

MESTRADO IN INTERACTION DESIGN

Final Master's Project designed to obtain
the Master's degree in Interaction Design

DEVELOPMENT OF AN INTERACTIVE SYSTEM FOR SHARED AUTONOMOUS VEHICLES

President: Professor Sónia Isabel Ferreira dos Santos Rafael (PhD)
Supervisor: Professor Paulo Ignácio Noriega Pinto Machado (PhD)
Arguent: Professor José Rui de Carvalho Mendes Marcelino (PhD)
Author: Gualter Renato da Costa Taveira Ferrada

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TESE DE MESTRADO EM DESIGN DE INTERAÇÃO

Projeto Final de Mestrado elaborado para a obtenção
do grau de Mestre em Design de Interação

DESENVOLVIMENTO DE UM SISTEMA INTERATIVO PARA VEÍCULOS AUTÓNOMOS PARTILHADOS

Presidente: Professora Sónia Isabel Ferreira dos Santos Rafael (PhD)

Orientador: Professor Paulo Ignácio Noriega Pinto Machado (PhD)

Arguente: Professor José Rui de Carvalho Mendes Marcelino (PhD)

Autor: Gualter Renato da Costa Taveira Ferrada

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FACULDADE DE ARQUITETURA
LISBON SCHOOL OF ARCHITECTURE
UNIVERSIDADE DE LISBOA

DEDICATION

I would like to dedicate this research final project to my girlfriend that encouraged me to apply for the Interaction Design master degree in the Faculty of Architecture of Lisbon University and always supported me along the way. Furthermore, to my mother, brother and grandmother for being there when I needed them to evaluate and iterate solutions without ever saying “no”. To my closest friends for understanding when I could not join them for partying and dinner out since I was working on this research.

Finally, to Landig.jobs Product team (my former professional colleagues) for helping me and providing insights during the generative phase that were very important to the development of this research project.

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First, I would like to thank the Faculty of Architecture, and especially the Interaction Design professors, for the knowledge and resources that they shared with me to develop this research project.

Paulo Noriega was a huge pillar during this research project for various reasons: patience, wisdom and comprehension. I believe that every thesis project development is harsh for the author and this one was not different. I had to find my way through my full-time job at Landing. jobs as a UX Designer, my house moves, supervisor problems and then a new full-time job at Millennium bcp as a Product Designer. In this regard, I truly appreciate that Paulo Noriega supported me and found a way to provide rich insights to our research project and sometimes my professional career.

Although Mafalda Casais had to abandon this research supervision, I appreciate the time we spent working on this project, since a big part of it is also hers. Francisco Rebelo was also a huge help during the writing of the paper “ForSav: A Mobile Application for Matchmaking Profiles in a Dynamic-Ride Sharing System” and I appreciate his effort during that time.

I believe that I am truly blessed by the friends, family and girlfriend I have since everyone supported me during this path allowing me to accomplish a life goal.

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ABSTRACT

Autonomous Vehicle's (AV's) are aimed to be the future of mobility due to the extinction of deadly crashes and the environmental friendliness. Considering autonomous driving, the solution that provides the biggest advantages towards consumption reduction is shared autonomous vehicles, but are future citizens willing to adopt this transportation modality? The development of an interactive system design for shared autonomous vehicles, that addresses in-vehicle needs to its different users in private and shared contexts, was pursued as a solution to the optimisation of shared rides. Through methods as literature review, benchmark, surveys, information architecture (IA), prototyping, brainstorming sessions, Usability and user experience (UX) tests, we defined in-vehicle activities and the criteria that affects future potential users' experience. The freedom to choose other passengers when scheduling a ride in a mobile application; constant feedback about CO² emissions reduction; in-vehicle voice commands and gestures interaction; and activities as watching a movie or making virtual journeys during a ride, were appreciated by future potential users. Perceived emotions as "Joy", "Interest" and "Amusement" were dominant during Usability and UX tests. Although comfort (a human experience regarding social aspects and personal safety) should be considered during the development of these systems, concerning issues were found in our solution regarding distrust in some cases or even minorities discrimination. Future studies using different solutions and evaluation methods are highly encouraged to the development of this research field area.

Keywords: Co-experience; Human-machine interaction; Immersive experience; Interactive system; Shared autonomous vehicles.

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RESUMO

Os VA's ambicionam ser o futuro da mobilidade pela extinção das colisões mortais e respeito pelo ambiente, no entanto a solução que apresenta maiores vantagens para a redução de consumos são os veículos autónomos partilhados. Mas estarão os futuros cidadãos dispostos a adotar esta modalidade de transporte? O desenvolvimento de um projeto para um sistema interativo para veículos autónomos partilhados, que atenda às necessidades de diferentes utilizadores durante a viagem em contextos privados e partilhados, foi perseguido como uma solução para a otimização de viagens partilhadas. Através de métodos como o estado da arte, benchmark, questionários, arquitetura da informação (AI), prototipagem, sessões de brainstorming, testes de Usabilidade e Experiência do Usuário (UX), definimos as atividades no veículo e os critérios que afetam a experiência de potenciais futuros utilizadores. A liberdade de escolher outros passageiros no agendamento de uma viagem numa app; feedback constante sobre a redução de emissões de CO²; comandos de voz e interação por gestos no veículo; e atividades como assistir a um filme ou fazer viagens virtuais durante uma viagem foram apreciadas por potenciais futuros utilizadores. A percepção de emoções como "Alegria", "Interesse" e "Diversão" foram dominantes durante os testes de Usabilidade e UX. Embora o conforto (uma experiência humana relacionada com aspectos sociais e de segurança pessoal) deva ser considerado durante o desenvolvimento destes sistemas, foram encontrados problemas preocupantes na nossa solução relacionados com desconfiança em alguns casos ou mesmo discriminação de minorias. Estudos futuros usando diferentes soluções e métodos de avaliação são altamente encorajados para o desenvolvimento da área de investigação.

Palavras-chave: *Co-experience*; Experiência imersiva; Interação homem-máquina; Sistema interativo; Veículos autónomos partilhados.

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ACRONYMS

AR - Augmented reality

AVs - Autonomous Vehicles

BCI - Brain-computer interface

CAVs - Connected autonomous vehicles

CES - Consumer electronic show

DARPA - Defense Advanced Research Projects Agency

DH - Declaration of Helsinki

ECCRI - European Code of Conduct for Research Integrity

ECG - Electrocardiography

EEG - Electroencephalography

EMG - Electromyography

GEW - Geneva emotions wheel

HCI - Human-computer interaction

HMC - Human-machine cooperation

HMI - Human-machine interaction

IDT - Interactive disruptive technologies

IoT - Internet of things

IVIS - In-vehicle infotainment system

L - Law

NBIC - Nano-bio-info-cogno

NHTSA - National Highway Traffic Safety Administration

NRTD - Non-related to driving

SAVs - Shared Autonomous Vehicles

SAM - Self-assessment Manikin

UI - User interface

UX - User experience

VAs - *Veículos autónomos*

VAMR - Virtual augmented mixed reality

VE - Virtual environment

XR - Extended Reality

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GLOSSARY

AVs - Autonomous vehicles

Autonomous vehicles are vehicles capable of driving with less assistant from humans or without assistant at all. Vehicles are divided in five different levels of autonomy: zero when driver fully control the vehicle; one for steering or acceleration performed by the vehicle; two for some functions using external information about the driving environment; three for fully autonomous vehicles under specific environments and traffic conditions; four for safety-critical driving scenarios, but not all of them; five when vehicles are capable of operating in every scenario (Duarate et al., 2018).

CAVs - Connected autonomous vehicles

Connected autonomous vehicles are vehicles connected through an external network to prevent traffic accidents and reduce gas emissions, which are inserted in level five of vehicles autonomy (Kopelias et al., 2020).

Co-experience

Co-experience is about experience in shared social contexts, which leads to different interpretations and meanings, that are created and complemented by different people using the same product, service or system (Forlizzi et al., 2004; Battarbee et al., 2005).

DRS - Dynamic-ride sharing

Dynamic-ride sharing intends shared journeys that have dynamic itineraries. The main purpose of DRS systems is to join different passengers with similar destinations and schedules in the same vehicle to reduce the number of vehicles used for personal traveling (Agatz et al., 2012).

IDT - Interactive Disruptive Technologies

Disruptive technologies characterize products that, for its innovation, turns out to displace established markets (Bower et al., 1995). In this

research, IDT describes innovative products emerging in the Interaction field area .

IVIS - In-vehicle information system

An IVIS is a combination of in-vehicle systems related to entertainment and information provision to the driver and passengers through audio, speech and video interfaces, which commonly provide interactions such as touchscreens and in-vehicle panels (Angelini et al., 2016).

SAVs - Shared autonomous vehicles

Shared autonomous vehicles are fully autonomous and shared between different people through the day or at the same moment (Burns, 2013).

XR - Extended Reality

Extended reality is defined as an enhancement of the real-world perception through sensory experiences and “computer-generated perceptual information”(Casais, 2021, p. 929).

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CHAPTER 1_
INTRODUCTION



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1.1 RESEARCH CONTEXT

Autonomous vehicles (AVs) will drastically change transport systems because of their potential to avoid deadly crashes, provide mobility to the elderly and disabled people, decrease the current traffic and lower emissions (Fagnant and Kockelman, 2015). Furthermore, a good mobility option inside the AVs area is shared autonomous vehicles (SAVs) for the advantages they have considering the last-mile (journey destination) and dynamic-ride sharing solutions (Krueger et al., 2016). Future users are more likely to adopt AVs in shared contexts than in private ones, which is a sign that researchers should be working more towards shared experiences (Pakusch et al., 2018). The academic knowledge gap regarding this area is tremendous, since everyone is working for the social acceptance, trust and comfort in AVs, leaving behind the co-experience of use of interactive systems (Strömberg et al., 2018). The role of human-machine interaction (HMI) in this area is so profound that, in the design of interactive systems to AVs, designers and researchers should be taking into account user experience (UX) in every process stage (Morra et al., 2019). Converging different innovation technologies to SAVs' concept and integrating them within an interactive system is a possibility to answer future users' needs. The wide innovations' range being researched include tactile and motion technologies (Cannan et al., 2011), brain computer interaction (BCI), electroencephalography (EEG), electrocardiography (ECG), and electromyography (EMG) as transparent interfaces to new environments (Schirner, 2013). Extended reality contexts that enhance reality with entertaining solutions, information provision and sensory experiences (Casais, 2021) have been brought to the automation area as an effort to support immersive experiences non-related to driving (NRTD) to future users and increase the advances towards the social acceptance of these mobility solutions (Riegler et al., 2020). In order to achieve a desirable outcome with the present investigation, since it involves a range of different areas, further research was conducted in the following six areas: 1) Shared autonomous vehicles (SAVs); 2) Human-machine Interaction (HMI); 3) Interactive Disruptive Technologies (IDT); 4) Co-experience; 5) Immersive experiences; 6) Interactive Systems.

1.2_RESEARCH STRATEGY

1.2.1_Research Problem

Autonomous vehicles are urging the market to not only change our society's mobility but also the behavior of present drivers and future passengers. This shift from a "joy of driving" to a "joy while driving" (Meschtscherjakov et al., 2015) will open numerous interaction possibilities and quality time to future users. AV's are aimed to be the future of mobility due to the extinction of deadly crashes and the environmental friendliness, however the solution that provides the biggest advantages towards consumption reduction is shared autonomous vehicles. But are future citizens willing to adopt this transportation modality?

The intention of the present research is to design an interactive system that approximates shared mobility to future citizens mentality by assisting their needs before and during a ride. The possibility of scheduling a ride considering users' preference and providing different in-vehicle activities to entertain passengers was pursued and achieved during this final project, because "The joint experience and use of an interactive system, or the co-experience of use, is an issue so far not sufficiently addressed in the research of autonomous vehicles" (Strömberg et al., 2018, p.5).

1.2.2_Research Questions

1.2.2.1_Main research question

How can we use interaction design as a way to optimize shared rides in autonomous vehicles?

1.2.2.2_Secondary research questions

What are in-vehicle activities of future potential users?

How can an interactive system consider users' preference when joining different passengers in the same ride?

How can an interactive system fulfill different needs for different people in the same vehicle?

1.2.3_Research Goals

1.2.3.1_General research goal

- Design an interactive system for SAVs with shared and individual experiences considering the moment when a user schedules a ride until he/she gets to his/her destination.

1.2.3.2_Specific research goals

- Define potential users needs, expectations and activities in shared autonomous vehicles;
- Define the criteria that affects the experience of potential users while sharing rides.

1.3_RESEARCH POSITIONING

In order to reach a desirable outcome with this research, a good understanding of our contribution to the research community and the state of the art is needed.

As identified (Fig.1), mobility, entertainment and interaction design are the main field areas involving six specific areas: 1) Shared autonomous vehicles (SAVs); 2) Human-machine Interaction (HMI); 3) Interactive Disruptive Technologies (IDT); 4) Co-experience; 5) Immersive experiences; 6) Interactive Systems. For research purposes, the three main field areas (Mobility, Entertainment and Interaction Design) will not be discussed in depth, but rather the specific identified areas. In this regard, looking at the specific areas, a greater importance is observed in the theme of SAVs and interactive systems, followed by co-experience field area, immersive experiences and human-machine interaction (HMI). Interactive disruptive technologies (IDT) will allow and justify our research approach through different technology applications into an integrated interactive system to SAVs that support future potential users in-vehicle activities.

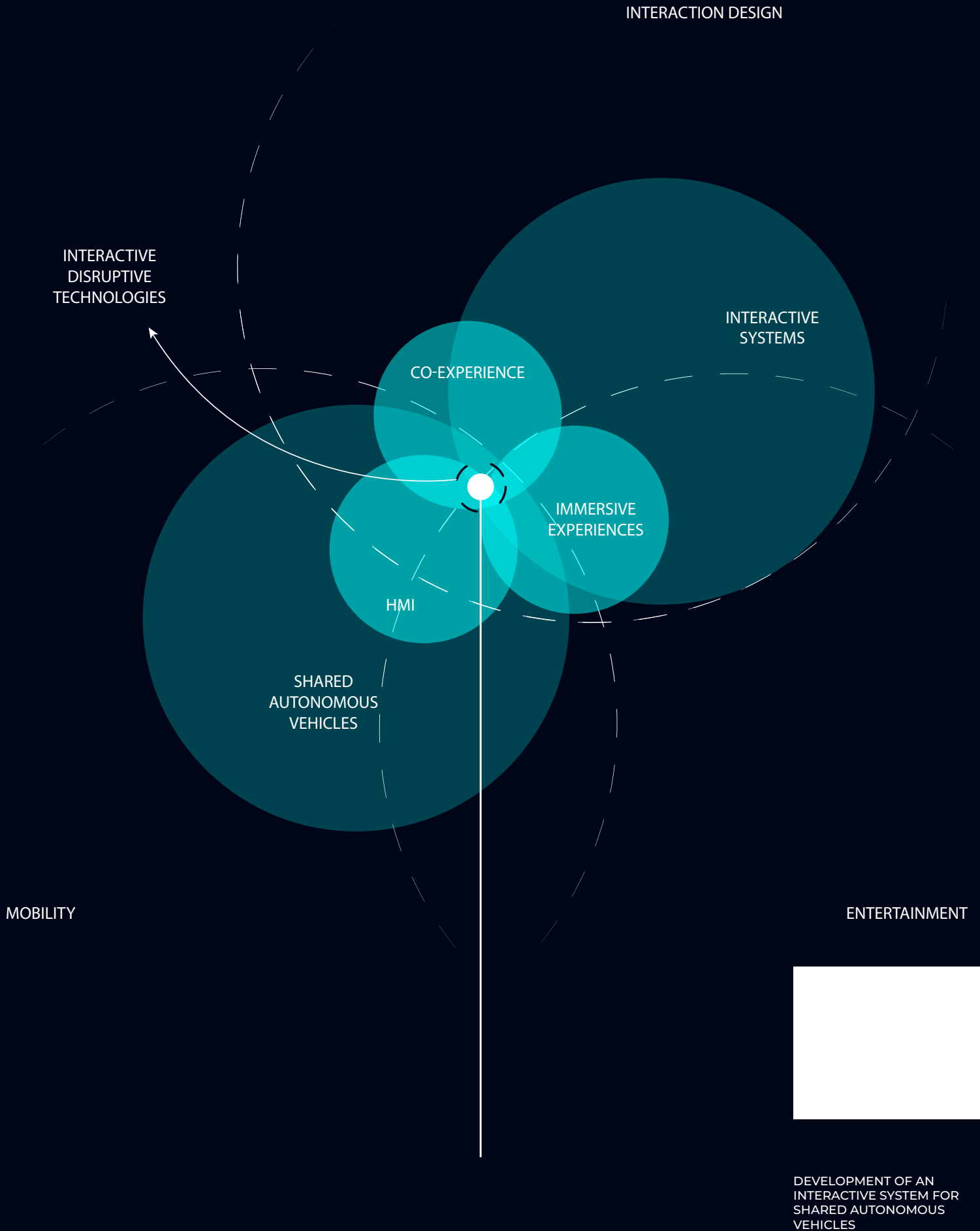


Fig. 1. Diagram of our research positioning.

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1.4_METHODODOLOGY

The present research was structured in three different phases: Exploratory, generative and evaluative to answer our research questions and help us achieve our research goals (Fig. 2). The exploratory phase is composed by the literature review, benchmark and an online survey. This three methods informed us with enough data to conduct the mobile application development for our interactive system and further development on the In-vehicle infotainment system (IVIS).

The generative phase was composed by information architecture, prototyping and brainstorming sessions. This phase was not conducted at once because the research involved the development of two products within the goals of the Interactive system we aimed to achieve. In this regard, the three methods described, defined our approach in both products to further ideate each possibility. Our intention with this phase was to explore different possibilities in both products (a mobile application and an in-vehicle infotainment system). The IA helped us to explore the system organisation and iterate it throughout the project development. Prototyping was essential not only to understand possible interactions but also to prepare the evaluative phase with potential users. The brainstorming sessions were important to generate ideas for the IVIS product development.

The evaluative phase, as in the generative phase, was not conducted at once for the same reason. In fact, the evaluative phase was composed by Usability and UX tests and a Think Aloud. Our intention with Think Aloud was to evaluate the users' mental model and perception when interacting with the developed mobile application to assess issues and generate improvement criteria. The usability and UX tests helped us understand the perceived emotions that potential users would feel in certain moments of the experience and iterate the product accordingly. The present methodology (Fig. 3) led us to a possible solution for our research problem, goals and questions in which we encourage further developments and future researches to ensure a continuous usage of shared autonomous vehicles.

RESEARCH STRATEGY

why this methodology

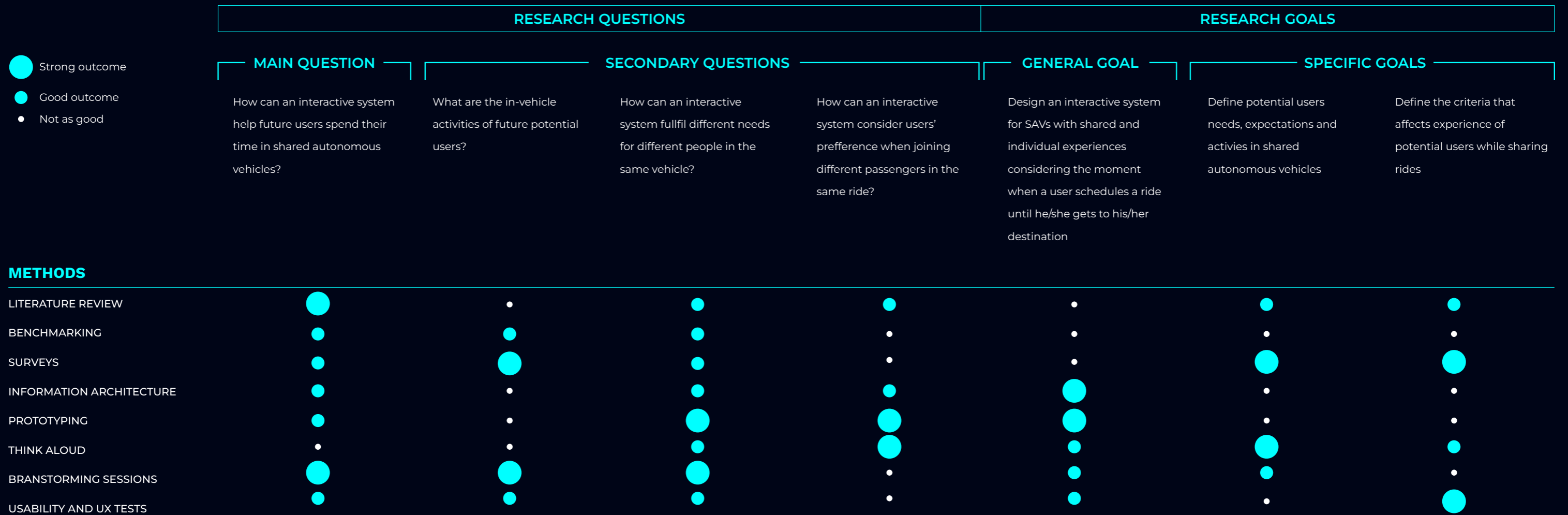


Fig. 2. Diagram of the relation between our research goals, questions and methodology.

ORGANOGRAM
(DEVELOPMENT OF TWO PRODUCTS)

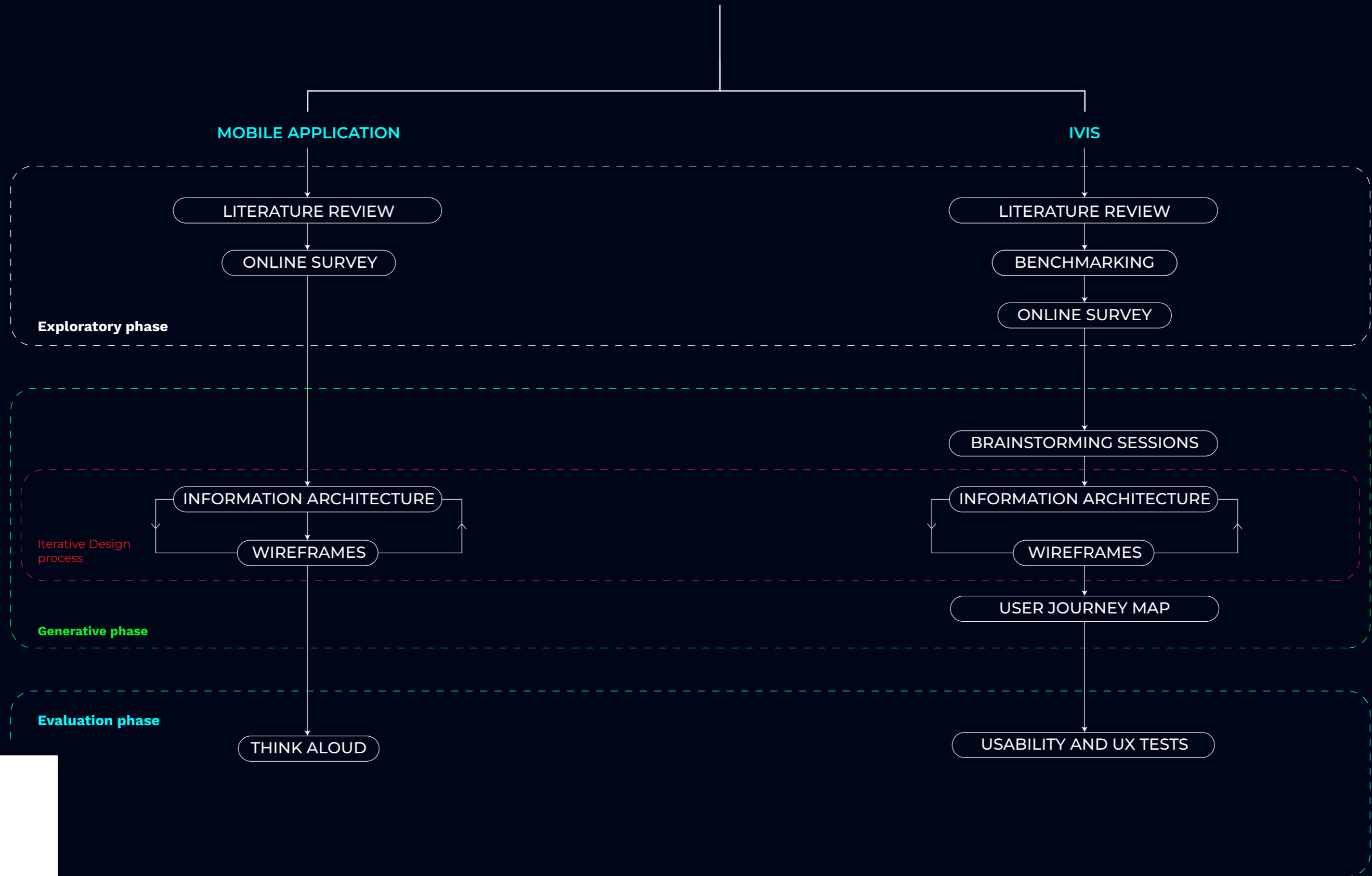


Fig. 3. Research chart.

CHAPTER 2_

PRELIMINARY RESEARCH



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2.1_STATE OF THE ART

2.1.1_Shared Autonomous Vehicles

Mobility is changing and the automotive market is evolving and providing more sustainable and safer solutions such as autonomous vehicles (AV), connected autonomous vehicles (CAV) and electric vehicles (Fagnant and Kockelman, 2015; Kassens-Noor et al., 2020; Kopelias et al., 2020). Autonomous vehicles are not a new concept, since the past century we have been dreaming about the possibility of enjoying a ride without an actual driver (Duarte and Ratti, 2018). However, it was in 2004 with the Defense Advanced Research Projects Agency (DARPA) that this dream became true, with five AVs completing a race of 244km (Duarte and Ratti, 2018). A massive and constant evolution continued after, with more DARPA challenges, published articles (DARPA, 2007; DARPA, 2013). And in 2013, the US Department of Transportation's National Highway Traffic Safety Administration (NHTSA) defined six levels of autonomy (zero to five) to include these vehicles in the American roads. The society of Automotive Engineers (SAE) reached a similar definition of each autonomy level and has been the most cited worldwide. The U.S. Department of transportation also adopted SAE taxonomy and for these reasons, we will consider it as a reference. The five autonomy levels from SAE are divided in two groups: 1) from level zero to level two, "You are driving" (SAE, 2021) and must supervise any driving support features; and 2) from level three to level five "You are not driving" (SAE, 2021) and there is no need to take over the control of the car at any point. As we can see in Fig. , the first identified group is also defined as "Driver support features" (SAE, 2021) and the last group as "Automated Driving features" (SAE, 2021). However, even though SAE includes autonomy level three is this last group, they claim that in level three the automated driving features can request humans' driving assistance at some point.

- Level zero: the driving assistance features are momentary and mostly related to warnings;
- Level one: features that provide assistance in steering or breaking/acceleration (e.g. adaptive cruise control);
- Level two: same features as level one, but can be conducted at the

same time (e.g. lane centering and adaptive cruise control);

- Level three: Traffic jam chauffeur in which its consider crash event detection and safe/danger proximity ;
- Level four: the autonomy is limited to a set of conditions that must be met to operate;
- Level five: full autonomy in every scenario.



