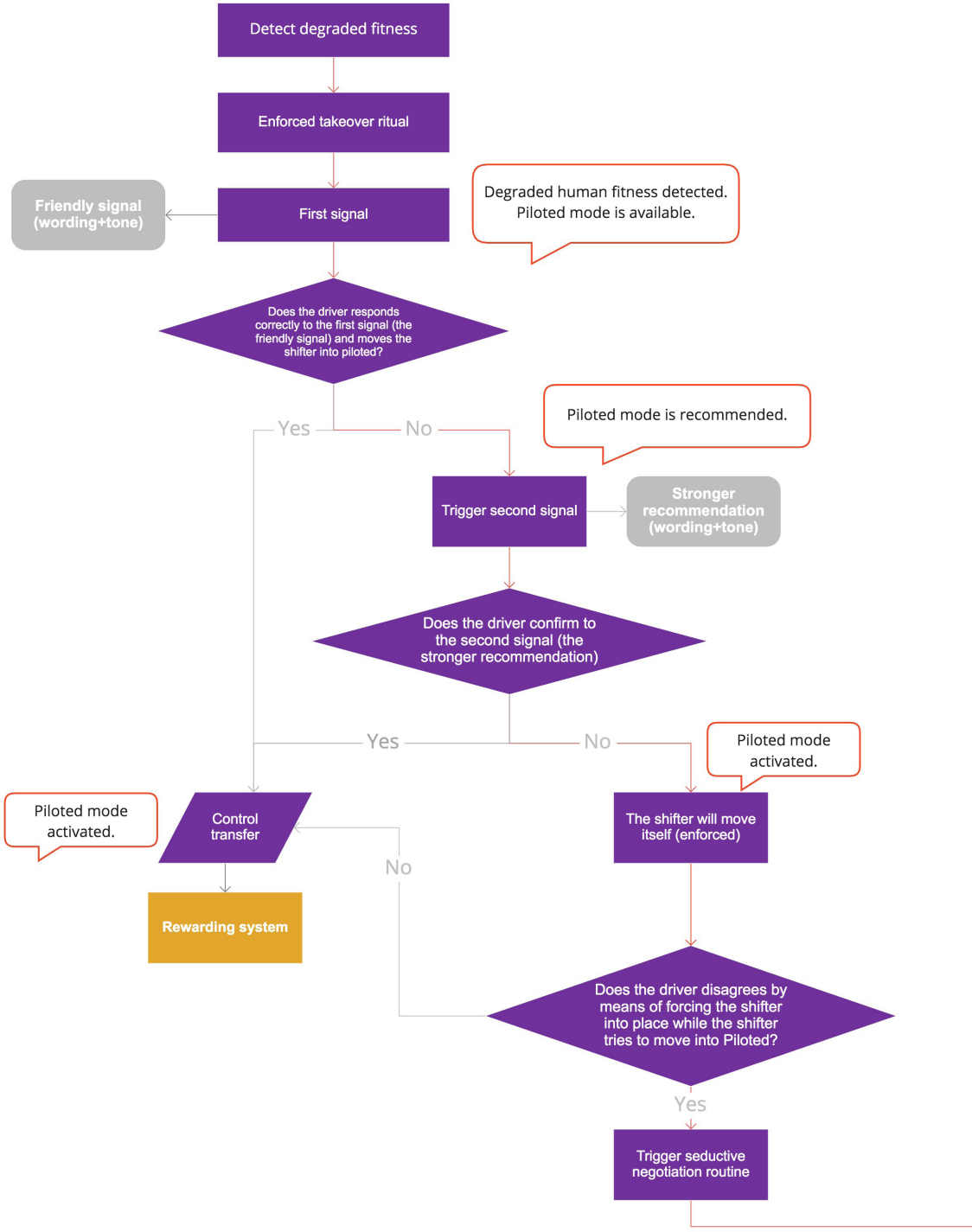