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	SAE LEVEL 0™	SAE LEVEL 1™	SAE LEVEL 2™	SAE LEVEL 3™	SAE LEVEL 4™	SAE LEVEL 5™
What does the human in the driver's seat have to do?	You are driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			You are not driving when these automated driving features are engaged – even if you are seated in “the driver’s seat”		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	

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	These are driver support features			These are automated driving features		
What do these features do?	These features are limited to providing warnings and momentary assistance	These features provide steering OR brake/acceleration support to the driver	These features provide steering AND brake/acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met	This feature can drive the vehicle under all conditions	
Example Features	<ul style="list-style-type: none"> • automatic emergency braking • blind spot warning • lane departure warning 	<ul style="list-style-type: none"> • lane centering OR adaptive cruise control 	<ul style="list-style-type: none"> • lane centering AND adaptive cruise control at the same time 	<ul style="list-style-type: none"> • traffic jam chauffeur 	<ul style="list-style-type: none"> • local driverless taxi • pedals/steering wheel may or may not be installed 	<ul style="list-style-type: none"> • same as level 4, but feature can drive everywhere in all conditions

Fig. 4. SAE Levels of Driving Automation (retrieved from SAE, 2021).

In an era of driving control shifting from drivers to computers, the world expects to extinguish most of the road accidents—90% are caused by drivers (Waldrop, 2015).

The shift from a ‘joy of driving’ to a ‘joy while driving’ may be amplified by the possibility of new forms of connectivity (entertainment and gaming activities) and other vehicle related services (Meschtscherjakov et al., 2015). However, Fagnant and Kockelman (2014) stated that the most promising opportunities come with the shared autonomous vehicles (SAVs) changing the paradigm of personal and private vehicles to shared (or hire) solutions by mixing different users. SAVs could be pur-

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sued as an inexpensive mobility option with its multiplicity of services as dynamic-ride sharing and last-mile solutions (Krueger et al., 2016). According to Pakusch et al. (2018), users are more reliable to use autonomous vehicles in shared contexts than in private ones, which leads us to not only work on individual experiences, but more importantly to develop memorable shared experiences. Shared experiences are amplified, even if the users do not convey what they are experiencing, not only because they are affected by their own way of experiencing, but also because of human capability of imagining how other people see, hear, smell, taste and feel (Boothby et al., 2014). Some non-related driving activities might interest future users, which could be by linking present artifacts and future autonomous systems or by sharing activities between occupants (Tang et al., 2020). Although there is built and shared knowledge about sharing and co-experiencing products, services and systems in various areas, in autonomous vehicles everyone is working for social acceptance, comfort and trust towards automation, leaving an enormous gap regarding the co-experience of use of interactive systems (Strömberg et al., 2018).

Legislation is needed and encouraged regarding SAVs and other autonomous mobility options and liability in the event of an accident. Should the manufacturer or owner of the vehicle be blamed in more serious cases? As Holstein et al. (2018) stated “those real-world techno-social problems must be taken seriously” and safety, security, privacy and even comfort should be addressed in the implementation of these solutions. However, Holstein et al. (2018) also compares these advances to the introduction of traditional human-driven cars on the road, where developers did not consider who would be responsible in traffic accidents or even human safety because that would lead to a non-accepted solution. Presented the evolution of SAVs and different perspectives on its implications to the society (Fig. 5), we will discuss HMI evolution and why HCI is not a sufficiently broad theme to address our intentions. The areas are related since the advancements in transport research and development are possible because of automation driving and human-machine interfaces continuous improvements (Riegler et al., 2021).

THEORETICAL CONTEXT DIAGRAM

Shared autonomous vehicles

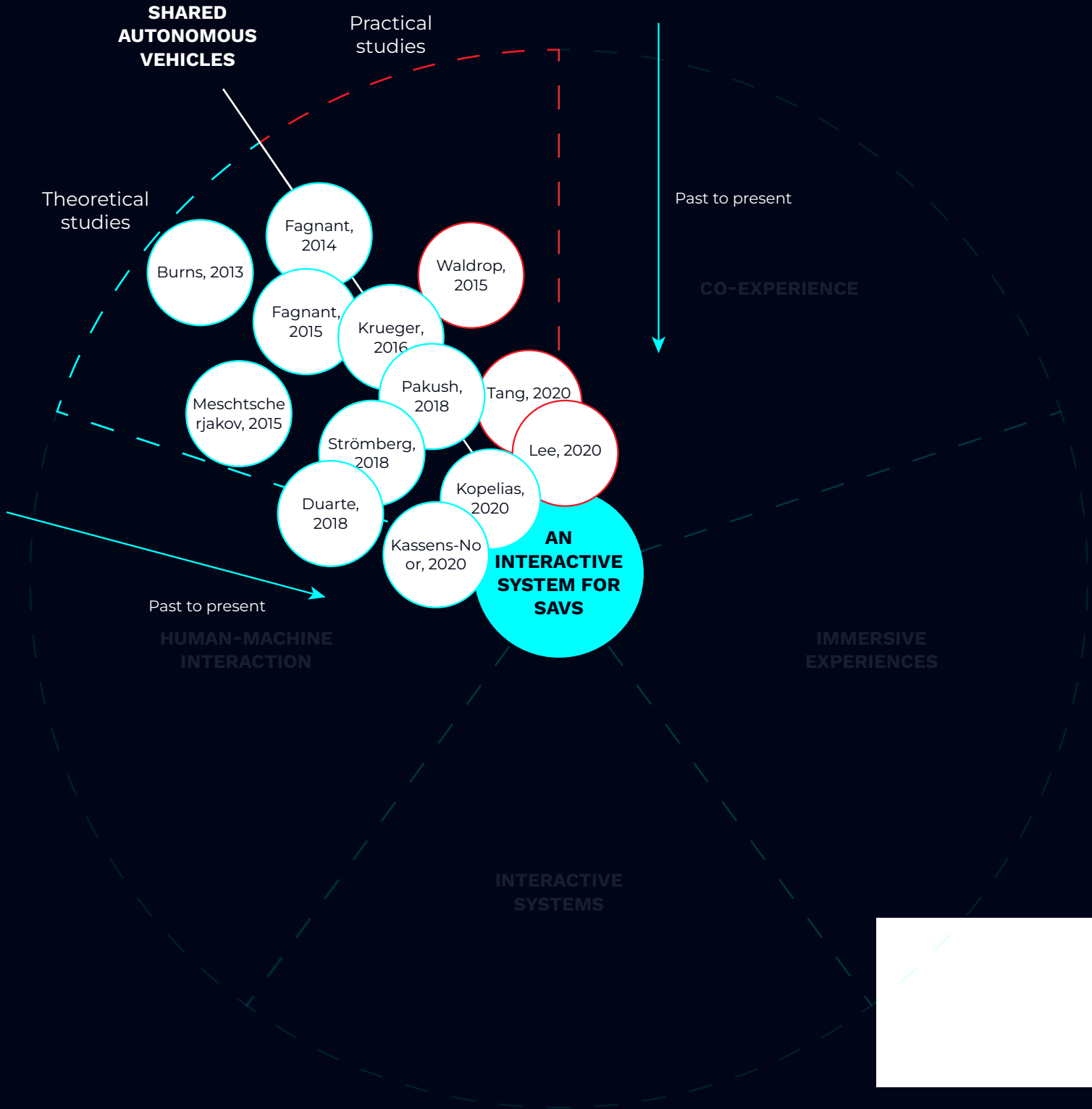


Fig. 5. Diagram of theoretical context in shared autonomous vehicles research.

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2.1.2_Human-machine Interaction (HMI)

HCI is a term that is not sufficiently broad to cover every human-machine interaction, especially when addressing highly dynamic and complex human-machine systems (Hoc, 2010). Human-machine interaction (Fig. 6) concept emerged with the change in the relationship between humans and machines, since humans stopped only using them to also start interacting with them (Suchman, 1990). Hoc (2010) went even further in this concept by proposing Human-machine cooperation (HMC) to address interactions in highly dynamic situations because these change autonomously, needing a full cooperation between operators' and machine's actions to produce desirable outcomes. Machine interactions are only possible through an interface designed to achieve a considerable reduction of injuries, fatigue and errors as well as improvements in efficiency and quality of use (Cannan and Hu, 2011). However, present interfaces are in desperate need to be tested in a new reality, because the machines we interact with are not tools anymore, but autonomous systems, equal collaborators that are projected to achieve a mutual objective (Visser et al., 2018). For instance, Sánchez-Nielsen et al. (2004) presented an approach where humans could interact with their own personal computers through gestures, improving the relationship between humans and machines. Another example is the case of Shibata et al. (1997) where he proposed an emotional pet robot that by changing behavior patterns through value-based learning, would trick the humans' mind to consider that these behavior changes were triggered by emotion.

Interaction design is a powerful tool when working with HCI, HMI and HMC since any of these concepts need an interface to allow interaction possibilities. According to Kolko (2010), interaction design practitioners need to develop the capacity to understand and solve complex problems and empathize with humans experiences in order to humanize technology and allow the occurrence of cooperation and interaction between humans and computers or machines. This communication between the human and the computer, that is observed through users' behavior must be clear enough to be understandable and to create an

emotional reaction. Essentially, a relationship between the human and the machine are possible through, not only, technology intervention, that could be emerging, converging, disruptive or sustaining, but most importantly, the intervention of interaction design that allows and enhances this relation.

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THEORETICAL CONTEXT DIAGRAM

Human-machine interaction

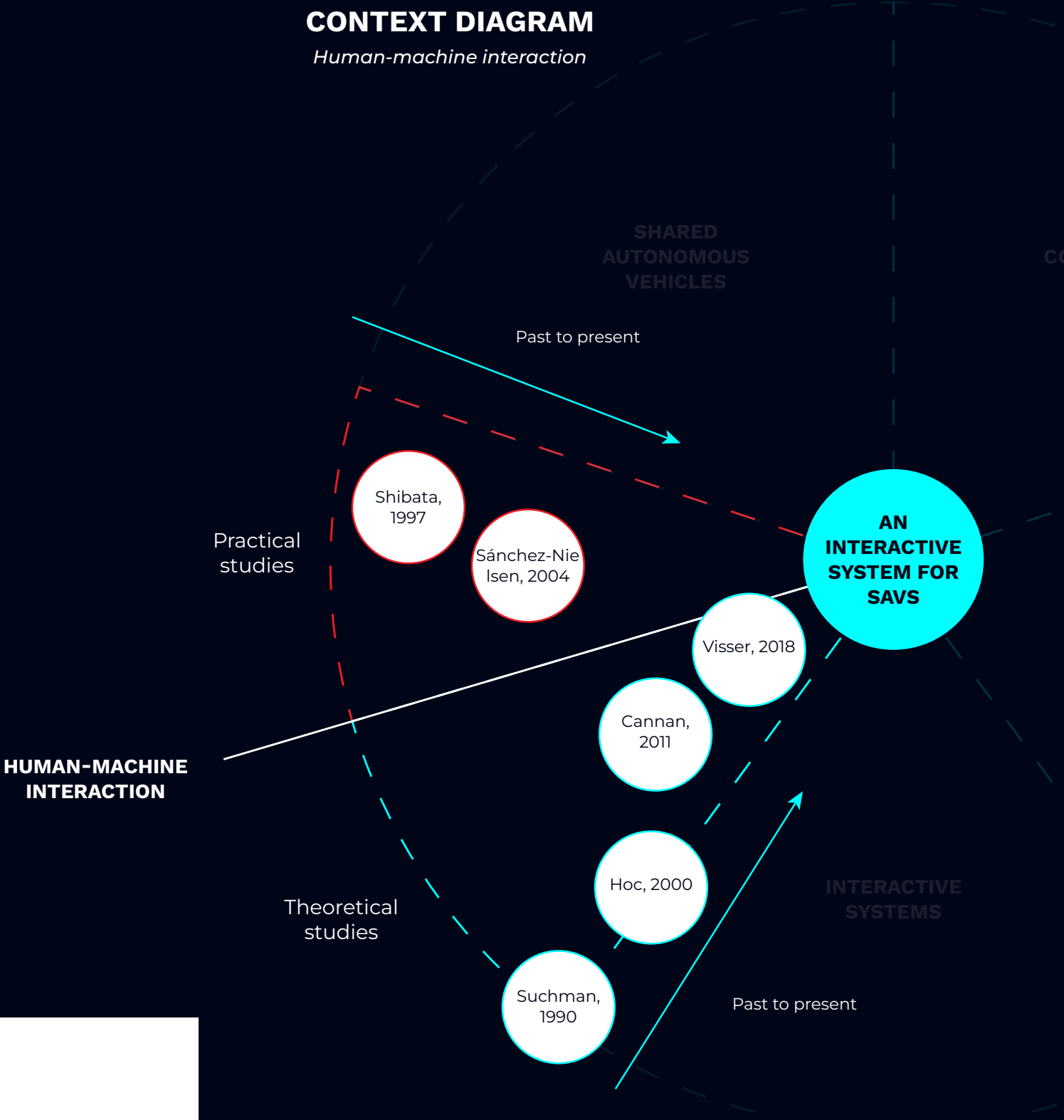


Fig. 6. Diagram of theoretical context in human-machine interaction research.

2.1.3_Interactive Disruptive Technologies (IDT)

Innovation and disruption have different meanings, since innovation describes the introduction of something new, a new idea, method or device. Disruption intends the act of disrupting, an interruption in the normal course of an activity (Merriam-Webster, n.d. a). Disruptive innovations that provoke established markets and change social behaviors or consumers' habits are radical but needed (Markides, 2006). Essentially, these technologies are not disruptive for the innovators that developed them but for the existing business market models (Lucas, 2012). Innovations should be segmented into emerging, converging, disruptive and sustaining technologies (Fedkin, 2020) and appear as products, services or business models (Lucas, 2012).

Following this statement, we can identify emerging disruptive technologies: cloud computing (a process of data storage in multiple servers that is accessed through the internet); internet of things (IoT - everyday objects and devices with the capability to send and receive information through the internet); internet of services (IoS - internet as a global platform that allows the combination and utilization of resources) and cyber-physical systems (the process of computing into a physical act such as wireless sensor networks) are perfect examples of these technologies (Manda and Ben Dhau, 2019). Emerging technologies are characterized by its ambiguous and unpredictable success since they are never fully developed at their final stage form (Armstrong, 2017).

For the main converging technologies, it is understandable that the value of nano-bio-info-cogno (NBIC) technologies for its purposes on enhancing human capabilities (Roco and Bainbridge, 2013). Disruptive technologies are described as the ones that help create new markets and replace earlier technologies (Fedkin, 2020) or improve products in unexpected ways for society and markets themselves (Christensen et al., 2008). As an example of disruptive technology, we can identify the emergence of metaverse for its non-existent precedence (Dionísio et al., 2013). Nevertheless, contrary to disruptive, sustaining technology is about improving well-established products, services and business models to be environmentally friendly (Fedkin, 2020) as shared autonomous

vehicles, that are being developed and improved continuously. Even if SAVs are expected to be a more sustainable option, it is not considered a sustaining technology because it is not a result of an incremental improvement process. However, our approach is not about creating a new vehicle, but to work on the optimization of shared rides for future potential SAVs' users through the development of an interactive system.

SAVs are considered disruptive because the public transportation market is well established with buses, trains and airplanes and the emergence of SAVs will transform the public mobility market as we know.

Regarding this, the approach we intend to apply is a converging innovation in SAVs concept, with the application of in-vehicle interactive materials, voice and gestural recognition systems, to be co-experienced by multiple users.

2.1.4_Co-experience

Co-experience emerged with Battarbee (2003) where he refers to a present need of including, not only the individual side of user experience, but also the social interactions that come with it. In shared autonomous vehicles, the researcher should be adopting methods that address social interactions between the vehicle and its passengers, evaluating situations with multiple users and overcoming mutual understanding of what should be happening in these contexts (Strömberg et al., 2018). The concept of shared vehicles has been brought by Burns (2013), in which he explains it as a vehicle that serves several people during the day, in contrast to owned personal cars, and even presents examples as Uber. We can observe solutions only focused on single users arising in this specific area, such as the BMW i Interaction Ease (Fig.7) presented at CES (Consumer Electronic Show) 2020. On the contrary, we identify LG Connected Car (Fig. 8) presented in CES 2020 as an effort from LG Global to present a solution regarding shared mobility services or Audi LUX (Fig. 9), presented at CES 2019 which is mainly focused on vehicles' interaction with exterior environment users.



Fig. 7. BMW i Interaction EASE - retrieved from BMW Blog (Nica, 2020).

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Fig. 8. LG Connected car ThinQ - retrieved from LG Newsroom (LG, 2020)



Fig. 9. Audi LUX - retrieved from Audi Media Center (Audi, 2019)

According to Battarbee and Koskinen (2005) by limiting the design process to individual experiences, the designer is also limiting the users' experience by not viewing every design possibility. For instance, Forlizzi and Battarbee (2004), proposed three types of experience: 1) experience that is defined by the constant assessment that humans do with people, products and environments; 2) an experience that is about something that had an ending and somehow changed an emotional state or a behavior to the experienter; 3) co-experience that is defined as experiencing in social contexts, sharing attention and differing in interpretations, which most of the times lead to social influences. Even in silence, different users while sharing the same experience are communicating without an explicit conversation, which leads to an amplification of users' experiences (Boothby et al., 2014). As we know, men and women are individuals that live in society and "(...)neglecting the social aspect of experiences would be to overlook a very important aspect of being human" (Battarbee, 2003, p.2). As a pivotal area in our research, the different co-experience theoretical approaches referred are presented in Fig. 10.

Specifically in virtual environments, sharing immersive experiences promotes outcomes as communication efficiency between participants and the competence to achieve mutual goals (Shi et al., 2016).

THEORETICAL CONTEXT DIAGRAM

Co-experience

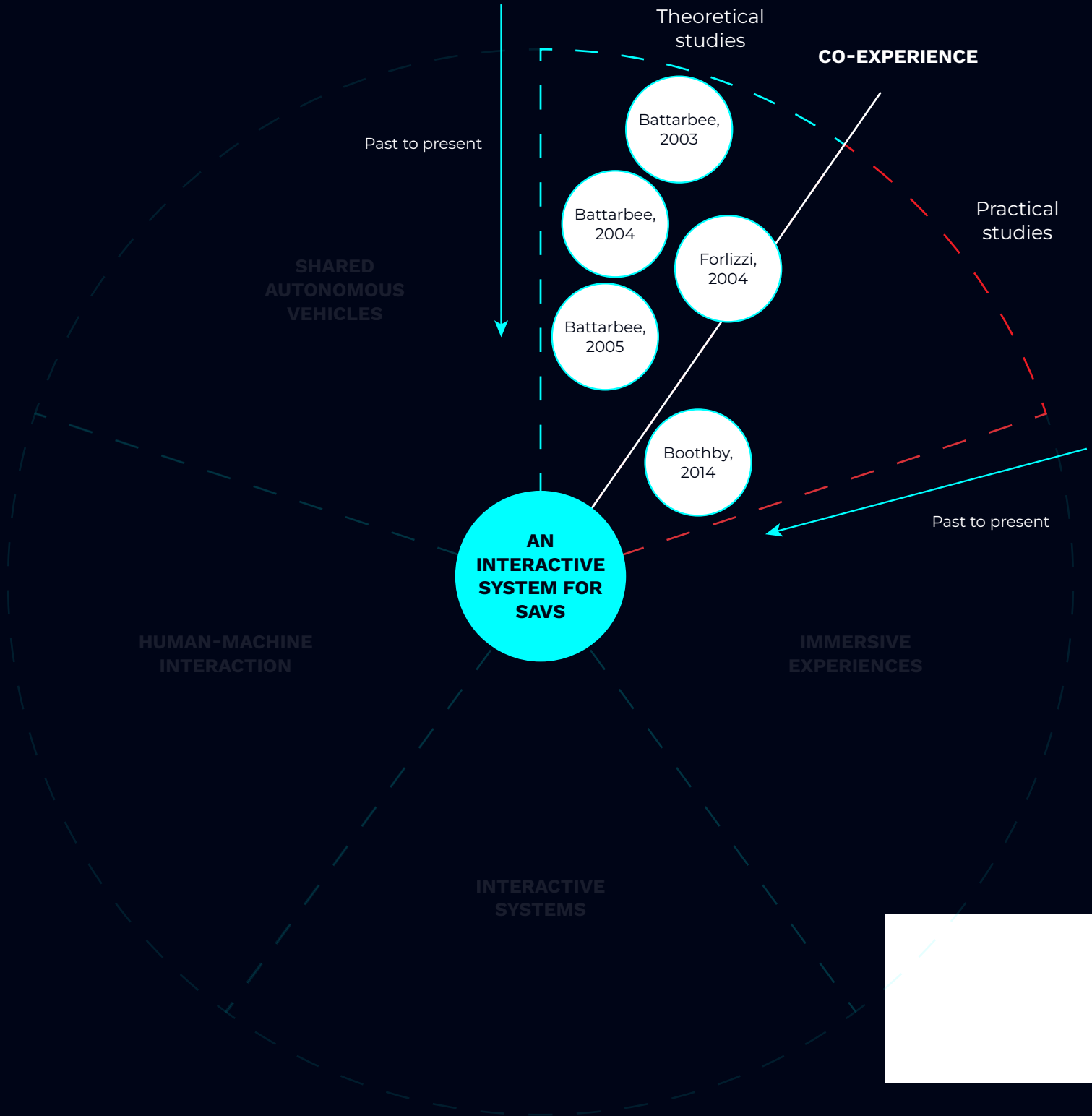


Fig. 10. Diagram of theoretical context in co-experience research.

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2.1.5_Immersive experiences

To support immersive experiences non-related to driving (NRTD) and focusing on the user experience to increase advances towards automation acceptance (Riegler et al., 2021), mixed reality has been recently studied in the automation field area. Future potential users of SAVs, by being relieved from driving task, will open numerous NRTD opportunities "(...)amongst them new forms of in-situ entertainment, productivity, and games grounded in the contextual specificity of the automotive, mobile situation" (Pfleging et al., 2016, p.2). Virtual environments (VE) that enable multiple levels of immersion through simple users' body motion is a powerful experience to users (Davis et al., 2003). According to Lee et al. (2020) one of the user's requirements to fully automated vehicles is the existence of a surrounding display to watch movies, make conference calls or provide other information to enhance passengers' experience. Co-operative AR could also open the possibility to users of communicating between different vehicles through in-vehicle available interfaces (Riegler et al., 2021). However, these simulated in-vehicle VE will constitute a problem in motion sickness, affecting the drivers that nowadays can escape from these feelings when engaged in their driving task (Iskander et al., 2019).

Immersive experiences and virtual reality can be wonderful tools in many contexts, but it is necessary to carefully analyze each case due to its implications and influences on social reality and cultural approaches (Rubio-Tamayo et al., 2017) specially in SAVs. Rehman et al. (2018) proposed the usage of immersive and non-invasive technologies, specifically Virtual reality, Augmented reality and Mixed reality (VAMR) linked with Electroencephalography (EEG) to interact with the vehicle, providing a whole new level of human machine interaction. In this regard, Immersive experiences researches done in the past (Fig. 11) will enrich our investigation with its open possibilities to entertain and support future users in shared rides. From resting, to gaming or even new journeys experiences, because driving ways might not be enjoyable, the possibilities are infinite. Immersive experiences through a personalized interactive system is a possible strategy to improve HMI in these individual and social contexts (Negru, 2010).

THEORETICAL CONTEXT DIAGRAM

Immersive experiences

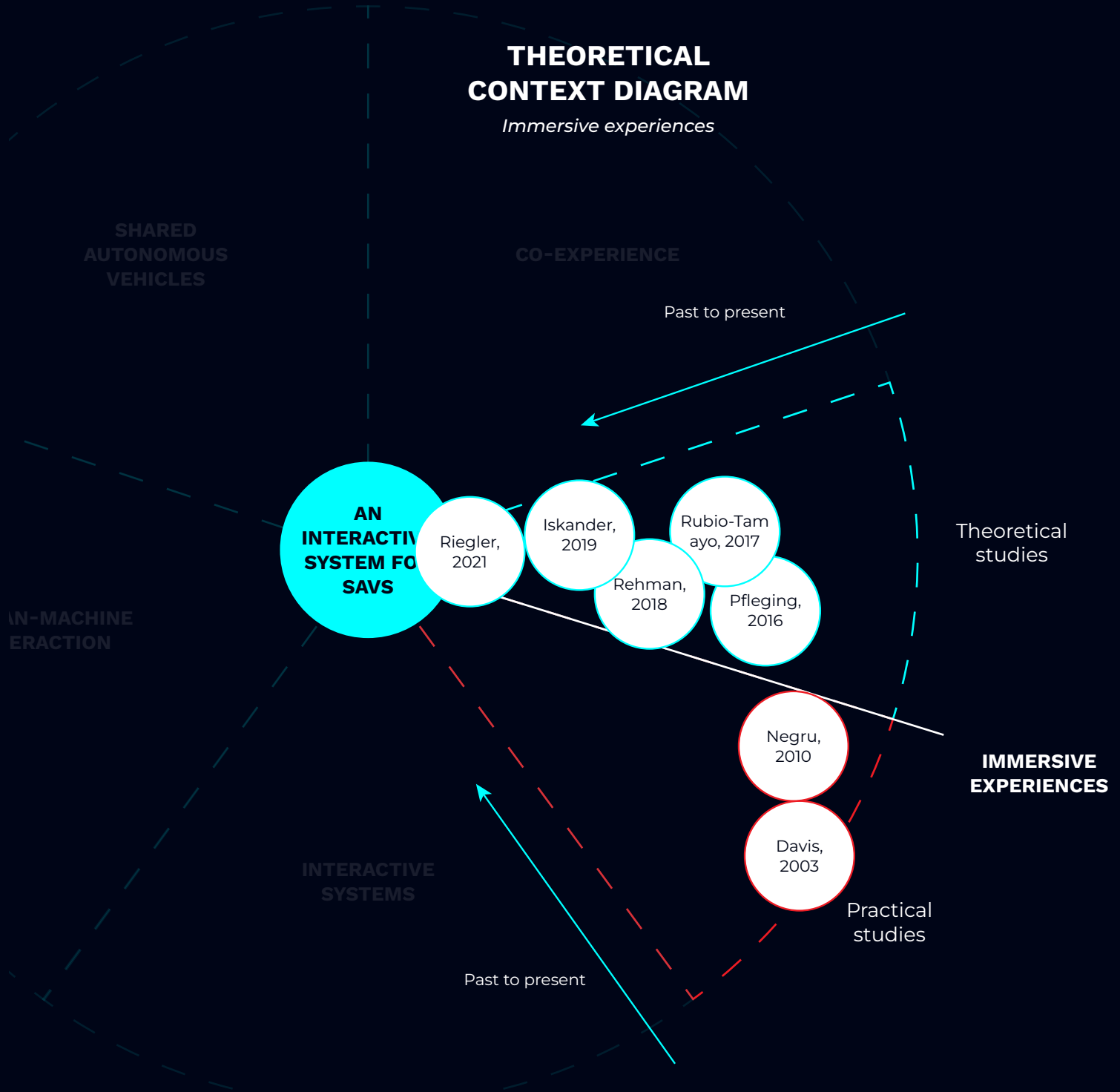


Fig. 11. Diagram of theoretical context in immersive experiences research.

2.1.6 Interactive systems

According to Stromer-Galley (2004), interactivity is an area worth of constant investigation and should be divided in two different phenomena: interactivity-as-product which entails the interaction between humans and technological systems and interactivity-as-process that focuses on human interaction in social contexts. Interactive systems (Fig. 12) and situations are dependent on structural affordances as an important basis for human interaction (Burgoon et al., 2000). Gesture-based interfaces is an example of a new form of interaction (Salgado et al., 2015) and although it has been addressed extensively in theory, it is worrying the remaining work undone in practice (Karam and Schraefel, 2005). However, it is remarkable the research of Burno et al. (2015), where it evaluated the error and performance rates on three different gesture-based interfaces and compared those rates to more known forms of interaction—mouses, touch pads and touchscreens. Another good example is the work of Angelini et al. (2016), where a novel in-vehicle interaction for IVIS was evaluated with 20 participants, comparing gestures, speech and touch as different interaction modalities. According to Wachs et al. (2011), the reasons behind the lack of available products with gesture-based interfaces in the current markets, are the inherent usability challenges such as fast response time, high recognition accuracy, quick to learn, and user satisfaction.

In-vehicle infotainment systems (IVIS) are becoming more complex and interaction modalities should be evolving with it to address different needs of car users, for instance, multimodal interactions such as speech and gestures to trigger different functions (Pfleger et al., 2012).

In this regard, a reflexion on the pivotal research areas will be following to summarize the findings and implications to our research and a clarification about intentions with the present investigation.

THEORETICAL CONTEXT DIAGRAM

Interactive systems

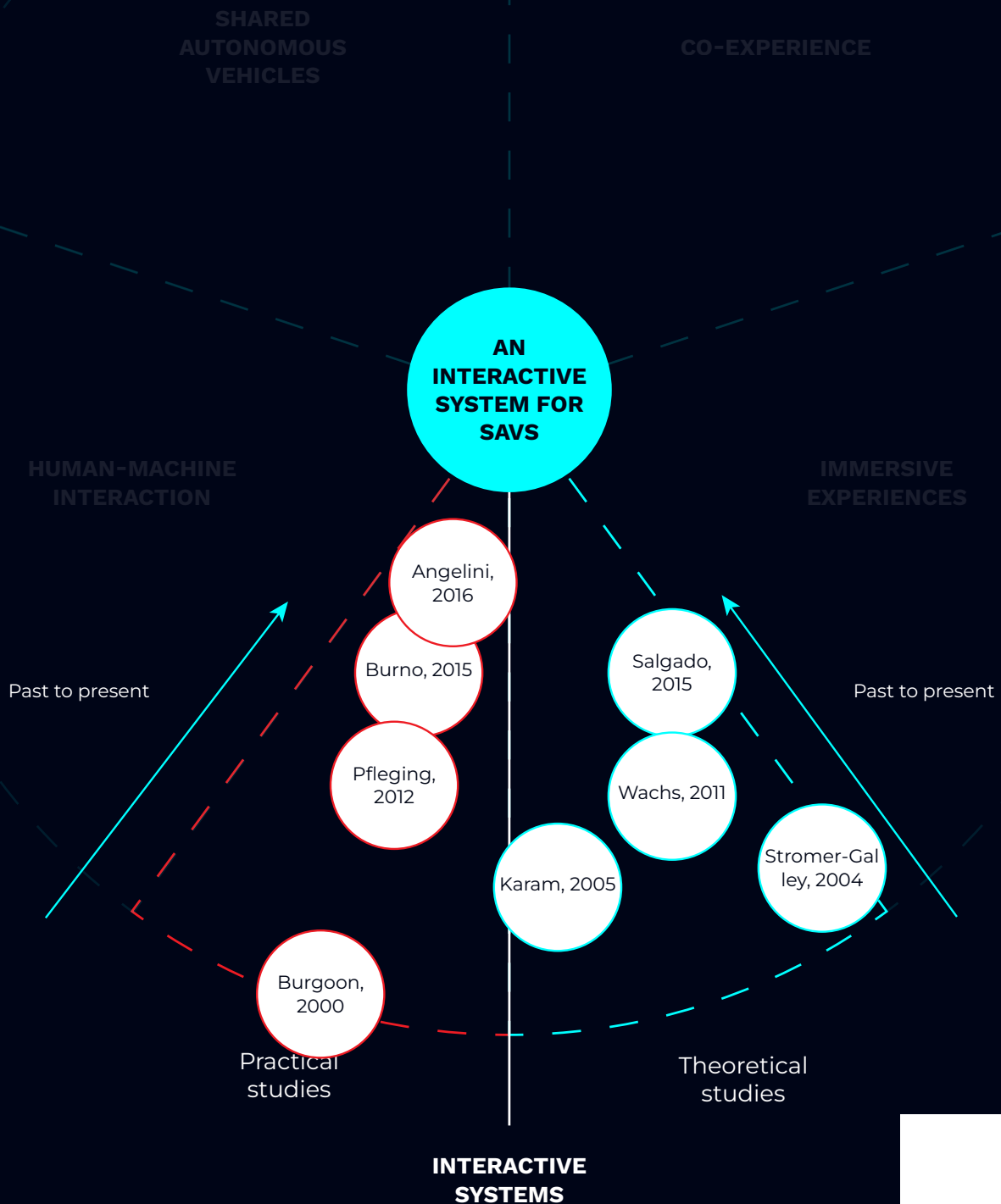


Fig. 12. Diagram of theoretical context in interactive systems research.

2.1.7_Summary

As identified earlier, pivotal areas to our research and relevant studies will be considered (Fig. 13). SAVs are inserted in level five of autonomy, and we intend to work towards dynamic-ride sharing and last-mile (journey destination) solutions. Considering the identified researches, much have been done from researchers to practitioners towards acceptance, trust and comfort in AVs and many others, even working for others purposes, considered users as unique individuals. Our contribution to the research community intends to address users as social beings in shared contexts, considering not only the relationship human-machine but also human-human and human-human-machine. In this regard, previous work in the co-experience and HMI field areas, will enlighten us on the importance of this areas to the user experience in social interaction contexts. As in the study of Boothby et al., (2014) where participants did not communicate what they were feeling, the results showed an enhancement of the experience, proving that co-experience is powerful and must be considered in social interactions. Interactive systems and the past solutions presented, such as IVIS, has proven to be common in the support of passengers and drivers in different automation levels. From information provision to entertainment, where the topic immersion was commonly associated, we intend to provide not only the possibility to passengers optimize rides to work, read and perform other activities, but also to enjoy different rides by experiencing exotic environments, other country streets or even the solar system once in a while. Our approach is about a converging innovation of different technologies as gestures, speech and interactive surfaces, into an integrated interactive system that will allow the optimization of shared rides. Might sound ambitious but we are talking about the future of mobility.

THEORETICAL CONTEXT DIAGRAM OF THE WHOLE RESEARCH



Fig. 13. Theoretical context diagram of all the main research areas.

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2.2_BENCHMARK

During the preliminary research, we conducted a benchmark in mobility area and other field areas in order to gather possible features and outcomes for the present research. In this regard, we chose the first three relevant projects/products within the mobility field area and other three from other areas: 1) LG Connected car; 2) BMW i interaction EASE; 3) Audi Urbansphere; 4) DuMont Discovery Dock; 5) Yacht Cloud Information system; 6) Disney: Star wars galactic cruiser. Furthermore, to retrieve a valuable outcome of this benchmark, we conducted a comparative analysis on the identified projects considering a set of criteria: 1) Engagement; 2) Comfort; 3) Co-experience; 4) Immersion. The set of criteria is explained and justified in the comparative analysis chapter.

2.2.1_Comparative analysis criteria

2.2.1.1_Engagement

Engagement or “User Engagement” as proposed by Sutcliffe (2009) is a complex concept that describes how users feel attracted to a certain product and considers satisfying arousal and pleasure produced during the interaction. We believe that engagement affects the constant usage of shared autonomous vehicles and should be pursued during the development of such systems. In this regard, engagement will also be considered to evaluate competitors solutions.

2.2.1.2_Comfort

In the present research, we define comfort as a human experience regarding social aspects and personal safety. In this regard, comfort is the most important criteria to evaluate competitors solutions and to consider during the development of this interactive system because we believe that it affects SAVs usage.

2.2.1.3_Co-experience

We consider Co-experience as a shared experience involving different persons in social environments. In this case, we chose this criteria to compare the flexibility between different solutions when interacting

with multiple users in a social environment.

2.2.1.4_Immersion

We chose Immersion as a criteria to assess the involvement of users when interacting with each of these solutions. We consider a total immersion as a positive value since the present research involves vehicles in autonomous level five.

2.2.1.6_Criteria evaluation matrix

We gathered the criteria for the comparative analysis, however we needed to understand the relations between each criteria in terms of importance to correctly consider the best solutions in the market. In this regard, we conducted a criteria evaluation matrix (table 1).

This matrix was conducted with the authors perception and professional opinion in order to achieve the present research goals. The criteria evaluation matrix helped us define the importance of each criteria. Furthermore, different weights were defined in order to assess rigorously each product/project during the analysis. The weights defined were 1.6 for Comfort, 1.4 for Engagement, 1.2 for Co-experience and 1 for Immersion.

Evaluation criteria:

- A - Engagement
- B - Comfort
- C - Co-experience
- D - Immersion

Degrees of importance:

- 5 - Much more important than
- 3 - More important than
- 0 - As important

	B	C	D	Total	Order
A	B3	A0	A5	5	2°
B		B3	B3	9	1°
C			C3	3	3°
D				0	4°

Table 1. Criteria evaluation matrix.

The first table entry (B3) means that when we compared engagement criteria (A) with comfort (B), we considered that comfort is more important (3) than engagement. The third entry (A5), when we compared

engagement criteria (A) with immersion (D), we considered that engagement is much more important (5) than immersion.

2.2.2_Objects for the comparative analysis evaluation

2.2.2.1_LG Connected car

As presented before, the LG Connected car (Fig. 8) is the prototype of a self-driving electric car presented at CES 2020 by LG. Among many features as passengers' authentication, private tablets for each passenger and an in-vehicle snack shop, it also has voice controls and a large OLED screen to entertain passengers during the ride in many ways. The OLED screen is able to show road images from kilometers ahead of where the vehicle is, in order to inform about traffic conditions and accidents. We chose this solution for the comparative analysis because it is the most advanced concept presented by a global brand within SAVs. It is one of the most important solutions presented here to understand how LG is willing to tackle the issues regarding shared mobility.

2.2.2.2_BMW i interaction EASE

Similar to LG Connected car, BMW i interaction EASE is a prototype that was presented at CES 2020, in this case by BMW. BMW i interaction EASE has developed towards a strong concept, ease the interaction between the passenger and the vehicle, pushing the HMI limits forward. The exterior appearance was not developed, to attract all the attention to the interior experience (Fig. 14), which has three different modes: explore, entertain and ease. Explore and entertain modes are opposites in terms of experience, since the explore mode works with augmented reality leading the passenger to explore the surroundings and find points of interest along the way, entertain completely isolates the passenger, immersing him/her into an entertainment environment such as movies or games. The ease mode lets the passenger lean back and relax with a calming sound and ambiance. We chose this solution for the comparative analysis to learn from the interaction channel chosen by the manufacturer (eye movement) and consider it during this final project development.



Fig. 14. BMW i Interaction EASE - retrieved from BMW Group Press (Ederer, 2020).

2.2.2.3_Audi Urbansphere concept

Although Audi Urbansphere (Fig. 15) has a big focus on the interior design aesthetic, we can see an effort towards the users needs and expectations of future mobility. Audi Urbansphere does not escape the Audi's signature of lights communication, where this vehicle can truly communicate with the surroundings through the exterior LEDs to inform turn directions or stops. In-vehicle features were developed focusing on passengers comfort, particularly on the back seats, with the ability to make conference calls or watch movies with a transparent led that comes from the top of the car. We chose this solution for the comparative analysis because of the features presented that were interesting to adapt considering our research purposes.

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Fig. 15. Audi Urbansphere - retrieved from Audi Mediacenter (Schloßmacher, 2022).

2.2.2.4_DuMont Discovery Dock

DuMont Discovery Dock is an interactive museum that uses mixed reality to immerse visitors in different views and perspectives of Port of Hamburg, that normally is not accessible to the general public (Fig. 16). Through different technologies such as touch tables or virtual reality glasses, visitors can visit every place of the Port of Hamburg in a controlled environment. We chose this solution for the comparative analysis because of all the different interaction possibilities presented during the exhibition and how co-experience was developed towards the exhibition intention.



Fig. 16. DuMont Discovery Dock - retrieved from Demodern (Claudia, 2019).

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2.2.2.5_Yacht Cloud Information system

Yacht Information system (YIS) is an infotainment system to track and control luxury yachts, accessible everywhere at any time (Fig. 17). Through this system, guests and owners of yachts are capable of accessing all the vehicle technical data in an intuitive and understandable way. We chose this solution for the comparative analysis to learn from the information architecture and how all the data is arranged together in the different areas.



Fig. 17. Yacht Cloud Information system - retrieved from Yacht Cloud Demo.

2.2.2.6_Disney: Star wars galactic cruiser

Star wars galactic cruiser (Fig. 18) is a two nights immersive adventure, provided by Disney where visitors aboard Halcyon Starcruiser, meet characters from the original movies, pilot the spaceship, have lightsaber trainings among other immersive interactions with the original story. Besides sleeping in cruiser cabins, visitors can also enjoy an excursion to Batuu, a planet on the edge of the galaxy. It is an interesting project to be considered in our research for the human approach it has and the immersion created to inspire children and fans of these series.



Fig. 18. Disney Star ward Galactic Cruiser - retrieved from CNN (Stroshane, 2022).

2.2.3_Procedure

We were not able to test the products/projects presented. In this regard, meeting sessions were conducted between the authors to evaluate our perception of each solution considering the identified criteria and how would users feel in these environments (i.e. for the co-experience criteria a certain flexibility is expected to attend diferent users' needs and expectations in solo and multiple interactions).

2.2.4_Results and Discussion

The results of the comparative analysis for the solutions in the mobility field area were very interesting for our research purpose (table 2).

The LG connected car had the highest rates in the comfort (the criteria with the biggest weight) because the purpose of the LG project is to conceive a mobility solution for future neighborhoods. In this regard, the fact that the passengers know each other highly impact their social comfort around each other. Furthermore, comfort also impacts co-experience, facilitating the cooperation in-vehicle for different tasks and the openness to share the moment together. The vehicle also presented solutions and features for multiple usage as the snacks machine that registered every user that interacted with it, charging each snack taken from the machine.

BMW i Interaction EASE had a great classification on Engagement criteria because of the interaction level provided by the in-vehicle interface. The BMW HMI is done through eye movement which turns this human-machine communication easier, simple and intuitive. In this regard, we believe that the interaction provided highly influences the engagement of passengers when interacting with the system. The immersion level of the solution should also be pursued because of the possibility to watch movies or isolate the user from the external surroundings through the vehicle windows that adapt to the user needs (i.e. when the passengers leans his/her seat, the vehicle windows turn opaque offering the user a short nap with privacy).

Audi Urbansphere had the highest rate on engagement criteria because of the project approach - a space for relaxation and recharging in the stress of the cities. Although the solution is much more focused on calm feelings rather than excitement, we perceived this project to be highly engaging, attending its users needs. Other features were pursued as good options for the present research as the transparent displays for conference calls and seats that rotate when a user is entering the vehicle. Further information regarding each criteria evaluation can be found in the Appendix 4 (A4).

Criteria	Weight	Lg Connected car	Total	BMW i Interaction EASE	Total	Audi Urbansphere	Total
Comfort	1,6	5	8	1	1,6	2	3,2
Engagement	1,4	4	5,6	5	7	5	7
Co-experience	1,2	5	6	2	2,4	3	3,6
Immersion	1	4	4	5	5	3	3
			23,6		16		16,8

Table 2. Comparative analysis of solutions in the Mobility field area.

As mentioned before, we also analysed projects outside the mobility field area that were good examples regarding the chosen criteria (table 3).

DuMont Discovery dock had the highest rates in comfort, engagement and immersion criteria. Regarding comfort we highlight the intimacy created in the exhibition space followed by the large space that encourages visitors exploration. We believe that visitors share a common goal which is to understand and learn more about the Hamburg dock and this reason alongside curiosity, enhances empathy and social comfort between the users. Furthermore, the technology used and how the different areas are connected immerses the user as if he/she were actually in the Hamburg dock, which is inaccessible to visitors.

Although Yach Cloud Interactive system had not a big evaluation in any of the criteria, we analysed this project because of the features provided by the system and how all the complex information was organised (e.g. wind velocity, yacht components, location, ocean waves,...).

Disney star wars galactic cruiser was highly evaluated in every criteria. As in DuMont, we believe that the exhibition visitors also share common goals and interests, in this case related to Star wars series and child memories. Costumes, decoration and role-playing enhance the storytelling during the experience influencing the visitors immersion and engagement.

Although we had enough information to conduct the present research,

we were still lacking on users' research. Boy (2017) enhanced the importance of Human-centered Design (HCD) in the development of complex systems, proposing the TOP Model which relates Technology, Organizations and People through HCD. In this regard, we intended to assess the expectations, goals and concerns of future potential users.

Criteria	Weight	DuMont Discovery Dock	Total	Yacht Cloud interactive system	Total	Disney: Star wars galactic cruiser	Total
Comfort	1,6	5	8	2	3,2	5	8
Engagement	1,4	5	7	4	5,6	5	7
Co-experience	1,2	4	4,8	2	2,4	5	6
Immersion	1	5	5	4	4	5	5
			24,8		15,7		24,5

Table 3. Comparative analysis of solutions in other field areas.

2.3 ONLINE SURVEY

During the preliminary research, we intended to understand user acceptance (i.e., their willingness to use) of SAVs, the impact it would have on their comfort in shared rides, which activities were they willing to perform and share in autonomous rides. The survey was developed in two languages – Portuguese and English with the objective of gathering a considerable amount of answers from different cultural backgrounds. The survey compiled an informed consent (A1), a short text about the concept of SAVs and questions with closed and open answers (A2).

2.3.1 Sample

We conducted an online survey and gathered 343 answers (A3) from a range of different countries using non-probability sampling. The countries with most answers were identified as Portugal, United States of America, and Brazil with a range of ages from 22 to 70, with an average of 45 (SD = 28,3).

2.3.2_Procedure

The online survey (A2) was developed in Google Forms and disseminated across social networking platforms and through Amazon Turk, with the goal of getting a considerable sample and targeting different countries and cultures. With that aim, the survey was developed in two languages – Portuguese and English. It consisted of an informed consent, a short text about the concept of SAVs, questions with closed and open answers, and Likert scales to establish the identification of user groups. The survey was developed to take, on average, 10 minutes to complete.

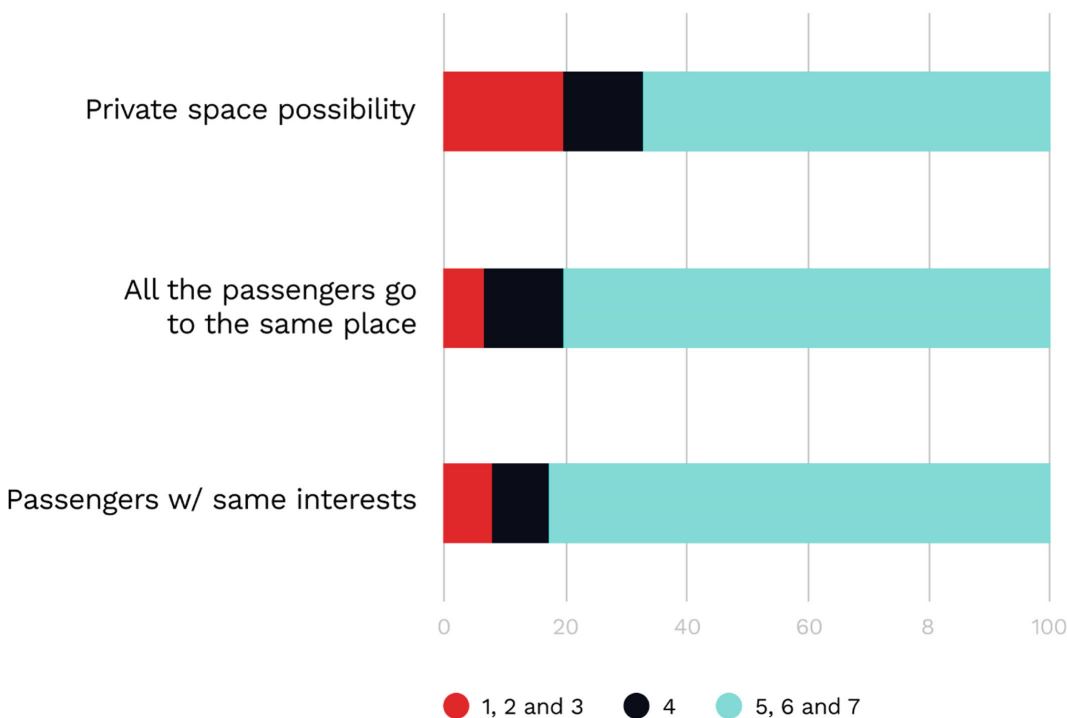
2.3.3_Results and discussion

No main difference was found between the different samples (from the multiple countries), so we compiled and analyzed all the data together. Concerning previous knowledge of the SAVs, the majority of the sample (71,6%) responded being aware of it. When asked about using of this type of vehicle in the future, 40% of participants stated that they would use SAVs, while 23% answered that they would only use it with known people (family or friends). The remaining sample, 32,4% were not sure about their future usage of SAVs (a sum of the answers “Maybe, but I would not use it right away” with a weight of 26%, and “I do not know”), and only 2,6% had a negative answer. When questioned about the physical sharing of the vehicle space, 56% responded positively, 40% answered positively with the condition that they knew the other passengers (family or friends), and 4% responded that they would prefer to travel alone. Considering user comfort (the human experience that takes into account social aspects and personal safety), when sharing the vehicle with others, participants answered positively on three the possibilities presented in the survey (Graph 1). From the collected data, we can observe that users’ acceptance of SAVs usage is far from one-sided. Despite a considerable percentage of users agreeing to share the vehicle space with other passengers, results indicate that the about half is conditioned by previous knowledge of others in this context. However, results also suggest that similarities between passengers’ destinations and/or interests tend to increase user comfort. In sum, users are looking

for something in common with other passengers, even if it turns into a slightly longer journey when considering similar interests. We understood here the importance of comfort (a human experience regarding social aspects and personal safety) to the adoption and constant usage of SAVs. The possibility of having a private space in a shared autonomous vehicle has also been deemed desirable for users, although the answers were more distributed in the Likert scale.

The presented data clearly indicates the users' willingness to adopt SAVs as a mobility option, while also revealing that they are conditioned by their comfort in this setting. In this regard, we identified the need to work towards interaction aspects and the matching between different passengers.

Users' comfort with different possibilities



Graph 1. User comfort ratings in different vehicle possibilities.

The graph 1 presented here, considers the data retrieved from the online survey on a likert scale in percentages for three different questions regarding comfort. The likert scale is from one to seven, with the values one, two and three being negative; four being neutral; and five, six and seven being positive.

CHAPTER 3_

FORSAV VISUAL IDENTITY

This chapter is about the ForSav branding development and the beginning of a Design System to maintain the visual consistency between the mobile application and the in-vehicle infotainment system.

3.1_LOGO DESIGN

We created a logo for ForSav (Fig. 19) in order to clearly communicate the brand, be easily identified and related to its purpose, which in this case is an interactive system for SAVs, an alternative mobility option that impacts positively the environment.



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Fig. 19. Logo design behaviour in light and dark backgrounds.

3.2_COLOR PALETTE

In order to represent the ForSav intentions towards a sustainable mobility option with a futuristic and technological approach, we choose principal and secondary colors (Fig. 20).

3.3_TYPEFACE

Typefaces are extremely important in branding development not only because of accessibility reasons but also because of its influence on users perception of a brand.

In this case, we chose a typeface that is not only legible in longer texts but also has a solid presence in short titles, which is a key factor in

in-vehicle infotainment systems - Work Sans. We defined different fonts, sizes and weights for different applications (Fig. 20).

DEVELOPMENT OF AN INTERACTIVE SYSTEM FOR SHARED AUTONOMOUS VEHICLES

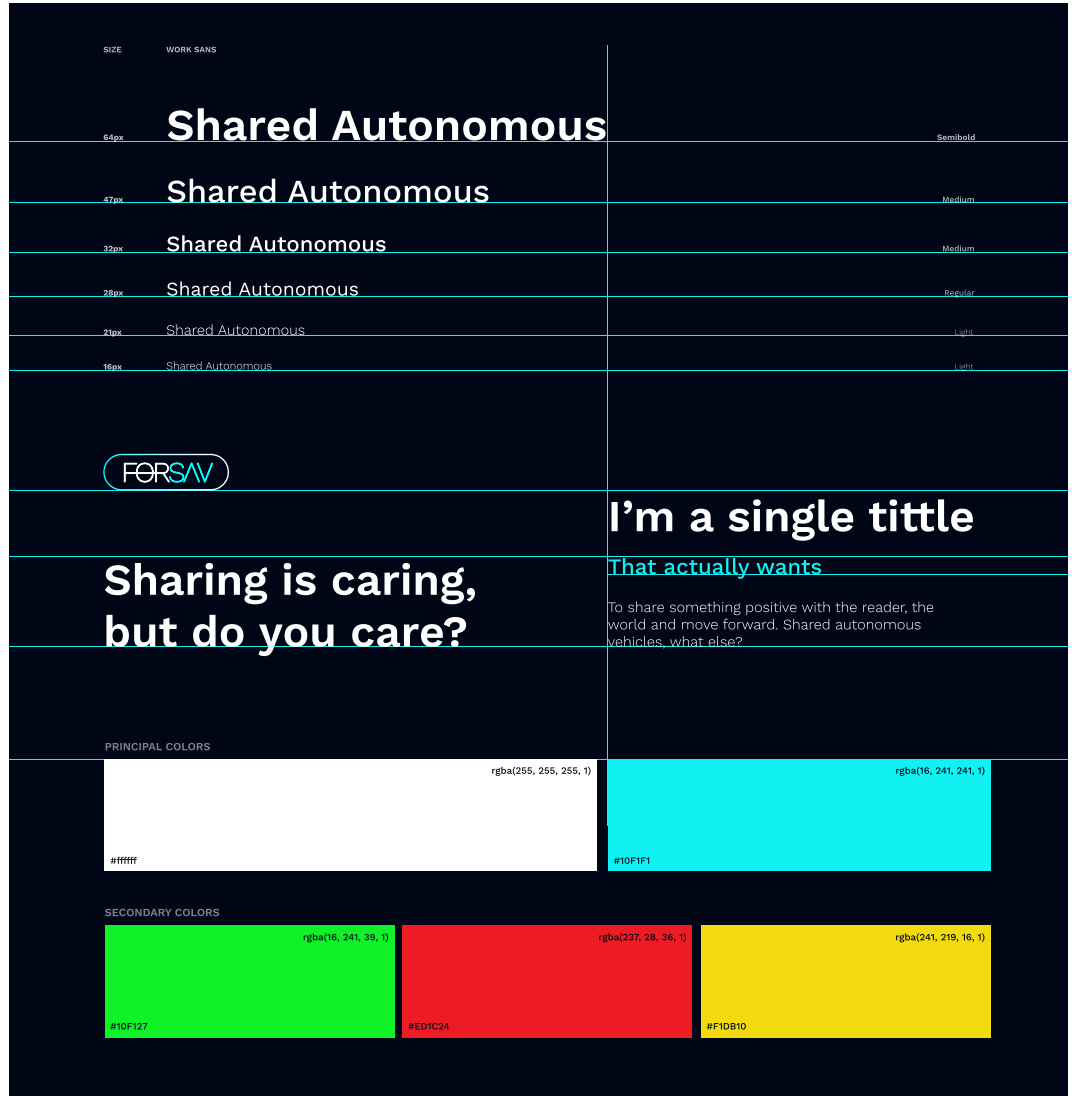


Fig. 30. ForSav typeface, fonts, sizes, weights and color palette.