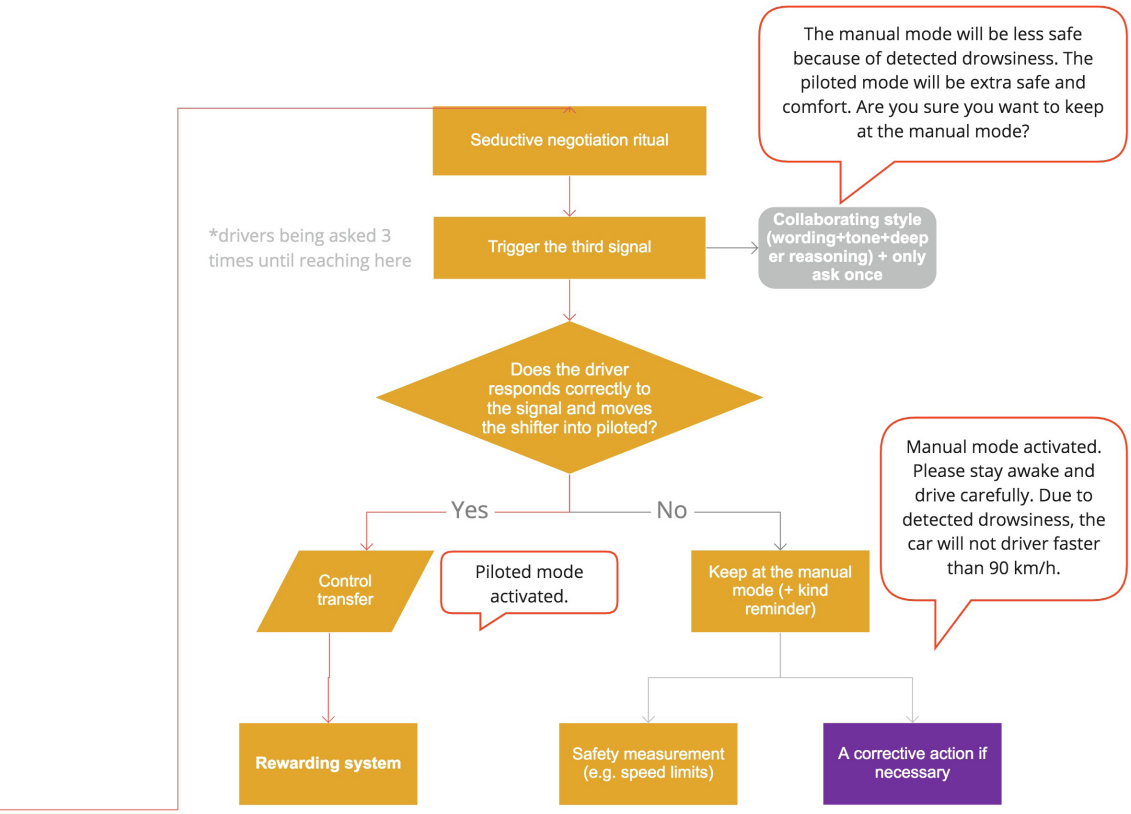