3.4_DIGITAL COMPONENTS

In this research, we designed digital components in Figma software due to its importance regarding visual consistency across both digital products: 1) Mobile application; and 2) In-vehicle infotainment system.

A set of components (e.g. buttons) were created alongside different variations (Fig. 21) to tackle possible applications (e.g. primary button, secondary button).

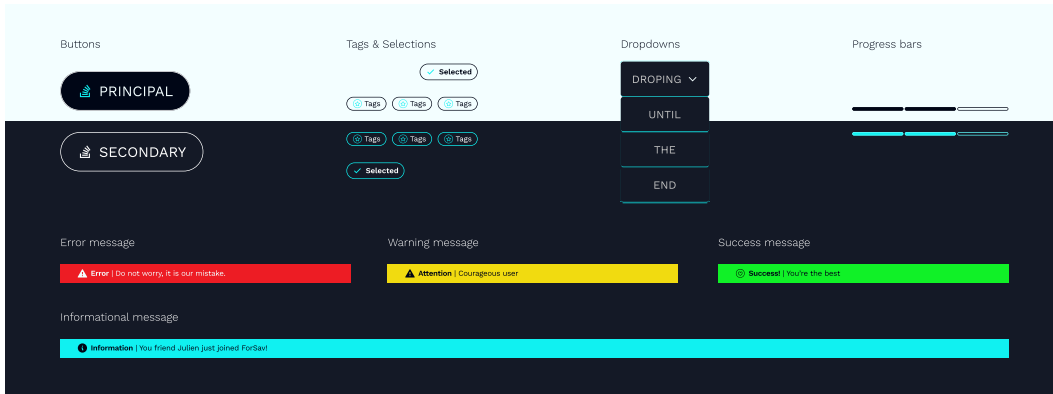


Fig. 21. ForSav components examples.

DEVELOPMENT OF AN INTERACTIVE SYSTEM FOR SHARED AUTONOMOUS VEHICLES

CHAPTER 4_

MOBILE APPLICATION DEVELOPMENT

The data retrieved from the online survey, made us realise the need to develop a mobile application capable of matching different profiles in the same ride in order to improve the acceptance of this mobility solution.

*This part of the present research was recognised by the **6th International Conference DIGICOM 2022 on Design and Digital Communication.***

4.1 ENVIRONMENTAL FEEDBACK

SAVs will dramatically change mobility and have huge impact on CO₂ emissions. In this regard, we wanted to allow users to keep track of their individual contribution to the planet when choosing ForSav option instead of personal vehicles. Across the mobile application we implemented environmental feedback (table 4) almost as a reward for using our solution.

	Environmental feedback
Login	“Ready to save the planet”
Landing screen	“Already saved x CO ₂ ”
Choosing ride	“Sustainable option Saving x CO ₂ ”
Payment successful	“Sustainable option Saved emissions = x CO ₂ ”
Chose Private vehicle	“Harmful option Your trip emission = x CO ₂ . Are you sure?”
Chose Private vehicle and shared the code	“Keep sharing the code Saving emissions = x CO ₂ ”
Shared code	“Hooray! Saving emissions = x CO ₂ ”

Table 4. Environmental feedback messages in the mobile application.

4.2 INFORMATION ARCHITECTURE

We structured the functionality of a DRS system mobile application for SAVs by identifying the main areas and its subsidiary areas into a visual scheme (Fig. 22). The presented structure was defined based on case studies, literature review, and brainstorming meetings with the research team.

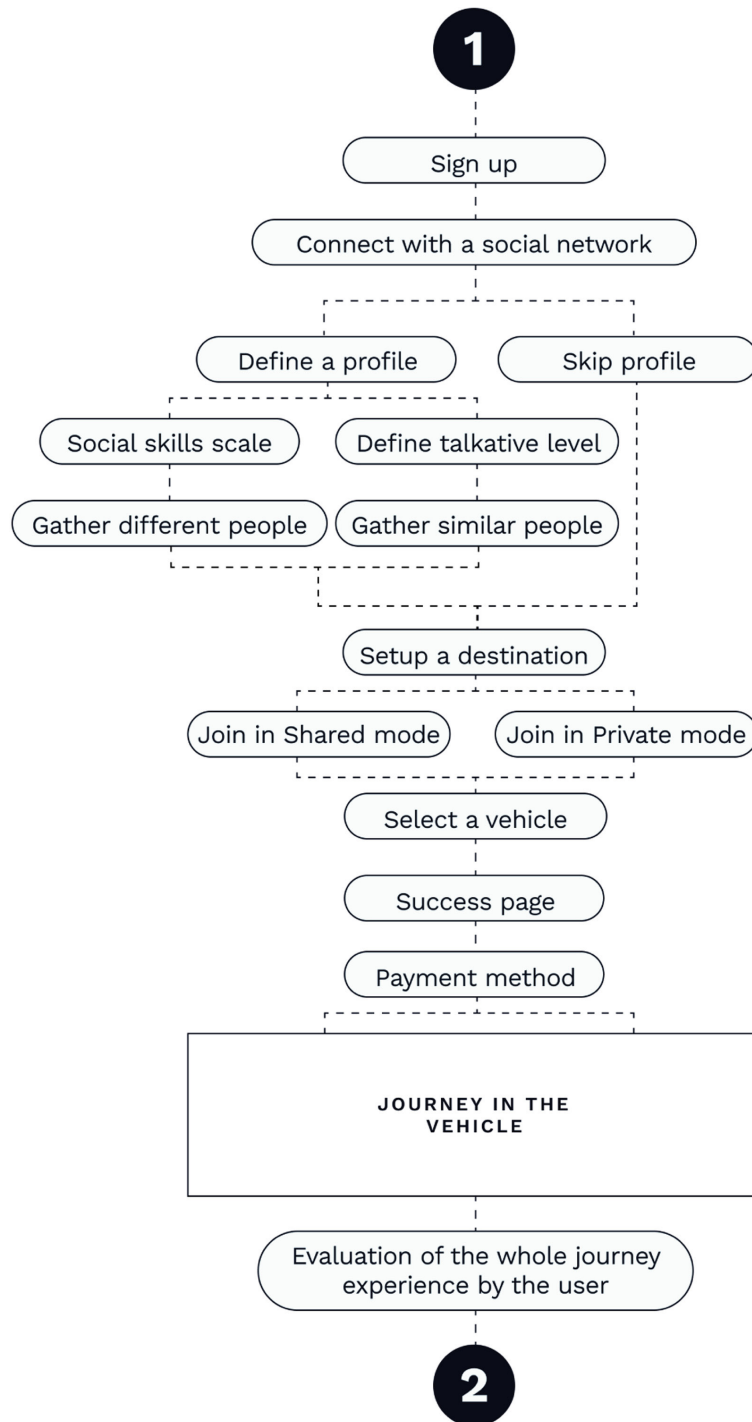


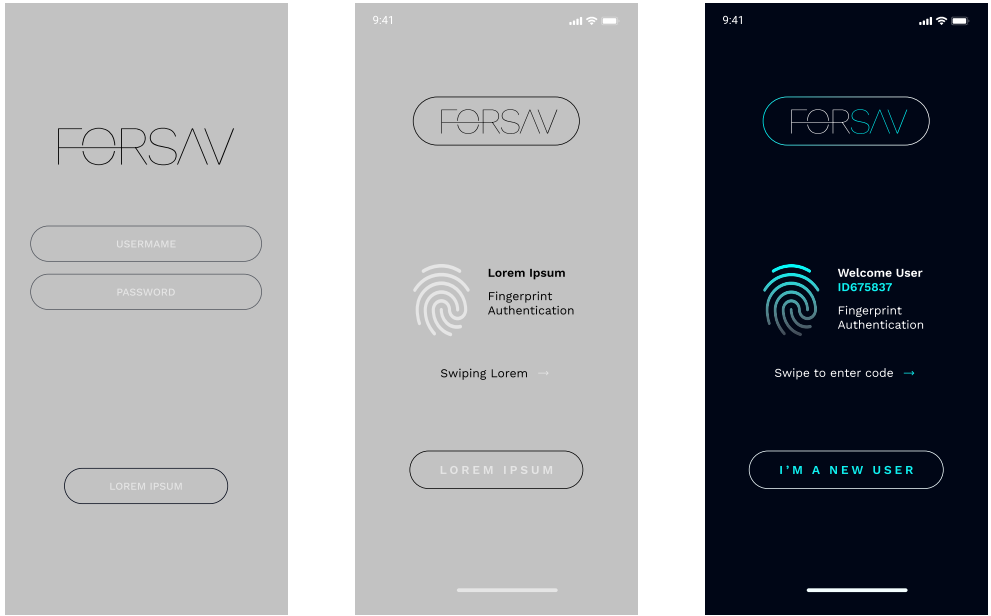
Fig. 22. The interaction between the user and the dynamic-ride sharing system in a ride between point 1 and point 2.

4.3_PROTOTYPING

4.3.1_Wireframes

Wireframes were created during the development of the mobile application. Through weekly meetings between the author and the supervisor, we iterated and improved the application considering information

architecture, usability heuristics (i.e. internal and external consistency, users' error prevention...) and visual aesthetics (Fig. 23).



DEVELOPMENT OF AN INTERACTIVE SYSTEM FOR SHARED AUTONOMOUS VEHICLES

Fig. 23. Wireframes development during our design iterative process.

4.2.2_Prototype development

Previous design process stages informed us to the creation of wireframes and the development of a prototype to evaluate users' acceptance on the concept and further research on the topic. The prototype was created using Figma software, considering sign up flow, ride scheduling for the moment and the future, payment methods, and the visualization of other passengers' interests (Fig. 24, Fig. 25, Fig. 26 and A5). The prototype was based on the previous design stages, case studies, literature review and obeyed the following usability heuristics: 1) consistency, 2) efficiency, 3) feedback, and 4) easy recovery from errors (adapted from ISO 9241-11:2018; ISO 9241-110:2020; ISO 9241-112:2017; ISO 20282-1:2006; ISO 9241-306:2018; Schlatter and Levinson, 2013).

DEVELOPMENT OF AN INTERACTIVE SYSTEM FOR SHARED AUTONOMOUS VEHICLES

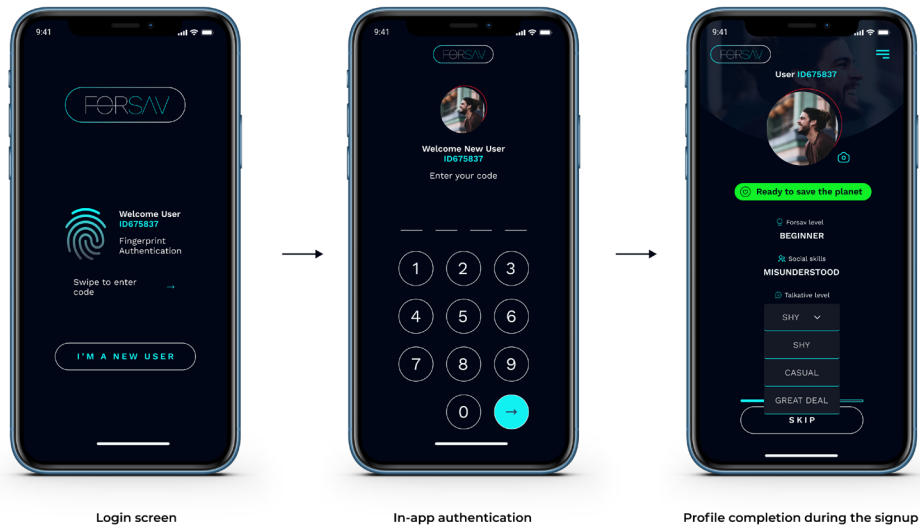


Fig. 24. Our prototype's functionality during sign up task.

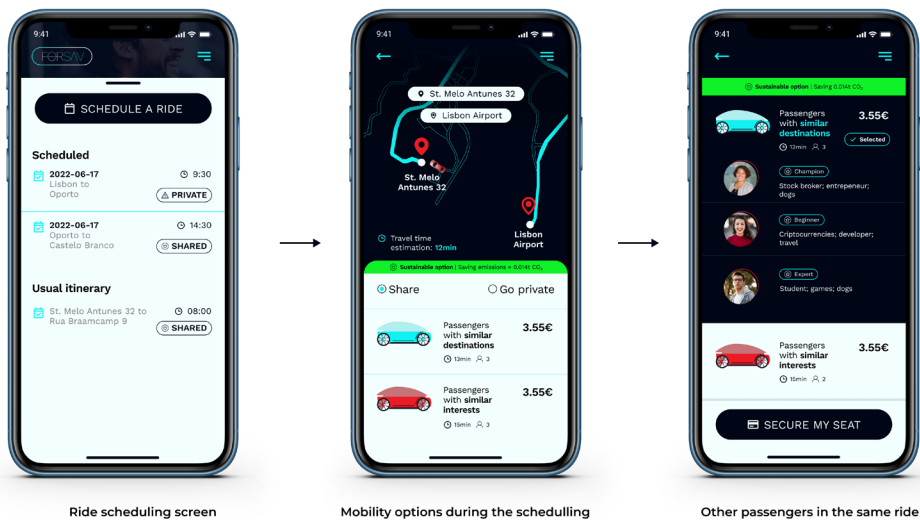


Fig. 25. Our prototype's functionality during scheduling task.

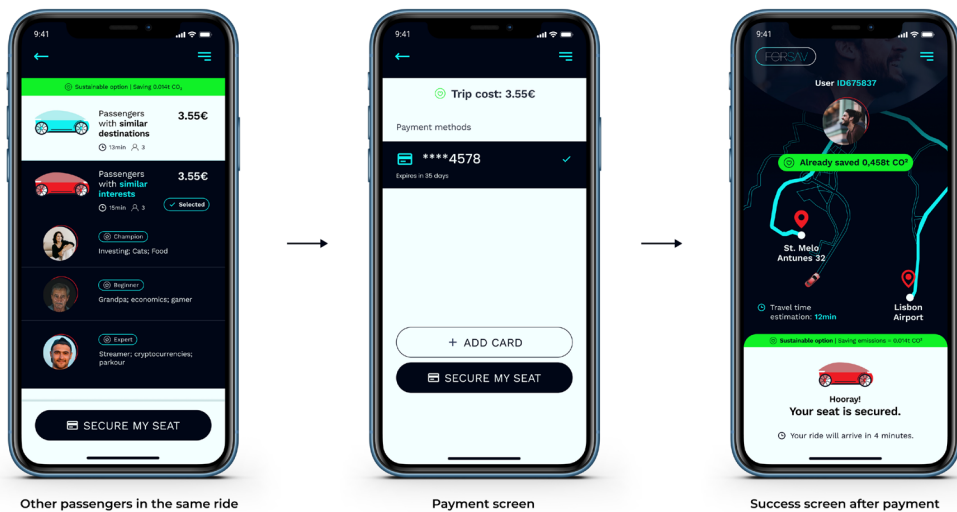


Fig. 26. Our prototype's functionality during payment task.

4.3_THINK ALOUD TEST

The developed prototype, which we named ForSav, was in an early development stage, with flaws and limitations related to the software used. Our main intention with it was to: 1) understand whether the authentication-imposed protocols helped in the users' confidence regarding the mobile application and its impact on their experience; and 2) understand whether the user preferred to choose the rides that best suit him/her or if it was considered preferable that the application matched the passenger automatically, considering user profiles. Considering that our main goal was to explore the mental model of our users and what they expected in these applications (A6), we conducted the Think Aloud method with a large enough sample to obtain results (Nielsen, 1994). The analyzed data (A7) was retrieved for further improvements on the ForSav solution.

4.3.1_Sample

The selected sample was composed of three males (from Portugal, Brazil, and Bolivia) and two females (from Portugal and Italy), with ages between 20s and 30s. The participants were recruited during university classes at the Lisbon School of Architecture (University of Lisbon). The sample had different backgrounds and cultures but a similar broad professional area, Design. None of the participants had previous knowledge of the research.

4.3.2_Procedure

A pilot test (n=3) was conducted to improve the evaluation protocol of the Think Aloud test. Subsequently, we conducted the Think Aloud test to a sample of five participants. The environment was isolated and controlled (a closed space with no external disturbance) to ensure the user was not distracted during evaluation. The five Think Aloud tests took, on average, 20 min to complete, and a mobile device model Huawei Mate 20 Lite black was used by the participants to interact with the system. An informed consent was given each participant alongside previous information regarding the study purpose and the participants' role.

The test was composed of two main tasks: 1) sign up in the mobile application and schedule a ride for the moment; and 2) schedule a ride for the subsequent day. During the interaction with the ForSav prototype, a mediator asked questions regarding what the participants were seeing on the screen, their expectations regarding specific actions, and their feelings considering personal confidence and comfort. The participants were sitting in a chair and close to the mediator to improve communication. The tests were recorded to revisit and assess the information produced by the participants in the analysis phase.

4.3.3_Results and discussion

We revisited the recordings, transcribed each test, and generated codes from the answers. Codes were grouped by similarity and subsequently transformed into a final code to serve the purpose of improving the mobile application. For instance, in the transcription “Now I see information about CO2 emissions, and I imagine I am doing good to the environment,” we identified the code “I am doing good to the environment,” which grouped with similar environmental codes originated the final code “I like ecological information” (Table 5).

The most common codes in all the tests focused on ecological information, generating nine initial codes, and comfort (of knowing other passengers before the ride), which generated fifteen initial codes. Following these, we found a preference for similar destinations in short rides, generating six initial codes. We found ambiguity in the authentication protocols and in the definition of “social skills” (both generated three initial codes in two different tests). From this information, we obtained five final codes: 1) “I like ecological information; 2) Authentication is confusing as-is; 3) Social skill is not understandable; 4) “I feel comfortable knowing others before the ride”; 5) and “I prefer similar destinations for short rides.” The research questions that led us to conduct a Think Aloud test were: 1) understanding whether the authentication-imposed protocols help in the users’ confidence regarding the mobile application and its impact on their experience; and 2) understanding whether the user prefers to choose the rides that best suit him/her or if it is pref-

erable that the application matches the passenger automatically considering user profiles. The authentication protocol implemented in our prototype was different from other applications, which affected users' experience during the evaluation. Users were expecting a protocol we commonly see in other applications, the two-factor authentication (2FA), which is known for fluid communication between two different channels owned by the same person. In this case, users expected to receive the code in their mobile phone (via SMS) or via email and only then set up their password and fingerprint authentication. The users' preference to choose the rides on their own was clear during the Think Aloud test. Users were interested about checking other options to see the passengers that already secured their seats. The tendency to explore the application happened in all the tests, mainly because of this possibility. According to our results, we recommend that the freedom to choose rides considering users' preferences be adopted in any DRS system.

Other unexpected results should also be considered for further steps. The environmental aspects of the mobile application were appreciated in all tests and were often referred. One of the participants said that they would appreciate the possibility of knowing more about the environmental advantages of this mobility option, in the form of a short description of the ForSav's vision, for example. Another interesting result relates to the comfort associated with knowing other passengers before the ride, which was appreciated in all the conducted tests. Lastly, an additional unexpected result was the confusion regarding the meaning of "social skills," which occurred in three tests. The option "similar destinations" was often chosen by the users because the presented journeys were at most 15 min long. However, two users said that they would choose the other option if the rides were longer because, according to them, an enjoyable conversation tends to easily happen if passengers share "similar interests."

Considering the results of our Think Aloud test, the mobile application need improvements regarding the login and signup authentication, where users found it confusing since its behaviour was different in other

platforms. Other designation for “social skills” should be pursued in further developments since it was not clear for some users and also an identity authentication protocol to increase trust within these systems.

Think Aloud data (examples)	Codes obtained	Final code
<p>User (U): “Now I should put my interests first and now I think I am ready to go on. [clicked] Now I see information about CO2 emissions, and I imagine I am doing good to the environment (...)” – P003</p> <p>U: “I would schedule here, [click schedule] now the date, hour and destination. Okay, I see that he’s telling me about the emission savings. [clicked private option] Okay, I like it because it tells me that I’m doing damage to the environment here and I see that here is my rides’ number (...)” – P003</p>	<p>“I imagine I am doing good to the environment”, “Maybe I will have more ecological information here”, “Important ecological information”, “Carbon emissions”, “It tells me how much emissions I am saving”, “In private mode it tells me that I am damaging the environment”</p>	<p>“I like ecological information”</p>

Table 5. An example of a code obtained during data analysis.

CHAPTER 5_

IN-VEHICLE INFOTAINMENT SYSTEM DEVELOPMENT

Although there were adjustments to be made on the application presented, we wanted to develop the whole interactive system and we perceive the in-vehicle infotainment system as equally important in terms of usage frequency of these alternative mobility options.

5.1_BRAINSTORMING

The preliminary research (i.e. literature review, comparative analysis and online survey) provided us insights to develop the in-vehicle infotainment system. Our intention was to explore a range of ideas for activities to perform with other passengers in future vehicles.

Brainstorming is a method commonly used in organisations to generate ideas in order to solve well-defined problems. In our case, the problem we were aiming to solve was “What are future potential users of ForSav willing to do during a shared ride, in private and shared contexts?”.

5.1.1_Sample

We invited professionals in product development to assist us in two Brainstorming sessions. We gathered two product owners, five software developers, two ux designers and one scrum master, all of them part of the Landing.jobs product team and experienced in developing products from scratch. The sample was unaware of the present research, being introduced to it during the brainstorming sessions.

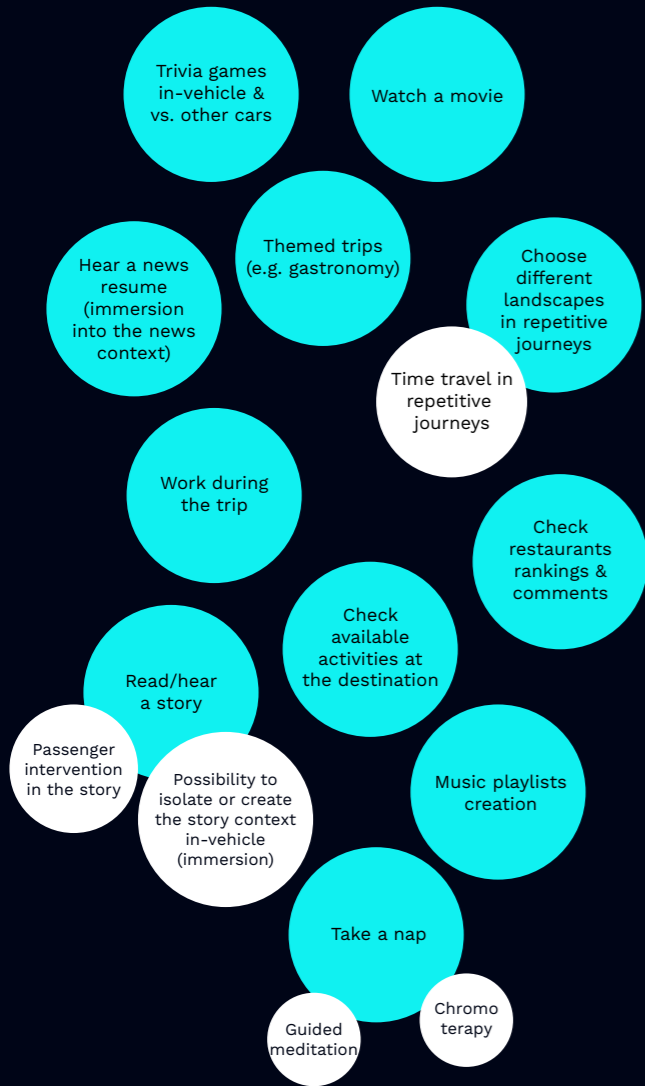
5.1.2_Procedure

Two brainstorming sessions were conducted via zoom with five professionals from the product department of Landing.jobs. At the start of the session, the moderator explained SAVs concept and what we were trying to achieve with the brainstorming session - generate ideas for possible in-vehicle activities in the future. During five minutes, everyone wrote the ideas that crossed their minds on their own. After that phase, the whole group explored more each idea, generating more ideas from the first idea that someone wrote. The first session was focused on shared rides with known people as family or friends and the second session focused on shared rides with unknown people.

We joint all the data from both sessions and arranged all the ideas generated in four different groups: 1) Activities to perform alone; 2) Activities to perform with unknown passengers; 3) Activities to perform with known passengers; and 4) Activities to perform with known or unknown passengers.

From the four groups (Fig. 27), we chose the ideas of “Activities to perform with known or unknown people” due to its flexibility in every context. We also compared each idea in this group, considering the set of criteria (comfort, engagement, immersion and co-experience) previously defined (page 27) to assess which were the best possibilities.

Activities alone



Activities with unknown passengers



Activities with known or unknown passengers



Activities with known passengers



Keys:
 ● Original idea
 ● Originated idea

Fig. 27. Brainstorming ideas divided in four different groups.

5.1.3_Results and discussion

The brainstorming sessions helped us define a path to the development of possible activities for the ForSav IVIS, with known and unknown passengers (table 6). The generated ideas were evaluated according to the defined set of criteria (page 28) by the authors.

The first idea evaluated was “The windows create new environments in the car as time-traveling or places where we have never been”, which opens a broad number of possibilities to entertain passengers during the rides as exploring and learning more in virtual environments. This option had the best total score regarding the chosen criteria.

“Music playlist co-creation” was an interesting option to explore but has issues regarding Social comfort if we consider different genres and artists. In order to provide this solution efficiently, changes would be necessary in the mobile application structure to gather passengers with similar music interests instead of interests in general.

“Random facts and chat topics” would be done through the IVIS in order to ease the conversation between passengers. However, we believe that the system developed in the mobile application that matches profiles considering their common interests already helps passengers’ communication in the ride, since these interest chat topics will occur without the system intervention.

Thematic trips was also an interesting option coming in the brainstorming sessions since it is relatable to the case previously analysed about Star wars. In this case, passengers would join considering their interests for thematic trips about a particular subject.

Watch a movie was one of the best scored ideas too considering the chosen criteria. We believe that a broad sample of available movies in IVIS would be flexible enough to tackle both contexts - known and unknown passengers.

Chromotherapy and guided mediation was an interesting possibility but not “social comfortable” with unknown passengers.

The possibility to make teams with other passengers a compete versus other vehicles of the system was a very interesting idea that met every chosen criteria.

Finding places to visit at the destination would also be an interesting task if we consider passengers as tourists in a specific city. In this case, this task could be shareable since all the passengers are visiting a foreign country. However, we aimed to develop a flexible system that would attend most of passengers needs which made us drop this possibility.

Drinking games to ease and facilitate conversations could be interpreted as a service that encourages passengers to drink alcohol, which could be wrong. Also, this idea lays on the fact that all passengers drink alcohol, which is a limitation to the flexibility we were trying to achieve. The ideas with the best scores were “The windows create new environments in the car as time-traveling or places where we have never been” and “Watch a movie”, and the worst scores were “Find attractions to visit at the destination” and “The vehicle helps me with the sleep (chromotherapy, guided meditation)”. In this regard, we developed both ideas (virtual in-vehicle environments and the possibility to watch movies during the ride) in the ForSav IVIS.

	Comfort	Engagement	Co-experience	Immersion	
Weight	1,6	1,4	1,2	1	
The windows create new environments in the car as time-travelling or places where we have never been.	5	5	4	5	
Total	8	7	4,8	5	24,8
Music playlist co-creation	3	2	5	2	
Total	4,8	2,8	6	2	15,6
Random facts and chat topics	3	5	2	1	
Total	4,8	7	2,4	1	15,2
Thematic trips (gastronomy)	5	4	3	2	
Total	8	5,6	3,6	2	19,2
Watch a movie	5	4	3	5	
Total	8	5,6	3,6	5	22,2
The vehicle helps me with the sleep (chromotherapy, guided mediation)	2	3	1	5	
Total	3,2	4,2	1,2	5	13,6
Teamup with other passengers vs. other vehicle (i.e. game between passengers in different rides)	4	4	4	4	
Total	6,4	5,6	4,8	4	20,8
Find attractions to visit at the destination	3	2	3	1	
Total	4,8	2,8	3,6	1	12,2
Drinking games to ease the conversation	3	4	3	1	
Total	4,8	5,6	3,6	1	15

Table 6. Brainstorming sessions data analysis considering the chosen criteria.

5.2_IN-VEHICLE INTERACTION

5.2.1_Vehicles' physical space

During the IVIS development, we were pursuing not only the flexibility of the digital interactive system, but also the flexibility of vehicle's space to attend passengers' needs regarding private and social contexts.

Lee (2021) proposed a mode for leisure trips with personals and group modes (Fig. 28), where passengers have the control whether they want to share their space with others or ride by their own way. Previously, we presented survey data that supports the users' expectations to use this mobility option if they had a private space possibility (Page 38).

In this regard, we adapted this concept to the present research in order to reach a flexible interactive system. Passenger seats that can rotate 360° allowing users to choose between riding in their own private space or in a shared space with other passengers with a window in each seat with an interface to interact with, providing different activities.

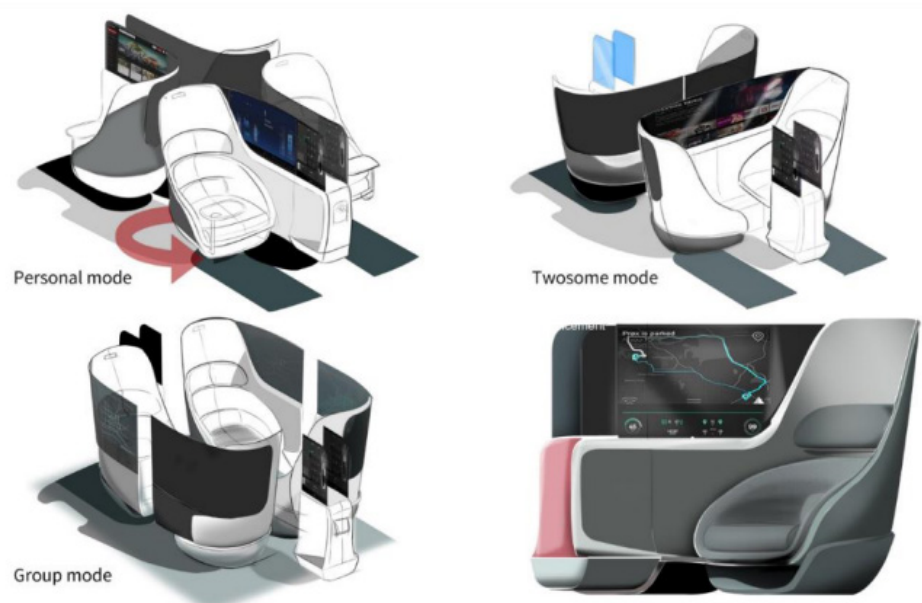


Fig. 28. Leisure interaction solution (retrieved from Lee, 2021).

In cases where all the passengers are conducting their own private activities, through lights animation on passenger seats (Fig. 29), the vehicle informs the passengers when the vehicle stops to pickup passen-

gers or leave them without distracting the user from its own task. When the lights are moving towards the seat center, the vehicle is picking up a passenger, otherwise the lights move away from the seat center. During the rest of the journey the seat has no lights.

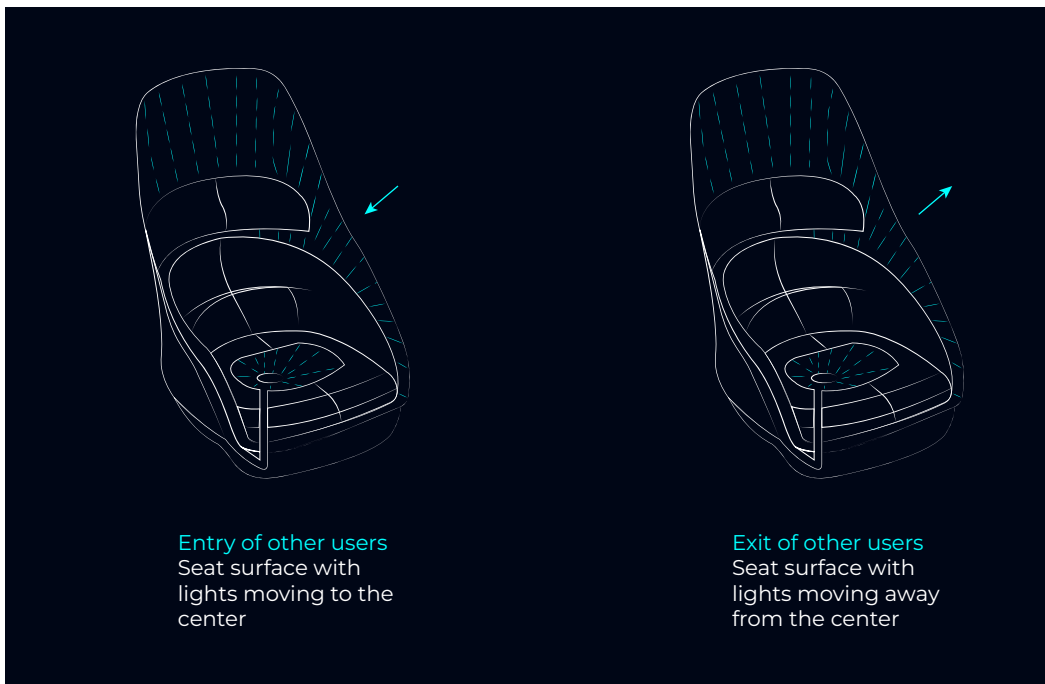


Fig. 29. Vehicles' mechanism to inform passengers in private mode about other passengers entering or leaving the vehicle.

During the generative phase, in-vehicle interaction explorations were conducted through sketching (Fig. 30). Understanding vehicle space and interaction possibilities was crucial in these phase to guide us in the system development.

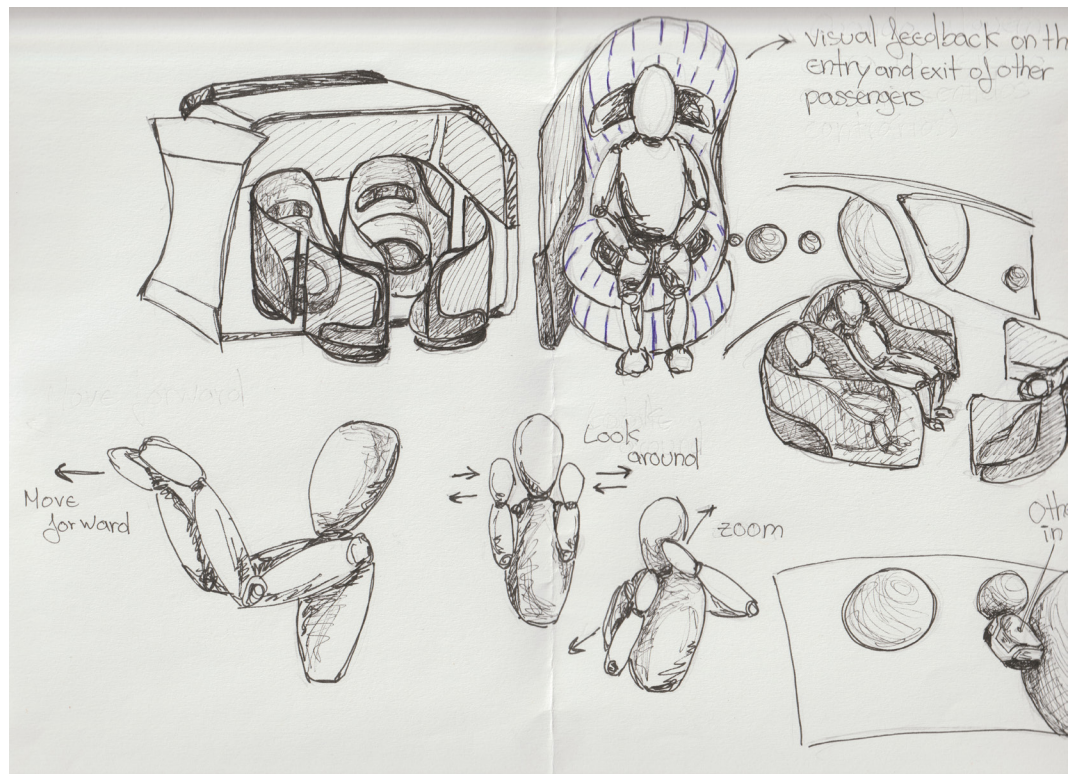


Fig. 30. Initial sketches about in-vehicle interaction during generative phase.

5.2.2_In-vehicle infotainment system development

5.2.2.1_Information architecture

In order to provide the in-vehicle activities presented alongside vehicle's information and other possible features, we structured the system architecture (Fig. 31).

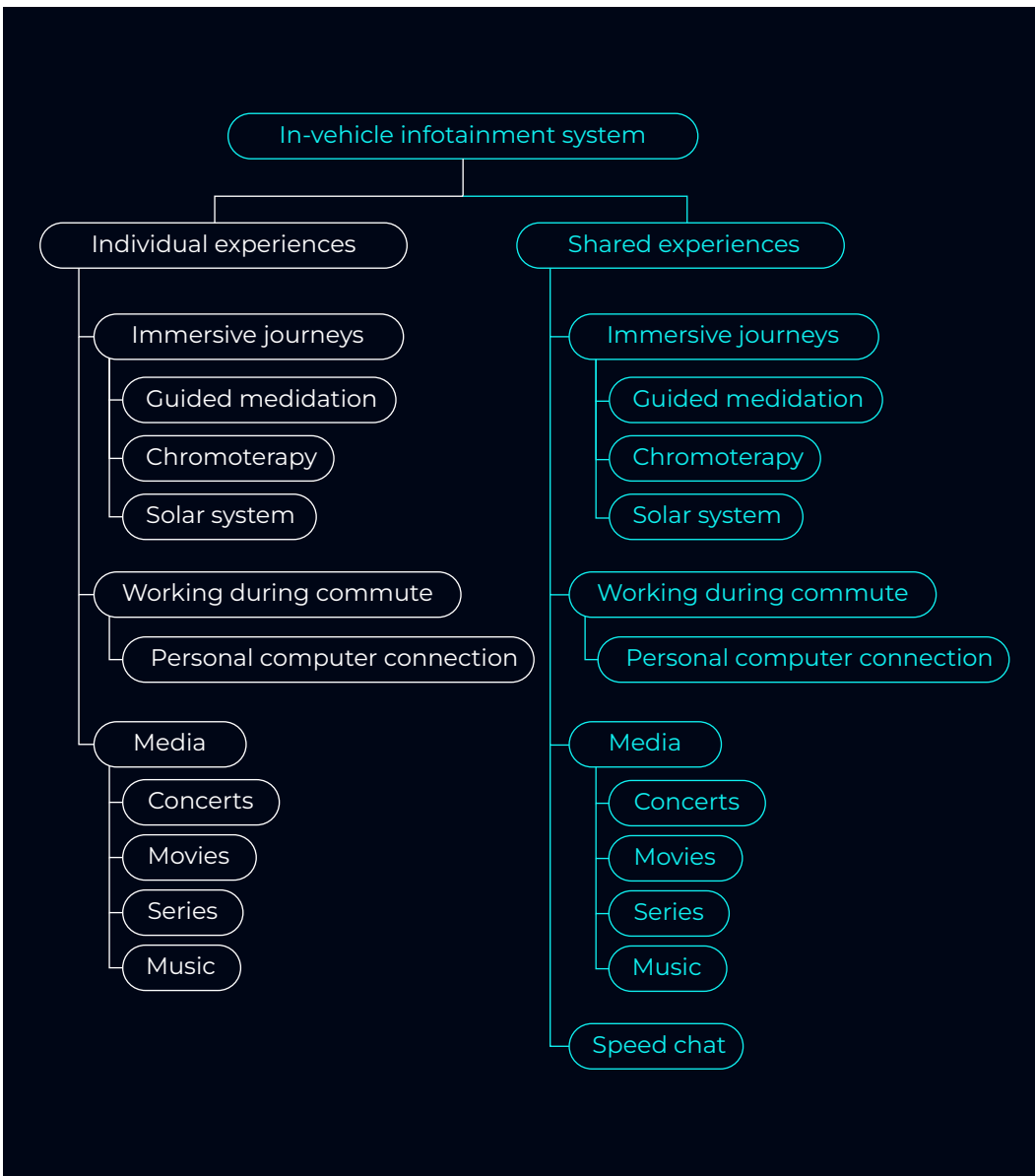


Fig. 31. IVIS information architecture.

5.2.2.2_Wireframes

We developed wireframes to assess the organization and functionality of IVIS' structure and tackle potential issues with the gesture interaction we were perceiving. Each screen was developed closely to maintain consistency across the ForSav system and iterated to keep the gesture controls reachable and intuitive (Fig. 32).

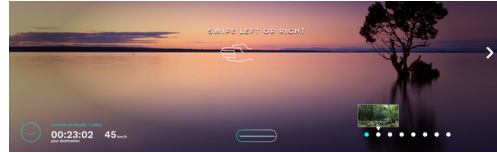
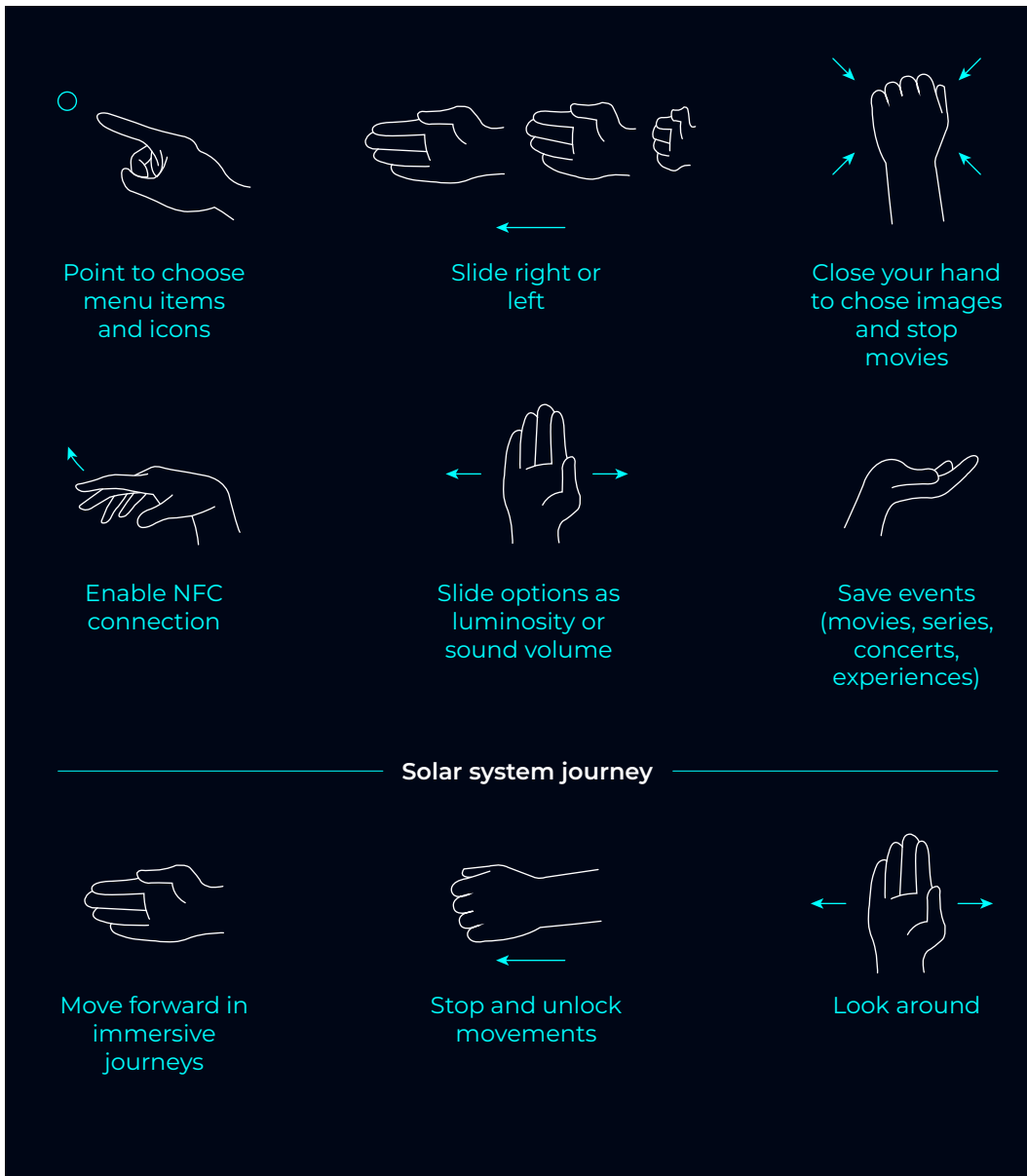


Fig. 32. Example of the iteration process on working during commute activity.

5.2.3_Gestures Library

BMW i Interaction EASE provides an effortless and intuitive interaction with passengers. Our intention was to provide a similar sensation when interacting with ForSav IVIS but with less prone to error. In this regard, we worked on a gesture library to interact with the system, maintaining an intuitive and consistent communication in HMI, across the ForSav IVIS.

The principle gestures to interact with the system are: 1) Finger point to select menu items and other features; 2) Slide right or left; 3) Close the hand to chose items and save moments (Fig. 33). Other gestures were developed to support remaining features and possibilities regarding the presented activities.



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Fig. 33. Gestures library.

5.2.4_Activities to perform during the ride

We considered the ideas generated in the brainstorming sessions and compared them through the set of chosen criteria. The best scored ideas were developed in order to provide activities do be conducted simultaneously by multiple users or individually in private rides.

5.2.4.1_Solar system journey

The best scored idea “The windows create new environments in the car as time-traveling or places where we have never been” led us to the development of a virtual ride to the solar system where users can decide

where they are going, visit planets and satellites and learn more about the galaxy along the way. This activity could be done with other passengers or individually, depending on each ride and passengers' expectations. For instance, four passengers interacting with the system in this activity, would complement each other during the solar system exploration since two people making the gesture to move forward, would accelerate the experience. If passengers start to move forward and look around, complementing each other, the journey experience would be more natural, where the ride is moving in the space, looking around the planets and gathering more information (Fig. 34).

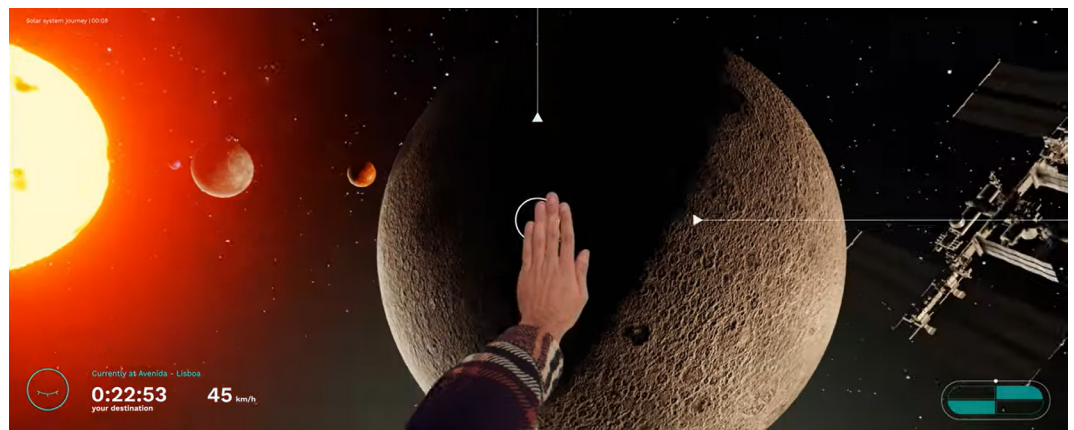


Fig. 34. Solar system journey.

5.2.4.2_Movies and series

Watch movies was the second best scored idea and was developed for individual and multiple usage. In this regard, different features have different positioning to assist multiple interactions. Also, we wanted to provide the possibility to save movie moments and scenes to watch later on future rides, especially if we consider short journeys (Fig. 35).

All these features and possibilities were an interaction challenge which led us to the development of a gesture library.



Fig. 35. Watch a movie activity - Interface.

5.2.4.3_Work during commute

Working task was not a high scored idea during the brainstorming sessions because it was focused on activities to perform with other passengers. However, we understood with the mobile application development that potential users' would prefer passengers with similar destinations for short rides. This implicates that these passengers are most likely willing to perform activities individually due to the journeys' duration. In this regard, we developed a feature to connect personal computers' with vehicle's system to access windows screens and work during the ride (Fig. 36). All the work is performed on the passengers' PC to keep his/her privacy while the vehicle's system allows the passenger to adjust sound volume, luminosity and the background with the flexibility we aimed.

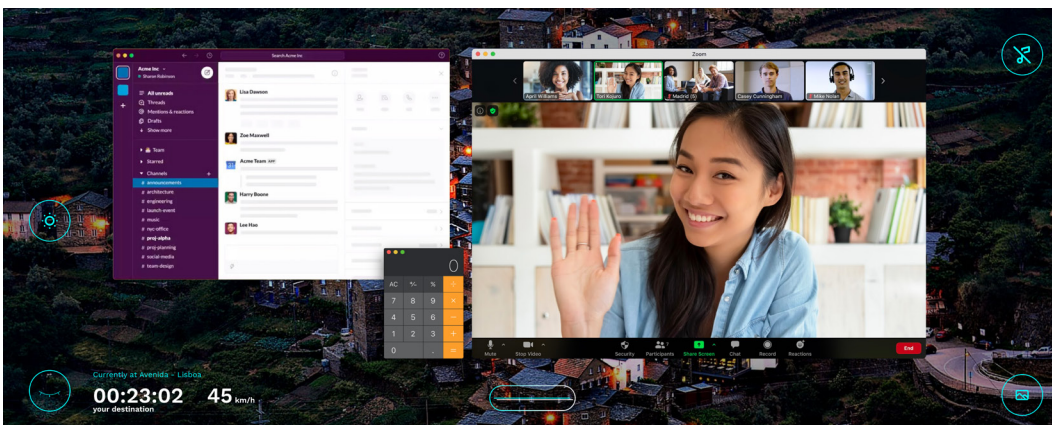


Fig. 36. Working during the ride - Interface.

In every task that passengers might be performing, they are able to stop it and

check how is traffic through the vehicle's cameras (Fig. 37).

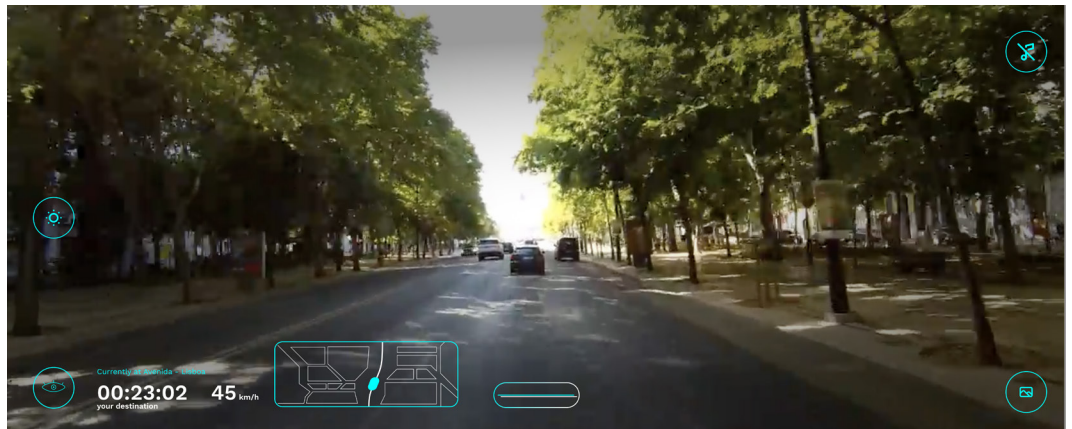


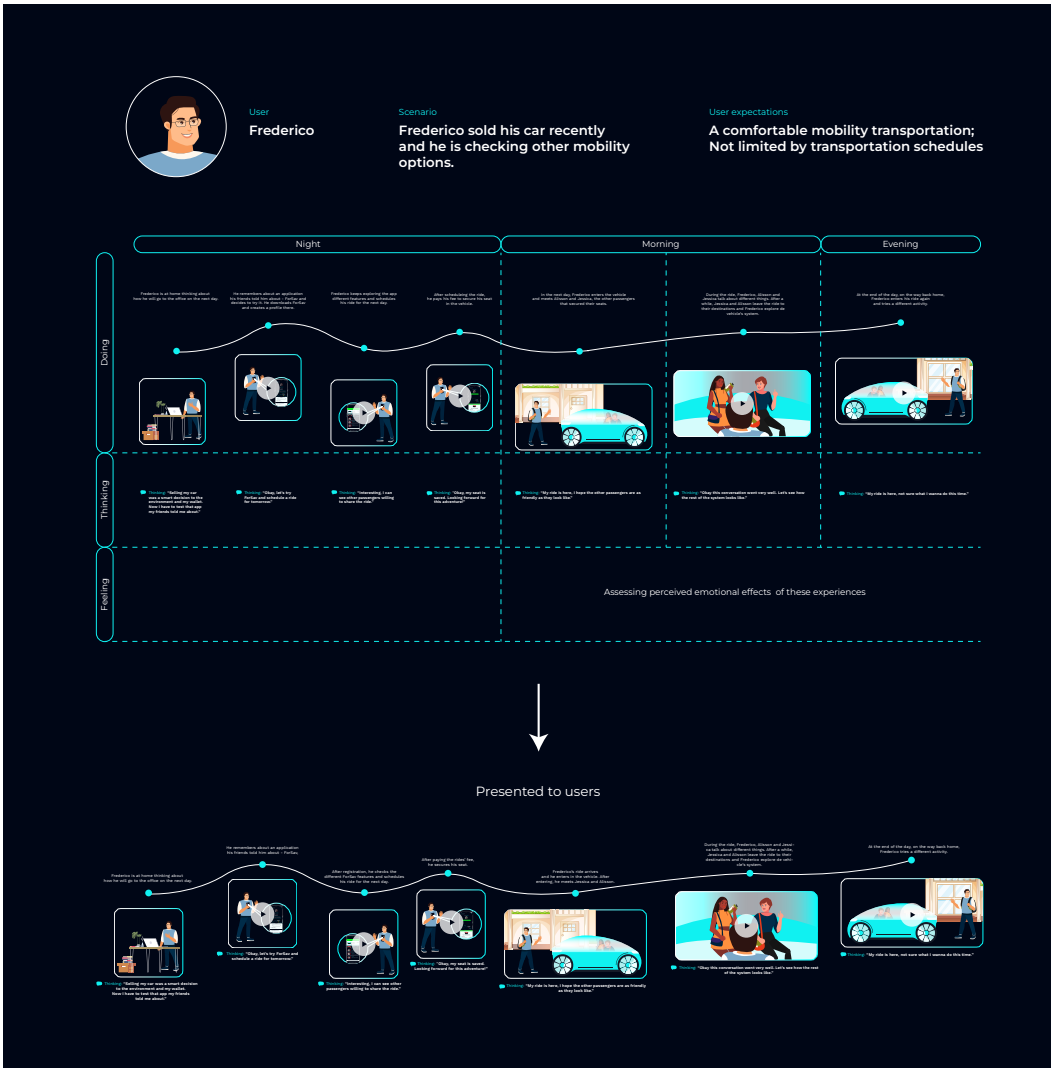
Fig. 37. Checking traffic in IVIS.