Figure 107. Detailed workflow for testing concept iteration 1.


The manual mode will be less safe because of detected drowsiness. The piloted mode will be extra safe and comfort. Are you sure you want to keep at the manual mode?
Seductive negotiation ritual
*drivers being asked 3 times until reaching here
Trigger the third signal
Collaborating style (wording+tone+deeper reasoning) + only ask once
Does the driver responds correctly to the signal and moves the shifter into piloted?
Yes
No
Manual mode activated. Please stay awake and drive carefully. Due to detected drowsiness, the car will not driver faster than 90 km/h.
Control transfer
Piloted mode activated.
Keep at the manual mode (+ kind reminder)
Rewarding system
Safety measurement (e.g. speed limits)
A corrective action if necessary

XI.High fidelity visuals

The visuals were created in Figma and were based on the design systems made by Ilse van Zeumeren.

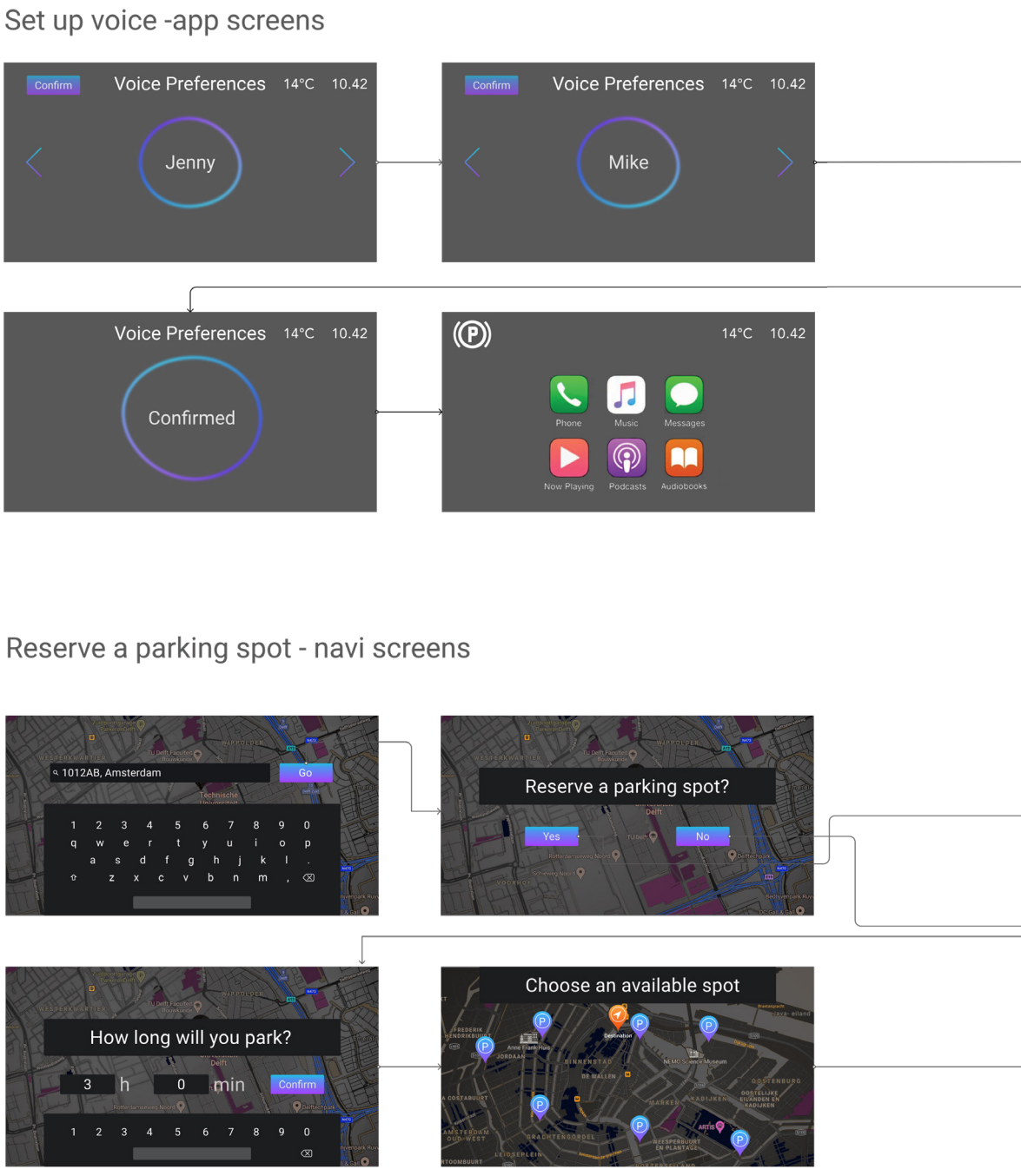
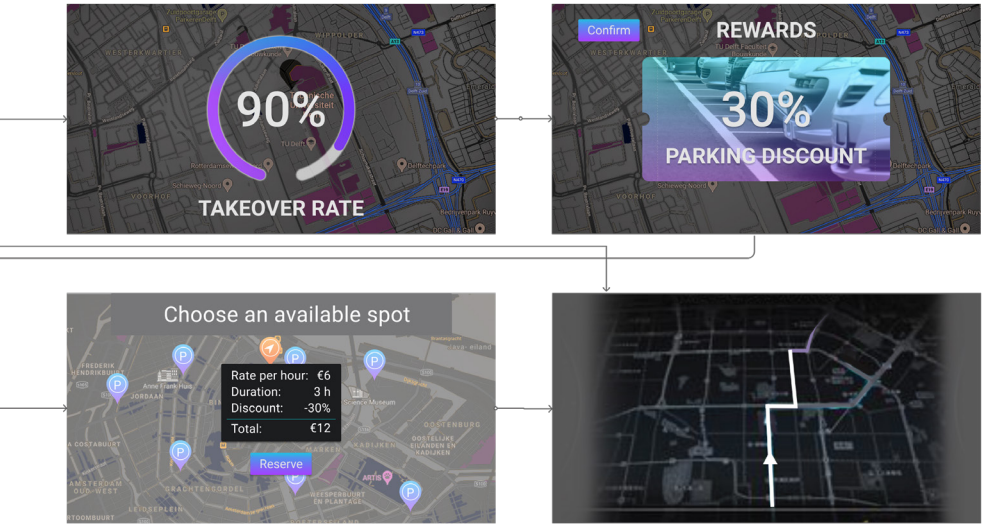