5.3_ASSESSING PERCEPTION OF SYSTEM USABILITY AND UX

The present research compiles not only the development process of a mobile application that precedes the journey experience, but also all the possible activities provided by the system during the ride. We opted to create a user journey map since a user schedules a ride, until he/she reaches the destination and assess the perceived effects of this journey on the user emotional state.

5.3.1_User journey map

According to Kaplan (2016), a customer journey map or user journey map compiles user goals, expectations and actions into a timeline skeleton with users' thoughts to create a narrative and insights from the whole process. Our purpose was to assess the perceived emotions felt during the process and perceived usability of the mobile application. In order to do that, we only presented a specific part of the user journey map to our sample with the only information needed to conduct the evaluation (Fig. 38). This approach also enriched us with data to complement the insights we already had from previous research.



DEVELOPMENT OF AN INTERACTIVE SYSTEM FOR SHARED AUTONOMOUS VEHICLES

Fig. 38. Developed user journey map, lacking user feelings and insights for further improvements.

5.3.2_Sample

We conducted three pilot tests to evaluate the protocol and adjust it accordingly. We found minor issues regarding the protocol and we also understood that we could not gather non-English speakers due to the fact that the whole content of the interactive system is in English. Using a non-probability sampling, we gathered 20 users in total, from Portugal, England, Brazil and Germany with a range of ages from 22 to 67, with an average of 32 (SD = 10,47).

5.3.3_Procedure

We took this opportunity to evaluate every step of the experience with different methods: 1) Ease of use (Adapted from SUS); 2) Geneva emotions wheel (GEW); 3) Self-assessment Manikin (SAM).

System Usability scale (SUS) was developed by Brooke in 1996 and is known for its capability in evaluating usability of digital products. However, we adapted the SUS for our research purpose, only focusing on the sentences that evaluated the ease of use of a system.

Geneva Emotions Wheel (GEW) is a self-reporting tool to measure emotional reactions and experiences (Scherer, 2005), that we believed to be a strong instrument to use in our evaluation context - identify perceived emotions during the interaction with the IVIS.

Self-assessment Manikin (SAM) was developed by Bradley and Lang in 1994 and is known as a picture-oriented questionnaire that intends to evaluate three different levels: 1) Arousal; 2) Pleasure; and 3) Dominance. In this project, we conducted the SAM evaluation on arousal and pleasure levels.

In order to clearly communicate our intentions in such a futuristic project, we developed short videos (Fig. 44) demonstrating the interactions possibilities in some of the scenes presented in the user journey map. The clips regarding the mobile application were recorded using an Iphone 13 with a Figma interactive prototype. The other two short videos were developed using Blender to build the scenarios, Figma to prototype the possible interactions and then gathered and finished using After Effects.

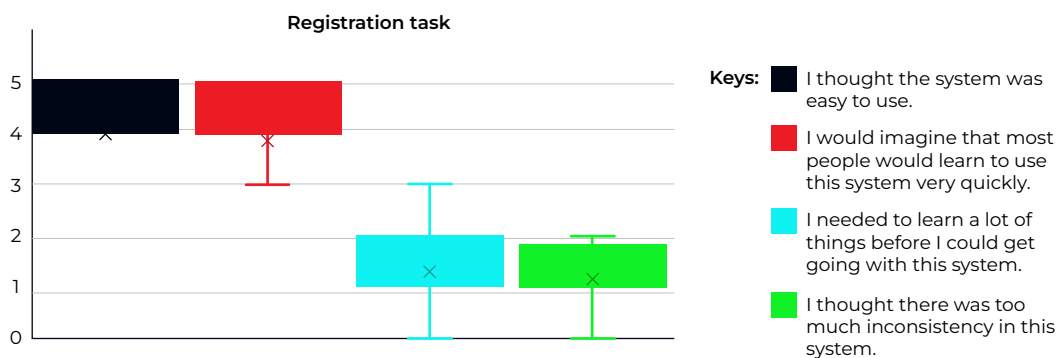
A pilot test was conducted with three users, in which we understood the need for improvements on the mobile application prototype and on the protocol.

5.3.4_Results and discussion

During SUS and SAM evaluations, the sample was commonly justifying their answers and we registered each answer.

In the first scene (registration in the platform), the sample expressed concerns regarding the accessibility of the application when being

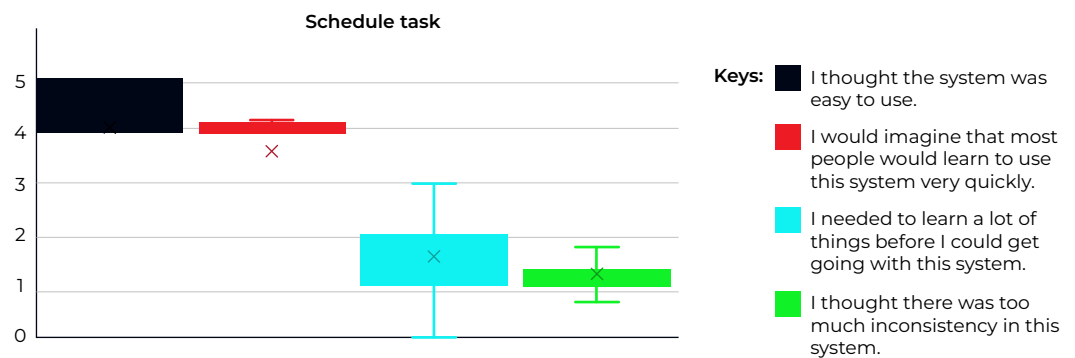
used by older people with less digital knowledge (Graph 2). The adapted SUS Evaluation comprehended four sentences, two of them written in a positive way, meaning that higher values are related to a better perception of the mobile application ease of use. The other two sentences, written in a negative way, low values relate to better perception of the mobile application ease of use. In the first sentence (positive sentence) “I thought the system was easy to use”, the average answer was 4.70 (SD = 0,47); the second sentence (positive sentence) “I would imagine that most people would learn to use this system very quickly”, the average answer was 4.50 (SD = 0,61); the third sentence (negative sentence) “I needed to learn a lot of things before I could get going with this system”, the average answer was 1.40 (SD = 0,60); and the fourth sentence (negative sentence) “I thought there was too much inconsistency in this system”, the average answer was 1.30 (SD = 0,47). Furthermore, some users did not understand why the system would ask for the user interests during the registration. We highlighted the need to give further information about the service and where are the user interests being considered to ensure trust and transparency in ForSav.



Graph 2. Usability and UX evaluation – Results from the first scene.

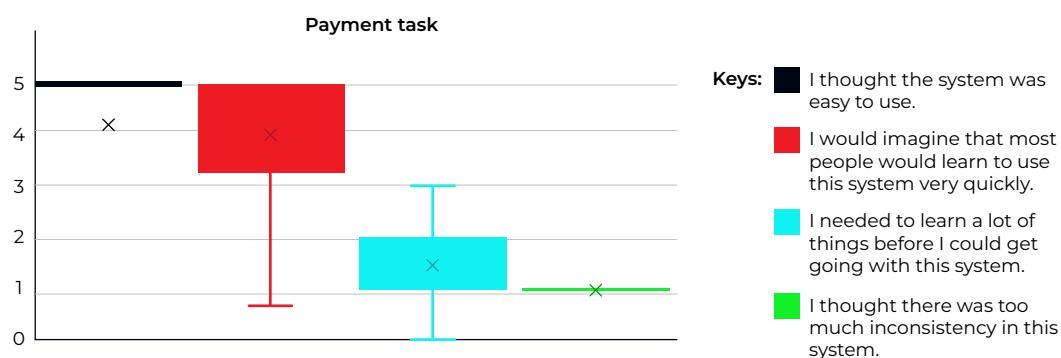
In the second scene (scheduling a ride), most of the users understood the initial request to type their interests during the registration (Graph 3). In the first sentence “I thought the system was easy to use”, the average answer was 4.80 (SD = 0,41); the second sentence “I would imagine that most people would learn to use this system very quickly”, the aver-

age answer was 4.25 (SD = 0,44); the third sentence “I needed to learn a lot of things before I could get going with this system”, the average answer was 1.70 (SD = 0,80); and the fourth sentence “I thought there was too much inconsistency in this system”, the average answer was 1.35 (SD = 0,67). Furthermore, in this scene the users’ feeling about ForSav mobile application accessibility became stronger due to the complexity of the task “Although this is familiar to me, I am not sure if my parents would use the application without my assistance”.



Graph 3. Usability and UX evaluation – Results from the second scene.

In the third scene (payment task), most of the users felt the need to know more about the payment process and which were the payment options (Graph 4). In the first sentence “I thought the system was easy to use”, the average answer was 4.95 (SD = 0,22); the second sentence “I would imagine that most people would learn to use this system very quickly”, the average answer was 4.65 (SD = 0,67); the third sentence “I needed to learn a lot of things before I could get going with this system”, the average answer was 1.55 (SD = 0,89); and the fourth sentence “I thought there was too much inconsistency in this system”, the average answer was 1.10 (SD = 0,31). Although the results are much better than the other scenes, the video presented does not show how the user associates a credit/debit card with his/her account or other payment methods.



Graph 4. Usability and UX evaluation – Results from the third scene.

GEW is composed by 20 emotions and it is possible to choose “No emotions felt” or even identify an emotion that is not described in the picture. During the GEW evaluation, we asked users to choose three emotions from the picture and the intensity level of each emotion on a scale from one to five. Whenever a user was in silence for some time, we said that it was possible to choose another emotion that was not represented in the picture.

In the fourth scene, considering the perceived emotions before entering the vehicle, 21 users chose interest; 3 users chose amusement; 1 user chose pride; 7 users chose joy; 1 user chose pleasure; 10 users chose contentment; 1 user chose admiration; 1 user chose relief; 2 users chose regret; 9 users chose fear; and 4 users chose different emotions from the GEW that we gathered into anxiety (Fig. 39). All the positive expressed emotions are related to the fact that the user made the choice to sell his/her personal vehicle to save emissions and the system worked. The negative expressed emotions (fear, anxiety and regret) were related to the fact that Frederico did not know the other passengers and his built expectations could not be met.

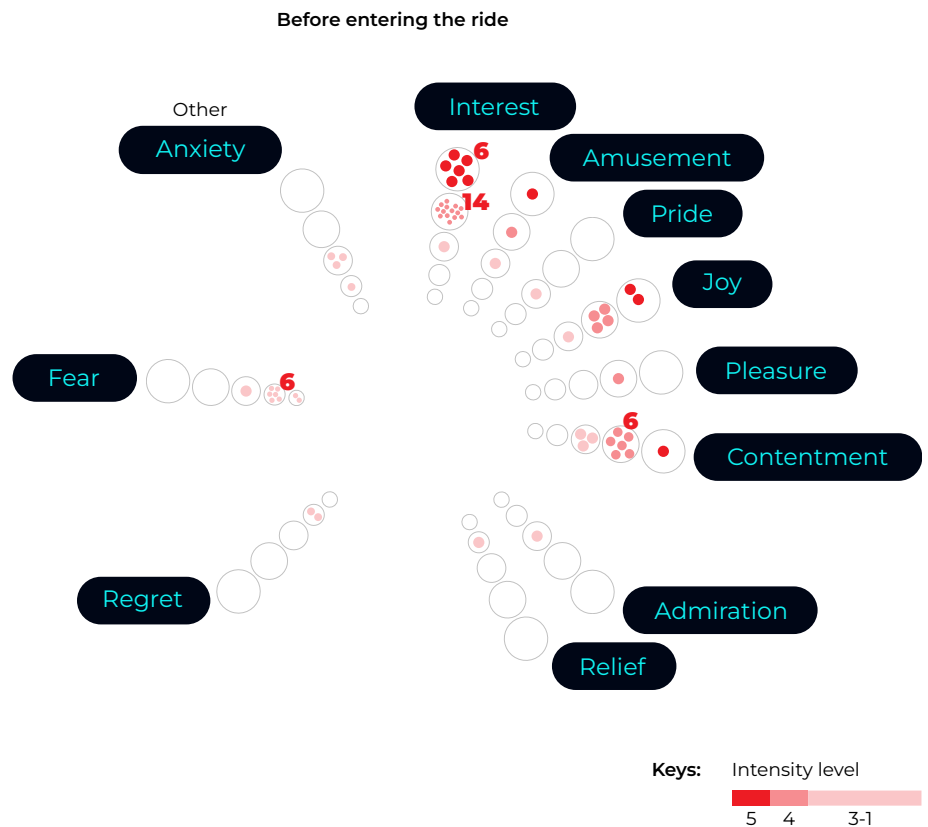


Fig. 39. Usability and UX evaluation – Results from the fourth scene (GEW).

In the fifth scene, considering the perceived emotions during the first interaction with the in-vehicle infotainment system, 15 users chose interest; 14 users chose amusement; 2 user chose pride; 12 users chose joy; 8 users chose pleasure; 2 users chose contentment; 6 user chose admiration; and 1 user chose relief from the GEW (Fig. 40). In this scene, all the chosen emotions were positive and we can observe an increase towards interest, joy and pleasure. We can argue that the interest increase is related with the interaction channel (gestures) where the user is experiencing something new and might be interested in continuing that exploration. Joy and pleasure is expected since the opportunity to do other activities during the ride was desired by potential users and watching a movie is often a joyful and relaxing task.

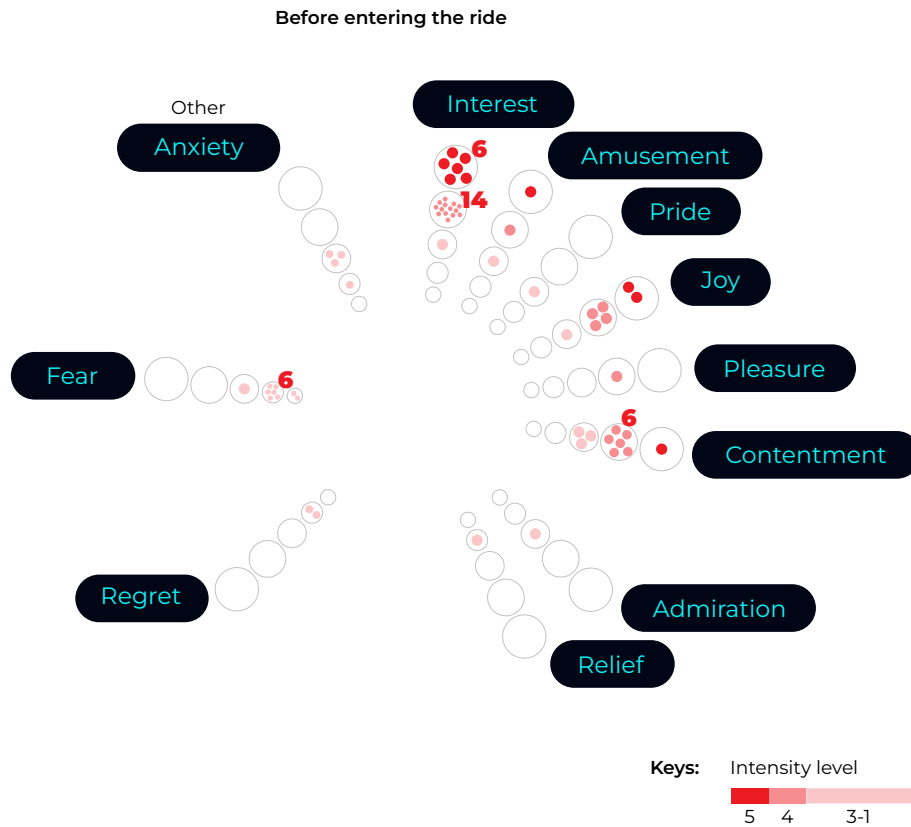


Fig. 40. Usability and UX evaluation – Results from the fifth scene (GEW).

During SAM evaluation, we guided users on how to assess the SAM pictures regarding arousal and pleasure and the scale associated with it. For each scene, only one classification was given regarding arousal and pleasure.

Additionally, we asked users to identify in the arousal and valence level in the SAM scale, the image that they perceived as similar to Frederico's feelings in that given context (Fig. 41). In the arousal level, the average answer was 5.40 (SD = 2,39) and in the valence level, the average answer was 7.75 (SD = 0,97). The answers in the arousal dimension were not one-sided because some users considered it an exciting context mainly because of the gestures' interaction and other users considered it a calm and joyful activity to perform during a ride. The answers regarding the valence level were positive and important to prove the acceptance of our solution.

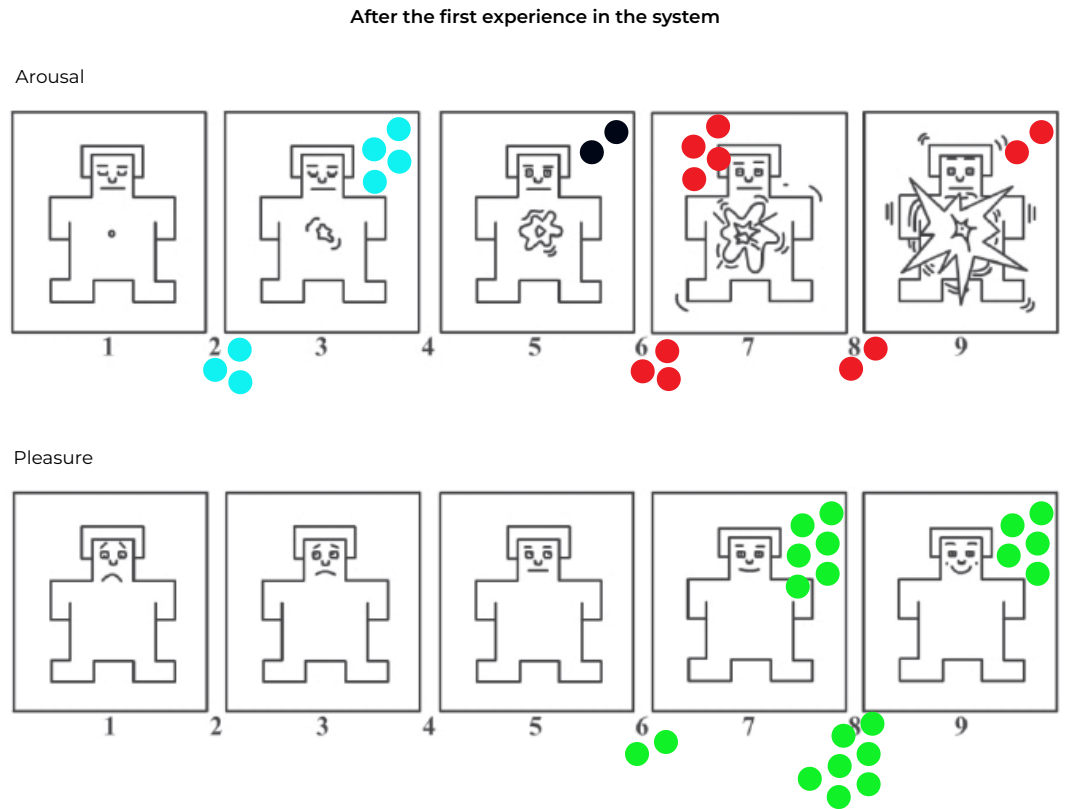
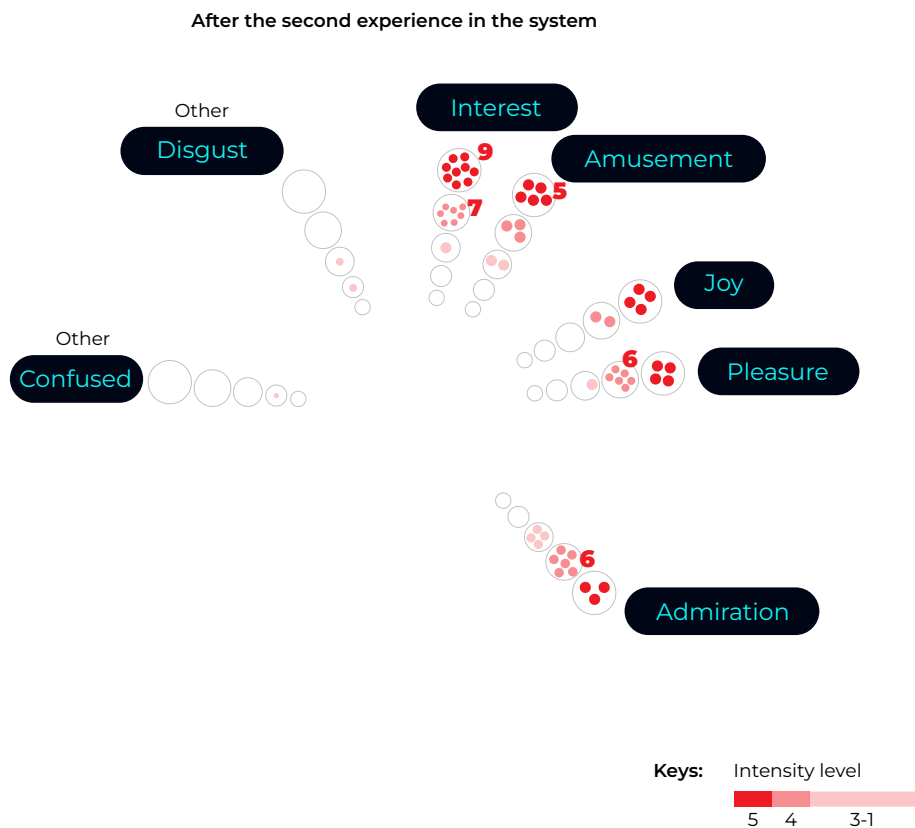


Fig. 41. Usability and UX evaluation – Results from the fifth scene (SAM).

In the sixth scene, considering the perceived emotions during the second interaction with the in-vehicle infotainment system, 17 users chose interest; 10 users chose amusement; 6 users chose joy; 11 users chose pleasure; 13 users chose admiration; 1 user chose confusion; and 2 users chose disgust from the GEW (Fig. 42). Although, most of the chosen emotions were positive, the disgust emotion needs to be considered in the development of these systems. Two of our users expressed concerns regarding motion sickness when interacting with such system during the ride. The solar system background sound was also pointed out was annoying and influenced their choices. The expressed confusion was related with the solar system dimension and the users' fear to get lost in there. We observed an increase towards admiration which is related to the context of observing and learning more about the solar system. The

possibility of exploring the galaxy influenced the choice for interest as an emotion felt. Pleasure was the third most chosen emotion and some users expressed that since Frederico was coming back home, he was enjoying his time observing and exploring the solar system.



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Fig. 42. Usability and UX evaluation – Results from the sixth scene (GEW).

As conducted in the fifth scene, we asked users to identify in the arousal and valence level in the SAM scale, the image that they perceived as similar to Frederico’s feelings in that given context (Fig. 43). In the arousal level, the average answer was 5.05 (SD = 2,31) and in the valence level, the average answer was 7.55 (SD = 1,47). As in the fifth scene results, the arousal level answers were scattered along the scale due to the uncertainty between a calm activity as traveling in the solar system, and the excitement of interacting with a new system through gestures and voice commands. The fact that disgust and confusion emotions were identified in the GEW (background sounds and motion sickness) also influenced the perception during the test. The answers regarding

the valence level were positive and important to prove the acceptance of virtual journeys during the ride.

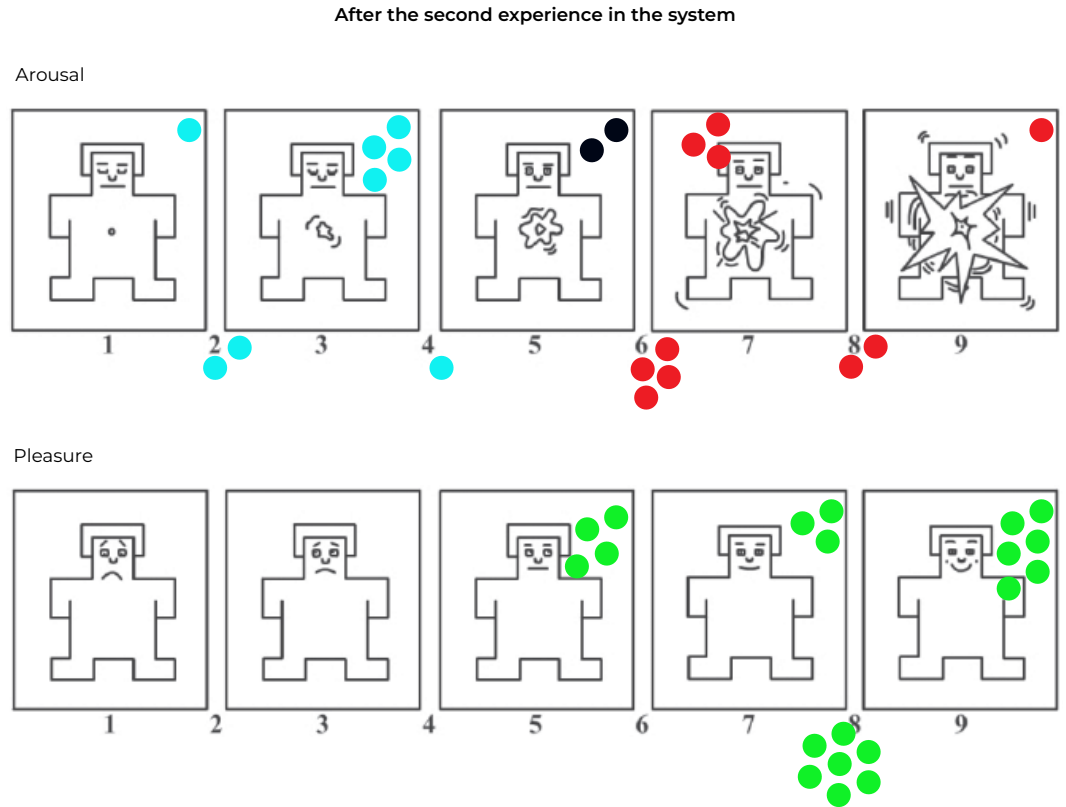


Fig. 43. Usability and UX evaluation – Results from the sixth scene (GEW).

The results from the Usability and UX evaluation were used to complete the user journey map (Fig. 44).



User
Frederico

Scenario
Frederico sold his car recently and he is checking other mobility options.

User expectations
A comfortable mobility transportation; Not limited by transportation schedules

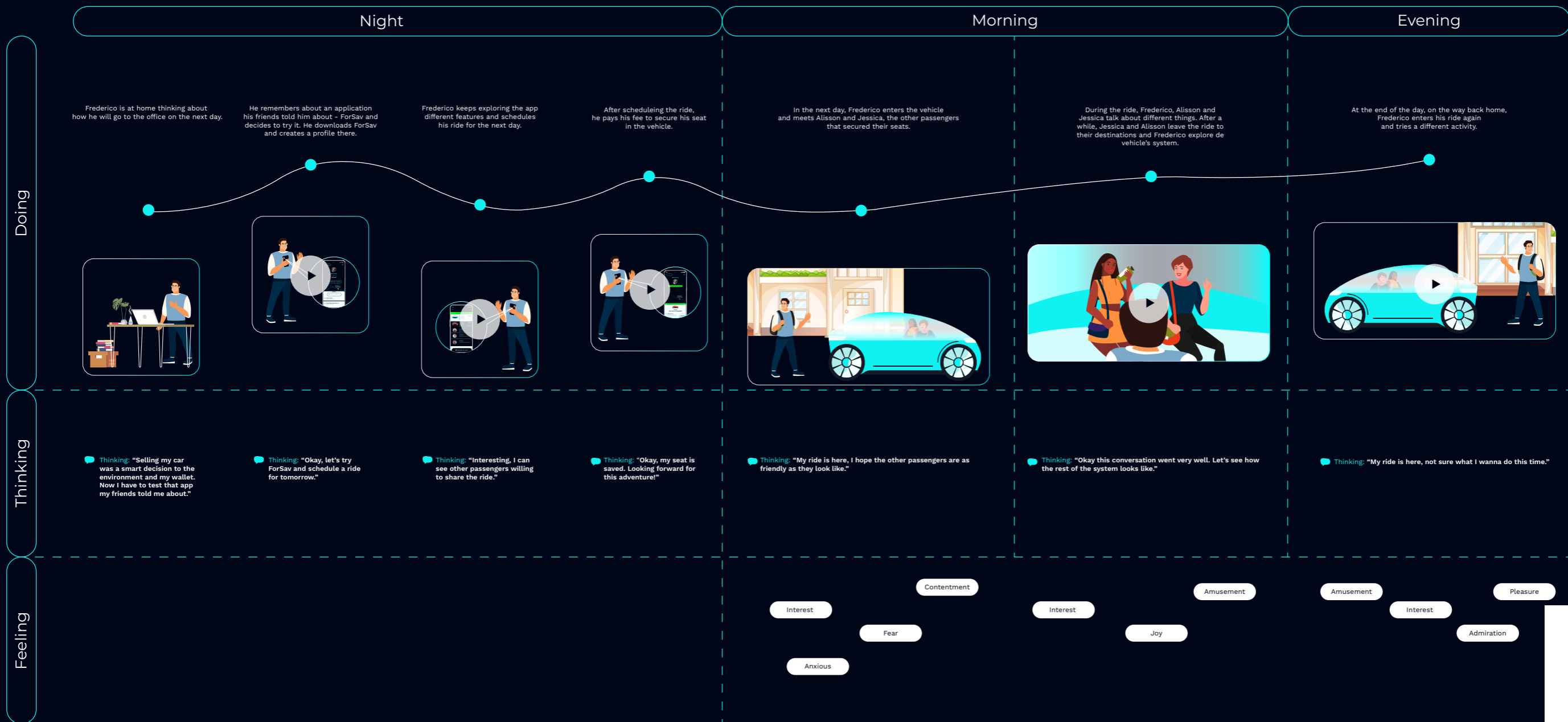


Fig. 44. User journey map completed after the Usability and UX evaluation.

CHAPTER 6_
CONCLUSION

6.1_Final considerations

The present research provides rich data to the development of interactive systems that facilitates public acceptance (willingness to use) of shared autonomous vehicles. We understood not only the importance of comfort (defined as a human experience that considers social aspects and personal safety) in the acceptance of these emerging mobility options, but also the role of environmental concerns in decision making. The constant environmental feedback across the mobile application was identified as a positive trigger to the continuous usage of SAVs. Furthermore, we found some concerning issues during the Think Aloud tests that highly impact trust and comfort in this service if users start defining what they aim to be instead of what they are (e.g., false profile pictures or interests), alongside the possibility of existing users without a profile picture, which would lead to misunderstandings and distrust between passengers. In addition to the identified social problems with this solution, we understood that even though users had previous knowledge of other passengers, fear, regret and anxiety emotions are perceived to be felt moments before entering the vehicle. We can argue that a mobile application that considers users' preference when scheduling a ride is a good solution in the acceptance and continuous usage of this emerging mobility option, but the fear and apprehension of the unknown will always be present. In fact, checking other passengers' profile pictures before scheduling a ride seems comforting, our solution could be working to bypass photo-based prejudice. The Usability and UX evaluation (in this case, ease of use evaluation adapted from SUS), also gave us interesting insights regarding consistency and learnability. We identified some problems during complex tasks as schedule a ride, where people with less digital knowledge could feel lost or confused. The fact that the payment feature was not fully developed and ready to test, turned out to be a problem during the evaluation of payment task since users could only see one way of paying the service without additional features such as the possibility of adding a new debit card. The development and implementation of this solution could lead us to more accurate results, but due to time and resources concerns,

the whole system was prototyped and worked towards the evaluation of perceived Usability and UX.

The experience of watching a movie and interacting with a modern IVIS triggered emotions as interest, amusement and joy during the ride.

Similar results were identified in the second experience (i.e. solar system virtual journey) which is a solid proof that entertainment activities are good incentives to the usage of SAVs and other autonomous mobility options. In fact, motor brands are already working on this idea since BMW presented a new concept at CES 2023 called BMW i Vision Dee where its feature “Mixed Reality Slider” can bring virtual worlds to the vehicle. However, disgust emotion mostly related to motion sickness when interacting with such system during a ride was identified by two users. Technological advancements are encouraged to avoid physical feelings as motion sickness and most importantly, the perception that this might happen to potential users. Alongside disgust, confusion was also identified by a user that was afraid of getting lost in the solar system due to the space dimension and the immersion into this experience.

We conclude that the present research aimed to solve a set a research questions and goals that we believe have been fulfilled. Interaction design as a research field has the capacity to provide solutions that facilitates and increase public trust in emerging mobility options. ForSav as a service could be adopted by the overall population when politics and technology evolves accordingly to consider these emerging mobility options. As presented before, potential users aim to perform a set of in-vehicle activities in order to optimize their rides. Watching a movie or make a virtual journey have been perceived as good solutions to isolate users from daily stress and enjoy the ride to their destination. A mobile application that considers users' preference in a matchmaking system to share rides, provides unprecedented freedom to its users and should be pursued as a possible service in shared mobility solutions. Also, as in Lee (2021) approach to Leisure trips, we adopted a similar behaviour to the vehicle interior in order to provide flexibility and private spaces to potential users. Further developments of these proposals are en-

couraged and should be pursued to be applied in shared autonomous vehicles and other public transports. Users intend to optimize their rides by performing activities that they do not have time to do on a daily-basis, as playing games, watching movies or do sports and they expect a system flexibility to choose if they want to share their space or not. In this regard, the criteria that affects not only the users experience in such system, but also the acceptance (i.e., their willingness to use) of this emerging mobility option is comfort (a human experience regarding social aspects and personal safety).

6.2_Future studies

Ethnicity, age, gender, or even social status discrimination are possible outcomes of this solution and should be addressed in further research. For example, Farajallaha et al. (2019) found evidence that drivers with Arabic names sell fewer seats than French names in the carpooling platform Blablacar. In this regard, we encourage continuous research to find a balance between comfort and an inclusive solution, free of discrimination. We also encourage further research to tackle the possibility of mutual authentication between passengers' identity to avoid distrust in the service. Although we developed a mobile application that considers user preference when scheduling a ride, we could not evaluate the success of the system matchmaking. In this regard, further research is encouraged in the evaluation of matchmaking profiles impact during rides with passengers that share similar interests.

Alternative evaluation methods as VR glasses with users to iterate and further develop systems as ForSav are also encouraged. In future studies, we also encourage researchers to perform the evaluation of a similar solution with larger samples, disfavoring technology professionals because of their potentially biased perspectives.

ForSav as a service could be adopted by the overall population and for that reason we believe that business models in similar systems should be developed and further researched. The profitability of such service could be an incentive to encourage governments and private companies to implement these systems in emerging mobility options.

6.3_Research limitations

The mobile application prototype presented in this research and the Usability and UX evaluation were tested by samples mainly composed of students of an Interaction Design master's degree. We consider that a limitation because we cannot confirm whether the details identified by our sample are relevant to the critical mass. Interaction designers are used to not only develop these mobile applications, but also to focus on wicked problems. The exercise of developing a mobile application for dynamic-ride sharing considering profile matchmaking alongside an in-vehicle infotainment system are good examples of wicked problems. The fact that ForSav interactive system was not implemented, physically prototyped or simulated in VR due to time concerns, also constitutes a limitation to this research.

6.4_Dissemination

The mobile application development presented in this research was published in the International Conference on Design and Digital Communication and presented via zoom in the DIGICOM 2022 event in November. In the near future, the authors will submit another part of this research for the 15th International ACM Conference AutomotiveUI 2023.

CHAPTER 7_
BIBLIOGRAPHY



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7.1_BIBLIOGRAPHIC REFERENCES

Agatz, N., Erera, A., Savelsbergh, M., & Wang, X. (2012). Optimization for dynamic ride-sharing: A review. *European Journal of Operational Research*, 223(2), Article 2. <https://doi.org/10.1016/j.ejor.2012.05.028>

Angelini, L., Baumgartner, J., Carrino, F., Carrino, S., Caon, M., Khaled, O. A., Sauer, J., Lalanne, D., Mugellini, E., & Sonderegger, A. (2016). *A comparison of three interaction modalities in the car: Gestures, voice and touch*. Actes de La 28ième Conference Francophone Sur l'Interaction Homme-Machine, 188–196. <https://doi.org/10.1145/3004107.3004118>

Armstrong, P. (2017). *Disruptive Technologies: Understand, Evaluate, Respond*. Kogan Page Publishers.

Audi AG. (2019, August 1). New communication channels: Lighting technologies of the future. Audi MediaCenter. Retrieved December 17, 2021, from <https://www.audi-media-center.com/en/audi-at-the-2019-ces-11175/new-communication-channels-lighting-technologies-of-the-future-11183>

Battarbee, K. (2003). *Defining co-experience*. Proceedings of the 2003 International Conference on Designing Pleasurable Products and Interfaces, 109–113. <https://doi.org/10.1145/782896.782923>

Battarbee, K., & Koskinen, I. (2005). *Co-experience: User experience as interaction*. *CoDesign*, 1(1), 5–18. <https://doi.org/10.1080/15710880412331289917>

Boothby, E. J., Clark, M. S., & Bargh, J. A. (2014). *Shared Experiences Are Amplified*. *Psychological Science*, 25(12), 2209–2216. <https://doi.org/10.1177/0956797614551162>

Bower, J. L., & Christensen, C. M. (n.d.). *Disruptive Technologies: Catching the Wave*. 13.

Boy, G. (2017). Human-centered design of complex systems: An experience-based approach. *Design Science*, 3, E8. doi:10.1017/dsj.2017.8

Brooke, J. (1995). SUS: A quick and dirty usability scale. *Usability Eval. Ind.*, 189.

Burgoon, J. K., Bonito, J. A., Bengtsson, B., Cederberg, C., Lundeberg, M., & Allspach, L. (2000). *Interactivity in human-computer interaction: A study of credibility, understanding, and influence*. *Computers in Human Behavior*, 16(6), 553–574. [https://doi.org/10.1016/S0747-5632\(00\)00029-7](https://doi.org/10.1016/S0747-5632(00)00029-7)

Burno, R. A., Wu, B., Doherty, R., Colett, H., & Elnaggar, R. (2015). *Applying Fitts' Law to Gesture Based Computer Interactions*. *Procedia Manufacturing*, 3, 4342–4349. <https://doi.org/10.1016/j.promfg.2015.07.429>

Burns, L. D. (2013). *A vision of our transport future*. *Nature*, 497(7448), 181–182. <https://doi.org/10.1038/497181a>

Cannan, J., & Hu, H. (2011). *Human-Machine Interaction (HMI): A Survey*. University of Essex.

Casais, M. (2021). Emotions as an Inspiration for Design. In International Conference on Applied Human Factors and Ergonomics (pp. 924-932). Springer, Cham.

Christensen, C., Johnson, C. W., & Horn, M. B. (2008). *Disrupting Class: How Disruptive Innovation Will Change the Way the World Learns* (1st ed.). McGraw-Hill.

Claudia. (2019). "Demodern - Creative Technologies" develops an interactive micro amusement park at the Port of Hamburg. English. Retrieved August 9, 2022, from <https://demodern.com/blog/discovery-dock-micro-amusement-park>

DARPA (2013). After Impressive Demonstrations of Robot Skill, DARPA Robotics Challenge Trials Conclude. Defense Advanced Research Projects Agency. Retrieved March 2, 2021, from <https://www.darpa.mil/news-events/2013-12-26>

DARPA (2007). Autonomous High-Altitude Refueling. (2007). Defense Advanced Research Projects Agency. Retrieved March 2, 2021, from <https://www.darpa.mil/about-us/timeline/autonomous-highaltitude-refueling>

Davis, L., Rolland, J., Hamza-Lup, F., Ha, Y., Norfleet, J., & Imielinska, C. (2003). *Enabling a continuum of virtual environment experiences*. IEEE Computer Graphics and Applications, 23(2), 10–12. <https://doi.org/10.1109/MCG.2003.1185574>

Dionisio, J. D. N., Iii, W. G. B., & Gilbert, R. (2013). *3D Virtual worlds and the metaverse: Current status and future possibilities*. ACM Computing Surveys, 45(3), 1–38. <https://doi.org/10.1145/2480741.2480751>

Duarte, F., & Ratti, C. (2018). *The Impact of Autonomous Vehicles on Cities: A Review*. Journal of Urban Technology, 25(4), 3–18. <https://doi.org/10.1080/10630732.2018.1493883>

Ederer, B. (2020). The BMW Group at the Consumer Electronics Show (CES) 2020 in Las Vegas. BMW Group PressClub. Retrieved November 11, 2022, from <https://www.press.bmwgroup.com/global/article/detail/T0304187EN/the->

Fagnant, D. J., & Kockelman, K. (2015). *Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations*. Transportation Research Part A: Policy and Practice, 77, 167–181. <https://doi.org/10.1016/j.tra.2015.04.003>

Fagnant, D. J., & Kockelman, K. M. (2014). *The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios*. Transportation Research Part C: Emerging Technologies, 40, 1–13. <https://doi.org/10.1016/j.trc.2013.12.001>

Farajallah, M., Robert, G.H., Thierry, P. (2019). What drives pricing behavior in peer-to-peer markets? Evidence from the carsharing platform BlaBlaCar. Inf. Econ. Policy 48, 15–31.

Fedkin, M. (2020). *Emerging, converging, disruptive technologies*. The Pennsylvania State University, John Dutton e-Education Institute. <https://www.e-education.psu.edu/eme807/node/8>

Forlizzi, J. & Battarbee, K. (2004). *Understanding experience in interactive systems*. In Proceedings of the 5th conference on Designing interactive systems: processes, practic-

es, methods, and techniques (DIS '04). Association for Computing Machinery, New York, NY, USA, 261–268. DOI: <https://doi.org/10.1145/1013115.1013152>

Holstein, T., Dodig-Crnkovic, G., & Pelliccione, P. (2018). Ethical and Social Aspects of Self-Driving Cars. ArXiv:1802.04103 [Cs]. <http://arxiv.org/abs/1802.04103>

Hoc, J.-M. (2000). *From human – machine interaction to human – machine cooperation*. Ergonomics, 43(7), 833–843. <https://doi.org/10.1080/001401300409044>

Iskander, J., Attia, M., Saleh, K., Nahavandi, D., Abobakr, A., Mohamed, S., Asadi, H., Khosravi, A., Lim, C. P., & Hossny, M. (2019). *From car sickness to autonomous car sickness: A review*. Transportation Research Part F: Traffic Psychology and Behaviour, 62, 716–726. <https://doi.org/10.1016/j.trf.2019.02.020>

Karam, M., & Schraefel, m c. (2005). *A Taxonomy of Gestures in Human Computer Interactions* [Monograph]. s.n. <https://eprints.soton.ac.uk/261149/>

Kassens-Noor, E., Dake, D., Decaminada, T., Kotval-K, Z., Qu, T., Wilson, M., & Pentland, B. (2020). *Sociomobility of the 21st century: Autonomous vehicles, planning, and the future city*. Transport Policy, 99, 329–335. <https://doi.org/10.1016/j.tranpol.2020.08.022>

Kaplan, K. (2016). Nielsen Norman Group: UX Research, Training, and Consulting. Nielsen Norman Group. Retrieved March 4, 2022, from <https://www.nngroup.com/articles/customer-journey-mapping/>

Kolko, J. (2010). Thoughts on interaction design. Morgan Kaufmann.

Kopelias, P., Demiridi, E., Vogiatzis, K., Skabardonis, A., & Zafiropoulou, V. (2020). *Connected & autonomous vehicles – Environmental impacts – A review*. Science of The Total Environment, 712, 135237. <https://doi.org/10.1016/j.scitotenv.2019.135237>

Krueger, R., Rashidi, T. H., & Rose, J. M. (2016). *Preferences for shared autonomous vehicles*. Transportation Research Part C: Emerging Technologies, 69, 343–355. <https://doi.org/10.1016/j.trc.2016.06.015>

Lee, S. C., Nadri, C., Sanghavi, H., & Jeon, M. (2020). *Exploring User Needs and Design Requirements in Fully Automated Vehicles*. Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems, 1–9. <https://doi.org/10.1145/3334480.3382881>

Lee, M. (2021). Shared Autonomous Vehicles: User Expectations and Opportunities for Design.

LG Global, (2020, February 4). LG Newsroom. Retrieved December 17, 2021, from <https://www.lgnewsroom.com/page/27/?p=l3jlc29lcmnlI3bvc3qvnda0ni9hx1bbrf84ljnfmduislbh&f=r19qqurfoc4zxzaylqpqrw%3D%3D>

Lucas, H.C. Jr., *The Search for Survival: Lessons from Disruptive Technologies*. Santa Barbara, CA., Praeger, 2012.

Manda, M. I., & Ben Dhaou, S. (2019). *Responding to the challenges and opportunities in*

the 4th Industrial revolution in developing countries. Proceedings of the 12th International Conference on Theory and Practice of Electronic Governance, 244–253. <https://doi.org/10.1145/3326365.3326398>

Markides, C. (2006). *Disruptive Innovation: In Need of Better Theory**. Journal of Product Innovation Management, 23(1), 19–25. <https://doi.org/10.1111/j.1540-5885.2005.00177.x>

Merriam-Webster. (n.d.)a. Disruption. In Merriam-Webster.com dictionary. Retrieved January 29, 2022, from <https://www.merriam-webster.com/dictionary/disruption>

Merriam-Webster. (n.d.)b. Innovation. In Merriam-Webster.com dictionary. Retrieved January 29, 2022, from <https://www.merriam-webster.com/dictionary/innovation>

Meschtscherjakov, A., Tscheligi, M., Szostak, D., Ratan, R., McCall, R., Politis, I., & Krome, S. (2015). *Experiencing Autonomous Vehicles: Crossing the Boundaries between a Drive and a Ride*. Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems, 2413–2416. <https://doi.org/10.1145/2702613.2702661>

Morra, L., Lamberti, F., Praticó, F. G., Rosa, S. L., & Montuschi, P. (2019). *Building Trust in Autonomous Vehicles: Role of Virtual Reality Driving Simulators in HMI Design*. IEEE Transactions on Vehicular Technology, 68(10), 9438–9450. <https://doi.org/10.1109/TVT.2019.2933601>

Negru, S. (2010). *A conceptual architecture of an arduino-based social-emotional interactive system*. Proceedings of the 2010 IEEE 6th International Conference on Intelligent Computer Communication and Processing, 93–98. <https://doi.org/10.1109/ICCP.2010.5606459>

Nica, G. (2020, January 7). BMW i Interaction EASE technology unveiled at CES 2020 in Las Vegas. BMW BLOG. Retrieved December 17, 2021, from <https://www.bmwblog.com/2020/01/07/bmw-i-interaction-ease-technology-unveiled-at-ces-2020-in-las-vegas/>

Nielsen, J.: Estimating the number of subjects needed for a thinking aloud test. Int. J.Hum ComputStud. 41(3), 385–397 (1994)

Pakusch, C., Stevens, G., Boden, A., & Bossauer, P. (2018). *Unintended effects of autonomous driving: A study on mobility preferences in the future*. Sustainability, 10(7), 2404.

Pettersson, I., & Karlsson, I. C. M. (2015). Setting the stage for autonomous cars: A pilot study of future autonomous driving experiences. IET Intelligent Transport Systems, 9(7), 694–701. <https://doi.org/10.1049/iet-its.2014.0168>

Pfleging, B., Rang, M., & Broy, N. (2016). *Investigating user needs for non-driving-related activities during automated driving*. Proceedings of the 15th International Conference on Mobile and Ubiquitous Multimedia, 91–99. <https://doi.org/10.1145/3012709.3012735>

Pfleging, B., Schneegass, S., & Schmidt, A. (2012). *Multimodal interaction in the car: Combining speech and gestures on the steering wheel*. 8.

Rehman, A. U., Ghaffarianhoseini, A., Naismith, N., Zhang, T., Doan, D., Tookey, J., Ghaffarianhoseini, A., & Lovreglio, R. (2018). *A Review: Harnessing Immersive Technologies*

Prowess for Autonomous Vehicles.

Riegler, A., Riener, A., & Holzmann, C. (2021a). *A Systematic Review of Virtual Reality Applications for Automated Driving: 2009–2020*. *Frontiers in Human Dynamics*, 3, 48. <https://doi.org/10.3389/fhumd.2021.689856>

Riegler, A., Riener, A., & Holzmann, C. (2020). *A Research Agenda for Mixed Reality in Automated Vehicles*. 19th International Conference on Mobile and Ubiquitous Multimedia, 119–131. <https://doi.org/10.1145/3428361.3428390>

Roco, M. C., & Bainbridge, W. S. (2013). *Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology and Cognitive Science*. Springer Science & Business Media.

Rubio-Tamayo, J. L., Gertrudix Barrio, M., & García García, F. (2017). *Immersive Environments and Virtual Reality: Systematic Review and Advances in Communication, Interaction and Simulation*. *Multimodal Technologies and Interaction*, 1(4), 21. <https://doi.org/10.3390/mti1040021>

SAE International. SAE Levels of Driving Automation™ Refined for Clarity and International Audience. SAE International. Retrieved June 7, 2022, from <https://www.sae.org/blog/sae-j3016-update>

Salgado, L., Pereira, R., & Gasparini, I. (2015). *Cultural Issues in HCI: Challenges and Opportunities*. In M. Kurosu (Ed.), *Human-Computer Interaction: Design and Evaluation* (pp. 60–70). Springer International Publishing. https://doi.org/10.1007/978-3-319-20901-2_6

Sánchez-Nielsen, E., Antón-Canalís, L., & Hernández-Tejera, M. (2004). *Hand gesture recognition for human-machine interaction*. <http://dspace5.zcu.cz/handle/11025/1847>

Scherer, K. R. (2005). What are emotions? And how can they be measured?. *Social science information*, 44(4), 695-729.

Schirner, G., Erdogmus, D., Chowdhury, K., & Padir, T. (2013). *The Future of Human-in-the-Loop Cyber-Physical Systems*. *Computer*, 46(1), 36–45. <https://doi.org/10.1109/MC.2013.31>

Shi, Y., Du, J., Lavy, S., & Zhao, D. (2016). *A Multiuser Shared Virtual Environment for Facility Management*. *Procedia Engineering*, 145, 120–127. <https://doi.org/10.1016/j.pro-eng.2016.04.029>

Shibata, T., Yoshida, M., & Yamato, J. (1997). *Artificial emotional creature for human-machine interaction*. *Computational Cybernetics and Simulation 1997 IEEE International Conference on Systems, Man, and Cybernetics*, 3, 2269–2274 vol.3. <https://doi.org/10.1109/ICSMC.1997.635205>

Schlatter, T., Levinson, D. (2013). *Visual usability: Principles and Practices for Designing Digital Applications*.

Schloßmacher, J. (2022). Audi urbansphere concept (2022). Audi MediaCenter. Retrieved October 5, 2022, from <https://www.audi-mediacycenter.com/en/audi-urbansphere-concept-2022-14596>

Strickland, B. C. A. (2022). What it's like aboard the Star Wars: Galactic Starcruiser at Disney World. CNN. Retrieved September 2, 2022, from <https://edition.cnn.com/travel/article/star-wars-galactic-starcruiser-disney-world/index.html>

Strömberg, H., Pettersson, I., Andersson, J., Rydström, A., Dey, D., Klingegård, M., & Forlizzi, J. (2018). *Designing for social experiences with and within autonomous vehicles – exploring methodological directions*. Design Science, 4. <https://doi.org/10.1017/dsj.2018.9>

Stromer-Galley, J. (2004). *Interactivity-as-Product and Interactivity-as-Process*. The Information Society, 20(5), 391–394. <https://doi.org/10.1080/01972240490508081>

Suchman, L. A. (1990). *What is human-machine interaction*. Cognition, computing, and cooperation, 25-55.

Sutcliffe, A. (2009). *Designing for User Engagement: Aesthetic and Attractive User Interfaces*.