Figure 109. Scene 2 - reserve a parking spot with a discount through navigation screens of the dashboard screen.

Figure 108. Scene 1 - Choose favorite voices of the car through app screens of the dashboard screen.



UC 1a,5a,3a - app screens

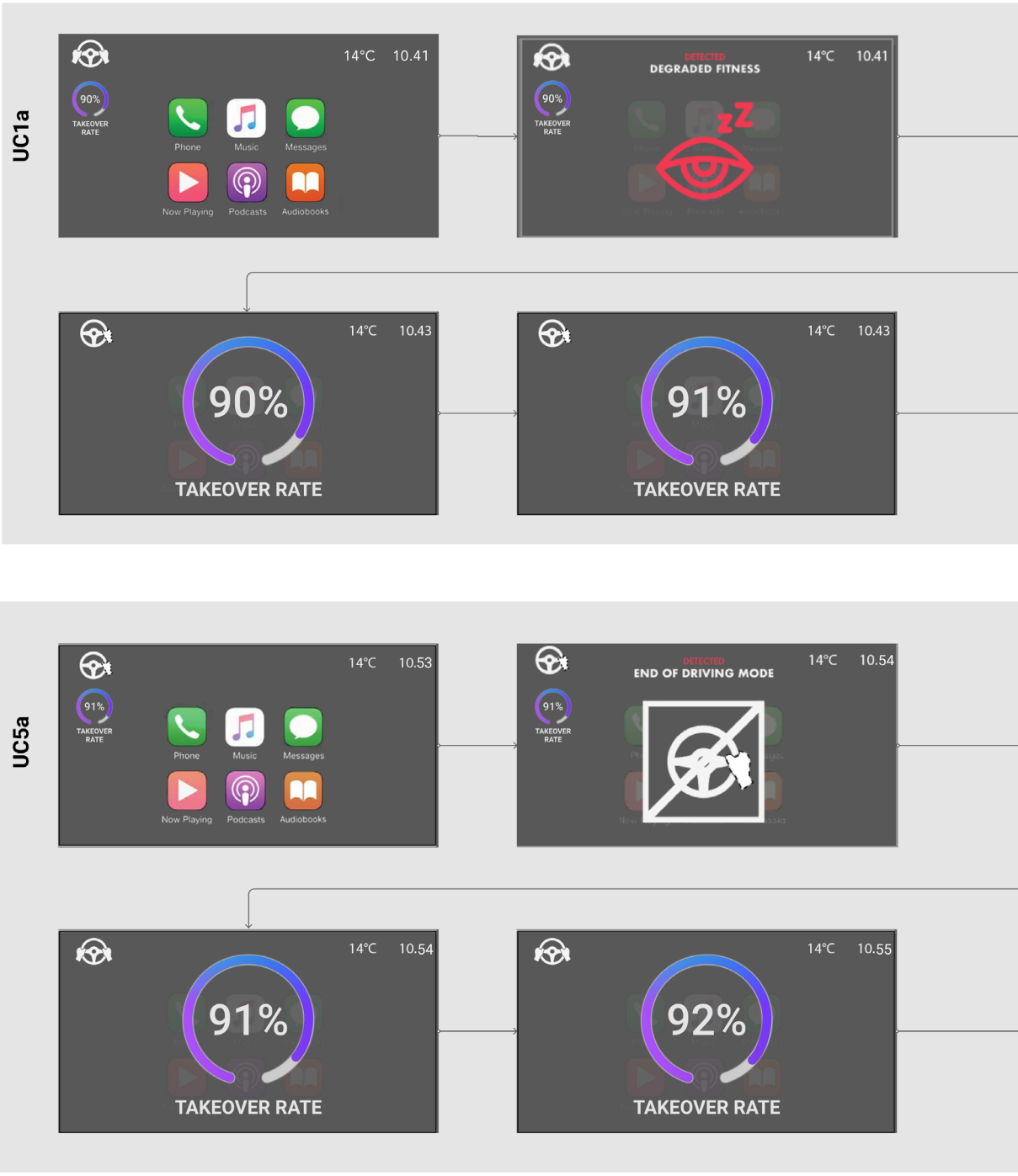
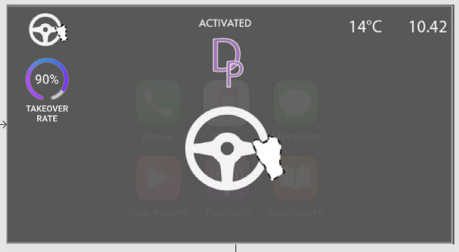
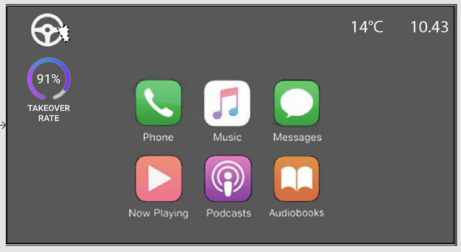
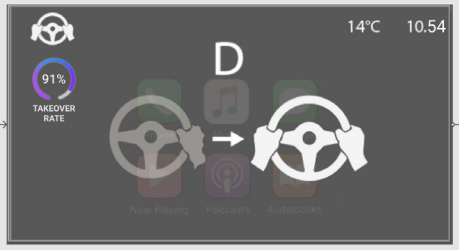


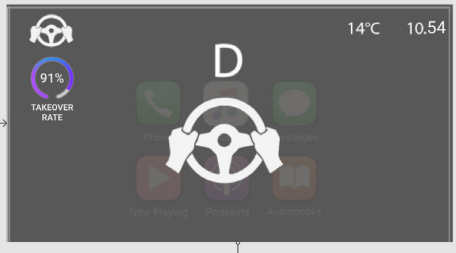
Figure 110. Scene 3 & 4 - take over rate increases on app screens when following recommendations in use case 1a & 5a.

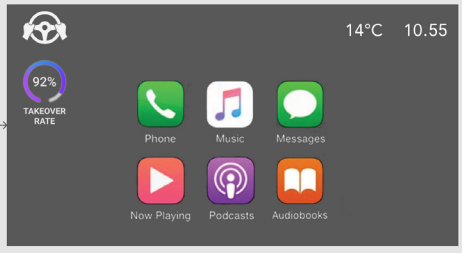

ACTIVATED
14°C 10.42
90%
TAKEOVER RATE


ACTIVATED
14°C 10.42
90%
TAKEOVER RATE


14°C 10.43
91%
TAKEOVER RATE
Phone
Music
Messages
Now Playing
Podcasts
Audiobooks


14°C 10.54
D
91%
TAKEOVER RATE


14°C 10.54
D
91%
TAKEOVER RATE


14°C 10.55
92%
TAKEOVER RATE
Phone
Music
Messages
Now Playing
Podcasts
Audiobooks

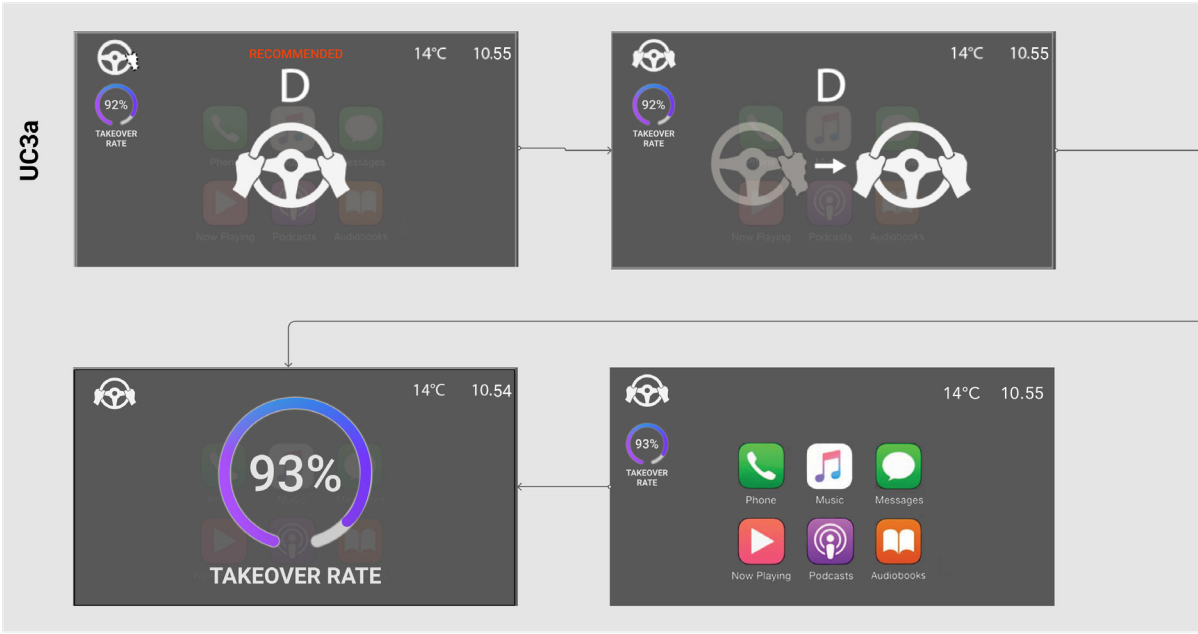


Figure 111. Scene 5 - take over rate increases on app screens when following recommendations in use case 3a.

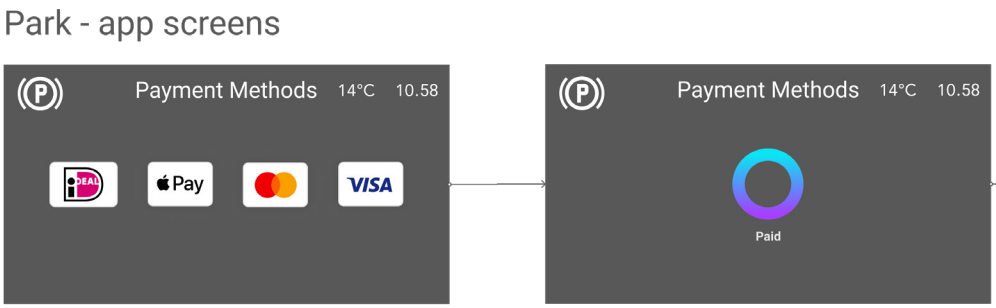
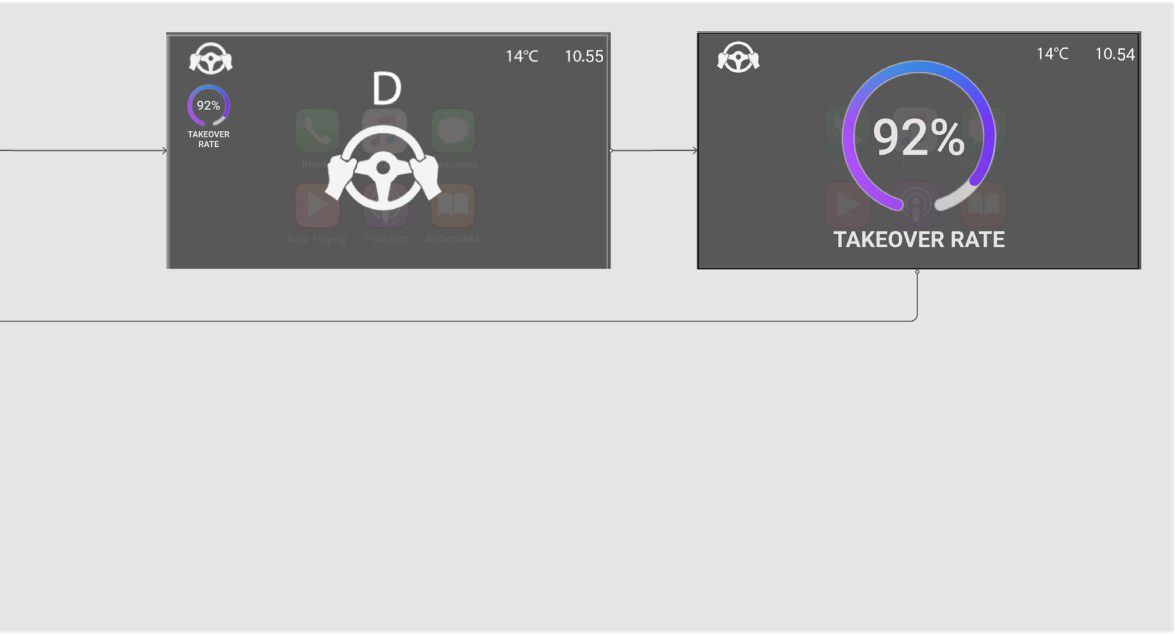
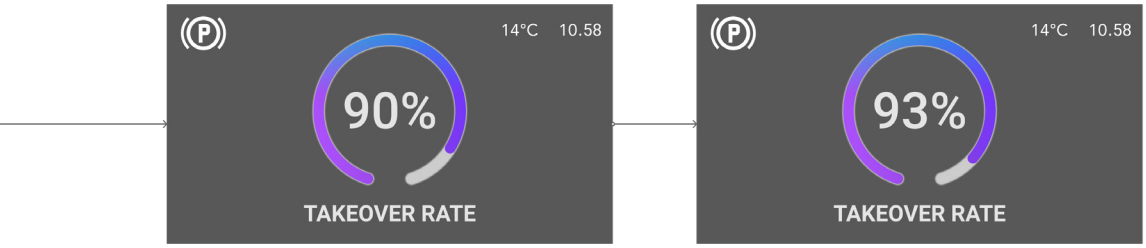


Figure 112. Scene 6 - park and pay for the reserved spot. Obtain a comprehensive glimpse of the entire journey's takeover rate changes on app screens.


14°C 10.55
D
92%
TAKEOVER RATE
14°C 10.54
92%
TAKEOVER RATE


14°C 10.58
90%
TAKEOVER RATE
14°C 10.58
93%
TAKEOVER RATE