Tang, P., Sun, X., & Cao, S. (2020). *Investigating user activities and the corresponding requirements for information and functions in autonomous vehicles of the future*. International Journal of Industrial Ergonomics, 80, 103044. <https://doi.org/10.1016/j.ergon.2020.103044>

Visser, E. J., Pak, R., & Shaw, T. H. (2018). *From 'automation' to 'autonomy': The importance of trust repair in human-machine interaction*. Ergonomics, 61(10), 1409–1427. <https://doi.org/10.1080/00140139.2018.1457725>

Wachs, J. P., Kölsch, M., Stern, H., & Edan, Y. (2011). *Vision-based hand-gesture applications*. Communications of the ACM, 54(2), 60–71. <https://doi.org/10.1145/1897816.1897838>

Waldrop, M. M. (2015). *Autonomous vehicles: No drivers required*. Nature, 518(7537), 20–23. <https://doi.org/10.1038/518020a>

Yacht Information System. (n.d.). Retrieved September 28, 2022, from <https://yis.yacht-cloud.eu/home/wind>

7.2_BIBLIOGRAPHY

Angelini, L., Baumgartner, J., Carrino, F., Carrino, S., Caon, M., Khaled, O. A., Sauer, J., Lalanne, D., Mugellini, E., & Sonderegger, A. (2016). A comparison of three interaction modalities in the car: Gestures, voice and touch. Actes de La 28ième Conference Francophone Sur l'Interaction Homme-Machine, 188–196. <https://doi.org/10.1145/3004107.3004118>

Armstrong, P. (2017). *Disruptive Technologies: Understand, Evaluate, Respond*. Kogan Page Publishers.

Audi AG. (2019, August 1). *New communication channels: Lighting technologies of the future*. Audi MediaCenter. Retrieved December 17, 2021, from <https://www.audi-media-center.com/en/audi-at-the-2019-ces-11175/new-communication-channels-lighting-tech->

nologies-of-the-future-11183

Barnes, M. J., Chen, J. Y. C., Jentsch, F., Oron-Gilad, T., Redden, E., Elliott, L., & Iii, A. W. E. (2014). Designing for Humans in Autonomous Systems: Military Applications. 36.

Battarbee, K. (2003). Defining co-experience. Proceedings of the 2003 International Conference on Designing Pleasurable Products and Interfaces, 109–113. <https://doi.org/10.1145/782896.782923>

Battarbee, K., & Koskinen, I. (2005). Co-experience: User experience as interaction. *CoDesign*, 1(1), 5–18. <https://doi.org/10.1080/15710880412331289917>

Bengler, K., Rettenmaier, M., Fritz, N., & Feierle, A. (2020). From HMI to HMIs: Towards an HMI Framework for Automated Driving. *Information*, 11(2), 61. <https://doi.org/10.3390/info11020061>

Bonnefon, J.-F., Shariff, A., & Rahwan, I. (2019). The Trolley, The Bull Bar, and Why Engineers Should Care About The Ethics of Autonomous Cars [point of view]. *Proceedings of the IEEE*, 107(3), 502–504. <https://doi.org/10.1109/JPROC.2019.2897447>

Booth, L., Norman, R., & Pettigrew, S. (2020). The potential effects of autonomous vehicles on alcohol consumption and drink-driving behaviours. *Drug and Alcohol Review*, 39(5), 604–607. <https://doi.org/10.1111/dar.13055>

Boothby, E. J., Clark, M. S., & Bargh, J. A. (2014). Shared Experiences Are Amplified. *Psychological Science*, 25(12), 2209–2216. <https://doi.org/10.1177/0956797614551162>

Bower, J. L., & Christensen, C. M. (n.d.). *Disruptive Technologies: Catching the Wave*. 13.

Bradley, MM & Lang, PJ (1994), Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavioral Therapy and Experimental. Psychiatry*, 25, 49-59.

Brooke, J. (1995). SUS: A quick and dirty usability scale. *Usability Eval. Ind.*, 189.

Burgoon, J. K., Bonito, J. A., Bengtsson, B., Cederberg, C., Lundeborg, M., & Allspach, L. (2000). Interactivity in human-computer interaction: A study of credibility, understanding, and influence. *Computers in Human Behavior*, 16(6), 553–574. [https://doi.org/10.1016/S0747-5632\(00\)00029-7](https://doi.org/10.1016/S0747-5632(00)00029-7)

Burno, R. A., Wu, B., Doherty, R., Colett, H., & Elnaggar, R. (2015). Applying Fitts' Law to Gesture Based Computer Interactions. *Procedia Manufacturing*, 3, 4342–4349. <https://doi.org/10.1016/j.promfg.2015.07.429>

Burns, L. D. (2013). A vision of our transport future. *Nature*, 497(7448), 181–182. <https://doi.org/10.1038/497181a>

Cannan, J., & Hu, H. (2011). *Human-Machine Interaction (HMI): A Survey*. University of Essex.

CES 2023: World premiere of BMW i Vision Dee. (n.d.). <https://www.bmwgroup.com/en/>

news/general/2023/i-vision-dee.html

Christensen, C., Johnson, C. W., & Horn, M. B. (2008). *Disrupting Class: How Disruptive Innovation Will Change the Way the World Learns* (1st ed.). McGraw-Hill.

Davis, L., Rolland, J., Hamza-Lup, F., Ha, Y., Norfleet, J., & Imielinska, C. (2003). Enabling a continuum of virtual environment experiences. *IEEE Computer Graphics and Applications*, 23(2), 10–12. <https://doi.org/10.1109/MCG.2003.1185574>

Dionisio, J. D. N., Iii, W. G. B., & Gilbert, R. (2013). 3D Virtual worlds and the metaverse: Current status and future possibilities. *ACM Computing Surveys*, 45(3), 1–38. <https://doi.org/10.1145/2480741.2480751>

Duarte, F., & Ratti, C. (2018). The Impact of Autonomous Vehicles on Cities: A Review. *Journal of Urban Technology*, 25(4), 3–18. <https://doi.org/10.1080/10630732.2018.1493883>

Ekmekçioğlu, D., & Özkaraman Şen, M. (2018). A proposal for a method of the redesign of self-organising systems: The case of minibus transportation in the Istanbul public transport system. *Strategic Design Research Journal*, 11(3), 230–240. <https://doi.org/10.4013/sdrj.2018.113.07>

Fagnant, D. J., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations. *Transportation Research Part A: Policy and Practice*, 77, 167–181. <https://doi.org/10.1016/j.tra.2015.04.003>

Fagnant, D. J., & Kockelman, K. M. (2014). The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios. *Transportation Research Part C: Emerging Technologies*, 40, 1–13. <https://doi.org/10.1016/j.trc.2013.12.001>

Farajallah, M., Robert, G.H., Thierry, P. (2019). What drives pricing behavior in peer-to-peer markets? Evidence from the carsharing platform BlaBlaCar. *Inf. Econ. Policy* 48, 15–31.

Fedkin, M. (2020). *Emerging, converging, disruptive technologies*. The Pennsylvania State University, John Dutton e-Education Institute. <https://www.e-education.psu.edu/eme807/node/8>

Flohr, L. A., Janetzko, D., Wallach, D. P., Scholz, S. C., & Krüger, A. (2020). Context-Based Interface Prototyping and Evaluation for (Shared) Autonomous Vehicles Using a Lightweight Immersive Video-Based Simulator. *Proceedings of the 2020 ACM Designing Interactive Systems Conference*, 1379–1390. <https://doi.org/10.1145/3357236.3395468>

Forlizzi, J. & Battarbee, K. (2004). Understanding experience in interactive systems. In *Proceedings of the 5th conference on Designing interactive systems: processes, practices, methods, and techniques (DIS '04)*. Association for Computing Machinery, New York, NY, USA, 261–268. DOI: <https://doi.org/10.1145/1013115.1013152>

Haeuslschmid, R., Shou, Y., O'Donovan, J., Burnett, G., & Butz, A. (2016). First Steps towards a View Management Concept for Large-sized Head-up Displays with Continuous Depth. *Proceedings of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, 1–8. <https://doi.org/10.1145/3003715.3005418>

Hoc, J.-M. (2000). From human – machine interaction to human – machine cooperation.

Ergonomics, 43(7), 833–843. <https://doi.org/10.1080/001401300409044>

Holstein, T. (2017). The Misconception of Ethical Dilemmas in Self-Driving Cars. *Proceedings*, 1(3), 174. <https://doi.org/10.3390/IS4SI-2017-04026>

Holstein, T., Dodig-Crnkovic, G., & Pelliccione, P. (2018). Ethical and Social Aspects of Self-Driving Cars. *ArXiv:1802.04103 [Cs]*. <http://arxiv.org/abs/1802.04103>

Hyland, M., & Mahmassani, H. S. (2020). Operational benefits and challenges of shared-ride automated mobility-on-demand services. *Transportation Research Part A: Policy and Practice*, 134, 251–270. <https://doi.org/10.1016/j.tra.2020.02.017>

Isaac, L. (2016). *Driving toward driverless*.

Iskander, J., Attia, M., Saleh, K., Nahavandi, D., Abobakr, A., Mohamed, S., Asadi, H., Khosravi, A., Lim, C. P., & Hossny, M. (2019). From car sickness to autonomous car sickness: A review. *Transportation Research Part F: Traffic Psychology and Behaviour*, 62, 716–726. <https://doi.org/10.1016/j.trf.2019.02.020>

John, V., Umetsu, M., Boyali, A., Mita, S., Imanishi, M., Sanma, N., & Shibata, S. (2017). Real-time hand posture and gesture-based touchless automotive user interface using deep learning. *2017 IEEE Intelligent Vehicles Symposium (IV)*, 869–874. <https://doi.org/10.1109/IVS.2017.7995825>

Karam, M., & Schraefel, m c. (2005). *A Taxonomy of Gestures in Human Computer Interactions [Monograph]*. s.n. <https://eprints.soton.ac.uk/261149/>

Kassens-Noor, E., Dake, D., Decaminada, T., Kotval-K, Z., Qu, T., Wilson, M., & Pentland, B. (2020). Sociomobility of the 21st century: Autonomous vehicles, planning, and the future city. *Transport Policy*, 99, 329–335. <https://doi.org/10.1016/j.tranpol.2020.08.022>

Kopelias, P., Demiridi, E., Vogiatzis, K., Skabardonis, A., & Zafiropoulou, V. (2020). Connected & autonomous vehicles – Environmental impacts – A review. *Science of The Total Environment*, 712, 135237. <https://doi.org/10.1016/j.scitotenv.2019.135237>

Krome, S., Goddard, W., Greuter, S., Walz, S. P., & Gerlicher, A. (2015). A context-based design process for future use cases of autonomous driving: Prototyping AutoGym. *Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, 265–272. <https://doi.org/10.1145/2799250.2799257>

Krueger, R., Rashidi, T. H., & Rose, J. M. (2016). Preferences for shared autonomous vehicles. *Transportation Research Part C: Emerging Technologies*, 69, 343–355. <https://doi.org/10.1016/j.trc.2016.06.015>

Laurier, E. (2004). Doing Office Work on the Motorway. *Theory, Culture & Society*, 21(4–5), 261–277. <https://doi.org/10.1177/0263276404046070>

Le Vine, S., Zolfaghari, A., & Polak, J. (2015). Autonomous cars: The tension between occupant experience and intersection capacity. *Transportation Research Part C: Emerging Technologies*, 52, 1–14. <https://doi.org/10.1016/j.trc.2015.01.002>

Lee, S. C., Nadri, C., Sanghavi, H., & Jeon, M. (2020). Exploring User Needs and Design Requirements in Fully Automated Vehicles. *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*, 1–9. <https://doi.org/10.1145/3334480.3382881>

Lee, M. (2021). Shared Autonomous Vehicles: User Expectations and Opportunities for Design.

LG Global, (2020, February 4). LG Newsroom. Retrieved December 17, 2021, from <https://www.lgnewsroom.com/page/27?p=l3jlc291cmnl3bvc3qvnda0ni9hx1bbrf84jnfmdiusl-bh&f=r19qqrufoc4zxzaylkpqrw%3D%3D>

Lindgren, T., Fors, V., Pink, S., & Osz, K. (2020). Anticipatory experience in everyday autonomous driving. *Personal and Ubiquitous Computing*, 24(6), 747–762. <https://doi.org/10.1007/s00779-020-01410-6>

Lucas, H.C. Jr., *The Search for Survival: Lessons from Disruptive Technologies*. Santa Barbara, CA., Praeger, 2012.

Manda, M. I., & Ben Dhaou, S. (2019). Responding to the challenges and opportunities in the 4th Industrial revolution in developing countries. *Proceedings of the 12th International Conference on Theory and Practice of Electronic Governance*, 244–253. <https://doi.org/10.1145/3326365.3326398>

Mercedes-benz. (2019, May 13). Vision URBANETIC – The mobility of the future. Retrieved December 17, 2021, from <https://www.mercedes-benz.com/en/vehicles/transporter/vision-urbanetic-the-mobility-of-the-future/>

Markides, C. (2006). Disruptive Innovation: In Need of Better Theory*. *Journal of Product Innovation Management*, 23(1), 19–25. <https://doi.org/10.1111/j.1540-5885.2005.00177.x>

Merriam-Webster. (n.d.)a. Disruption. In Merriam-Webster.com dictionary. Retrieved January 29, 2022, from <https://www.merriam-webster.com/dictionary/disruption>

Merriam-Webster. (n.d.)b. Innovation. In Merriam-Webster.com dictionary. Retrieved January 29, 2022, from <https://www.merriam-webster.com/dictionary/innovation>

Meschtscherjakov, A., Tscheligi, M., Szostak, D., Ratan, R., McCall, R., Politis, I., & Krome, S. (2015). Experiencing Autonomous Vehicles: Crossing the Boundaries between a Drive and a Ride. *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems*, 2413–2416. <https://doi.org/10.1145/2702613.2702661>

Meschtscherjakov, A., Tscheligi, M., Szostak, D., Krome, S., Pfleging, B., Ratan, R., Politis, I., Baltodano, S., Miller, D., & Ju, W. (2016). HCI and Autonomous Vehicles: Contextual Experience Informs Design. *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, 3542–3549. <https://doi.org/10.1145/2851581.2856489>

Morra, L., Lamberti, F., Praticó, F. G., Rosa, S. L., & Montuschi, P. (2019). Building Trust in Autonomous Vehicles: Role of Virtual Reality Driving Simulators in HMI Design. *IEEE Transactions on Vehicular Technology*, 68(10), 9438–9450. <https://doi.org/10.1109/>

TVT.2019.2933601

Narayanan, S., Chaniotakis, E., & Antoniou, C. (2020). Shared autonomous vehicle services: A comprehensive review. *Transportation Research Part C: Emerging Technologies*, 111, 255–293. <https://doi.org/10.1016/j.trc.2019.12.008>

Naujoks, F., Wiedemann, K., Schömig, N., Hergeth, S., & Keinath, A. (2019). Towards guidelines and verification methods for automated vehicle HMIs. *Transportation Research Part F: Traffic Psychology and Behaviour*, 60, 121–136. <https://doi.org/10.1016/j.trf.2018.10.012>

Negru, S. (2010). A conceptual architecture of an arduino-based social-emotional interactive system. *Proceedings of the 2010 IEEE 6th International Conference on Intelligent Computer Communication and Processing*, 93–98. <https://doi.org/10.1109/ICCP.2010.5606459>

Nica, G. (2020, January 7). BMW i Interaction EASE technology unveiled at CES 2020 in Las Vegas. *BMW BLOG*. Retrieved December 17, 2021, from <https://www.bmwblog.com/2020/01/07/bmw-i-interaction-ease-technology-unveiled-at-ces-2020-in-las-vegas/>

Nielsen, J.: Estimating the number of subjects needed for a thinking aloud test. *Int. J. Hum Comput Stud.* 41(3), 385–397 (1994)

Paddeu, D., Parkhurst, G., & Shergold, I. (2020). Passenger comfort and trust on first-time use of a shared autonomous shuttle vehicle. *Transportation Research Part C: Emerging Technologies*, 115, 102604. <https://doi.org/10.1016/j.trc.2020.02.026>

Pakusch, C., Stevens, G., Boden, A., & Bossauer, P. (2018). Unintended effects of autonomous driving: A study on mobility preferences in the future. *Sustainability*, 10(7), 2404.

Petterson, I., & Karlsson, I. C. M. (2015). Setting the stage for autonomous cars: A pilot study of future autonomous driving experiences. *IET Intelligent Transport Systems*, 9(7), 694–701. <https://doi.org/10.1049/iet-its.2014.0168>

Petterson, I., Rydström, A., Strömberg, H., Hylving, L., Andersson, J., Klingegård, M., & Karlsson, M. (2016). Living Room on the Move: Autonomous Vehicles and Social Experiences. *Proceedings of the 9th Nordic Conference on Human-Computer Interaction*, 1–3. <https://doi.org/10.1145/2971485.2987669>

Pettigrew, S., Nelson, J. D., & Norman, R. (2020). Autonomous vehicles and cycling: Policy implications and management issues. *Transportation Research Interdisciplinary Perspectives*, 7, 100188. <https://doi.org/10.1016/j.trip.2020.100188>

Pfleging, B., Rang, M., & Broy, N. (2016). Investigating user needs for non-driving-related activities during automated driving. *Proceedings of the 15th International Conference on Mobile and Ubiquitous Multimedia*, 91–99. <https://doi.org/10.1145/3012709.3012735>

Pfleging, B., Schneegass, S., & Schmidt, A. (2012). Multimodal interaction in the car: Combining speech and gestures on the steering wheel. 8.

Rehman, A. U., Ghaffarianhoseini, A., Naismith, N., Zhang, T., Doan, D., Tookey, J., Ghaffarianhoseini, A., & Lovreglio, R. (2018). A Review: Harnessing Immersive Technologies

Prowess for Autonomous Vehicles.

Riegler, A., Riener, A., & Holzmann, C. (2021a). A Systematic Review of Virtual Reality Applications for Automated Driving: 2009–2020. *Frontiers in Human Dynamics*, 3, 48. <https://doi.org/10.3389/fhumd.2021.689856>

Riegler, A., Riener, A., & Holzmann, C. (2020). A Research Agenda for Mixed Reality in Automated Vehicles. 19th International Conference on Mobile and Ubiquitous Multimedia, 119–131. <https://doi.org/10.1145/3428361.3428390>

Riener, A., Boll, S., & Kun, A. L. (2016). *Automotive User Interfaces in the Age of Automation*.

Robertson, S. P., Zachary, W., & Black, J. B. (1990). *Cognition, Computing, and Cooperation*. Intellect Books.

Roco, M. C., & Bainbridge, W. S. (2013). *Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology and Cognitive Science*. Springer Science & Business Media.

Rubio-Tamayo, J. L., Gertrudix Barrio, M., & García García, F. (2017). Immersive Environments and Virtual Reality: Systematic Review and Advances in Communication, Interaction and Simulation. *Multimodal Technologies and Interaction*, 1(4), 21. <https://doi.org/10.3390/mti1040021>

Sadiku, M. N., Wang, Y., Cui, S., & Musa, S. M. (2017). Cyber-physical systems: a literature review. *European Scientific Journal*, 13(36), 52-58.

Salgado, L., Pereira, R., & Gasparini, I. (2015). Cultural Issues in HCI: Challenges and Opportunities. In M. Kurosu (Ed.), *Human-Computer Interaction: Design and Evaluation* (pp. 60–70). Springer International Publishing. https://doi.org/10.1007/978-3-319-20901-2_6

Sánchez-Nielsen, E., Antón-Canalís, L., & Hernández-Tejera, M. (2004). Hand gesture recognition for human-machine interaction. <http://dspace5.zcu.cz/handle/11025/1847>

Scherer, K. R. (2005). What are emotions? And how can they be measured?. *Social science information*, 44(4), 695-729.

Schirner, G., Erdogmus, D., Chowdhury, K., & Padir, T. (2013). The Future of Human-in-the-Loop Cyber-Physical Systems. *Computer*, 46(1), 36–45. <https://doi.org/10.1109/MC.2013.31>

Shi, Y., Du, J., Lavy, S., & Zhao, D. (2016). A Multiuser Shared Virtual Environment for Facility Management. *Procedia Engineering*, 145, 120–127. <https://doi.org/10.1016/j.proeng.2016.04.029>

Shibata, T., Yoshida, M., & Yamato, J. (1997). Artificial emotional creature for human-machine interaction. *Computational Cybernetics and Simulation 1997 IEEE International Conference on Systems, Man, and Cybernetics*, 3, 2269–2274 vol.3. <https://doi.org/10.1109/ICSMC.1997.635205>

Schlatte, T., Levinson, D. (2013). *Visual usability: Principles and Practices for Designing*

Digital Applications.

Sjoberg, K., Andres, P., Buburuzan, T., & Brakemeier, A. (2017). Cooperative Intelligent Transport Systems in Europe: Current Deployment Status and Outlook. *IEEE Vehicular Technology Magazine*, 12(2), 89–97. <https://doi.org/10.1109/MVT.2017.2670018>

Stevens, G., Bossauer, P., Pakusch, C., & Vonholdt, S. (2019). Using Time and Space Efficiently in Driverless Cars: Findings of a Co-Design Study.

Strömberg, H., Pettersson, I., Andersson, J., Rydström, A., Dey, D., Klingegård, M., & Forlizzi, J. (2018). Designing for social experiences with and within autonomous vehicles – exploring methodological directions. *Design Science*, 4. <https://doi.org/10.1017/dsj.2018.9>

Stromer-Galley, J. (2004). Interactivity-as-Product and Interactivity-as-Process. *The Information Society*, 20(5), 391–394. <https://doi.org/10.1080/01972240490508081>

Suchman, L. A. (1990). What is human-machine interaction. *Cognition, computing, and cooperation*, 25-55.

Sutcliffe, A. (2009). Designing for User Engagement: Aesthetic and Attractive User Interfaces.

Tang, P., Sun, X., & Cao, S. (2020). Investigating user activities and the corresponding requirements for information and functions in autonomous vehicles of the future. *International Journal of Industrial Ergonomics*, 80, 103044. <https://doi.org/10.1016/j.ergon.2020.103044>

Terken, Z., Haex, R., Beurgens, L., Arslanova, E., Vrachni, M., Terken, J., & Szostak, D. (2013). Unwinding after work: An in-car mood induction system for semi-autonomous driving. *Proceedings of the 5th International Conference on Automotive User Interfaces and Interactive Vehicular Applications - AutomotiveUI '13*, 246–249. <https://doi.org/10.1145/2516540.2516571>

Vinkhuyzen, E., & Cefkin, M. (2016). Developing Socially Acceptable Autonomous Vehicles. *Ethnographic Praxis in Industry Conference Proceedings*, 2016(1), 522–534. <https://doi.org/10.1111/1559-8918.2016.01108>

Visser, E. J., Pak, R., & Shaw, T. H. (2018). From ‘automation’ to ‘autonomy’: The importance of trust repair in human-machine interaction. *Ergonomics*, 61(10), 1409–1427. <https://doi.org/10.1080/00140139.2018.1457725>

Wachs, J. P., Kölsch, M., Stern, H., & Edan, Y. (2011). Vision-based hand-gesture applications. *Communications of the ACM*, 54(2), 60–71. <https://doi.org/10.1145/1897816.1897838>

Waldrop, M. M. (2015). Autonomous vehicles: No drivers required. *Nature*, 518(7537), 20–23. <https://doi.org/10.1038/518020a>

Wolf, W. (2009). Cyber-physical systems. *Computer*, 42(03), 88-89.

Wollschlaeger, M., Sauter, T., & Jasperneite, J. (2017). The Future of Industrial Communication: Automation Networks in the Era of the Internet of Things and Industry 4.0. *IEEE Industrial Electronics Magazine*, 11(1), 17–27. <https://doi.org/10.1109/MIE.2017.2649104>

ANNEXES



DEVELOPMENT OF AN
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ANNEXES

ANNEXE 1 (AN1) - SYSTEM USABILITY SCALE

System Usability Scale

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	Strongly disagree					Strongly agree
1. I think that I would like to use this system frequently	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	1	2	3	4	5	
2. I found the system unnecessarily complex	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	1	2	3	4	5	
3. I thought the system was easy to use	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	1	2	3	4	5	
4. I think that I would need the support of a technical person to be able to use this system	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	1	2	3	4	5	
5. I found the various functions in this system were well integrated	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	1	2	3	4	5	
6. I thought there was too much inconsistency in this system	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	1	2	3	4	5	
7. I would imagine that most people would learn to use this system very quickly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	1	2	3	4	5	
8. I found the system very cumbersome to use	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	1	2	3	4	5	
9. I felt very confident using the system	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	1	2	3	4	5	
10. I needed to learn a lot of things before I could get going with this system	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	1	2	3	4	5	

System usability scale - retrived from Brooke (1995).

APPENDIXES



DEVELOPMENT OF AN
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APPENDIX

Appendix 1 (A1) - SURVEY INFORMED CONSENT

Your participation in this study is voluntary and you must be 18 or older to participate.

You have the right to withdraw from the study at any moment, without justification.

By accepting the present terms, you declare that there are no conflicts of interest with the present research, on personal and professional levels.

The analysis of the data obtained in this survey will have an exclusively academic purpose. In all works and publications generated from this study, the answers will be anonymized and treated in an aggregated way.

By answering “yes” to this informed consent, you allow the researchers to process the data anonymously, up to a period of 2 years, ensuring the applicable ethical considerations for this type of study. For the purpose of subsequent research output (e.g. publications) that arise from this research, the data will be kept indefinitely, due to its relevance for the academic community.

Appendix 2 (A2) - SURVEY

1 - Please select a language:

English;

Português.

Introduction

Hello, I'm Gualter Ferrada, master student in Interaction Design at the ULisboa, and I am conducting research for my thesis with the supervision of Professor Mafalda Casais. The research is about Shared Autonomous Vehicles (SAV) and Interactive Systems. The present survey (approximately 10 minutes) aims to build persona profiles of future potential users of these vehicles. If you have any questions about this research, please contact me at gferrada@edu.ulisboa.pt. Thank you for your participation.

Informed consent to participate:

Your participation in this study is voluntary and you must be 18 or older to participate.

You have the right to withdraw from the study at any moment, without justification.

By accepting the present terms, you declare that there are no conflicts of interest with the present research, on personal and professional levels.

The analysis of the data obtained in this survey will have an exclusively academic purpose. In all works and publications generated from this study, the answers will be anonymized and treated in an aggregated way.

By answering “yes” to this informed consent, you allow the researchers to process the data anonymously, up to a period of 2 years, ensuring the applicable ethical considerations for this type of study. For the purpose of subsequent research output (e.g. publications) that arise from this research, the data will be kept indefinitely, due to its relevance for the academic community.

2 - I declare that I am informed of and agree with the terms and conditions for participating in this study:

I wish to participate.

I do not wish to participate.

Example

Example of a shared autonomous vehicle:



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Shared Autonomous Vehicles (SAV) are communal driverless vehicles that operate at level 5 of driving automation (i.g. fully automated). At this level of autonomy, the vehicle assumes all the tasks related to driving in any type of condition, without the need for human intervention.

Interaction design as a way to optimize shared rides in autonomous vehicles

3 - Are you familiar with autonomy 5 SAV?

Yes.

No.

4 - Would you consider yourself a future user of this type of vehicle?

Yes, totally.

Yes, but only with people that I know.

Maybe, but I wouldn't be using it right away.

I don't know.

No.

5 - How do you travel around the city on a daily basis?

Car.

Public transports.

Bycicle.

On foot.

Other.

6 - What would you envision doing to spend time in a shared autonomous vehicle before arriving at your destination? Consider that this concept offers much wider opportunities than conventional cars currently provide. (Select 1 or more options)

Watch a movie.

Hear music.

Work earlier.

Talk to other passengers.

Play online games.

Draw.

Sleep a little more.
Rest.
Call family or friends.
Eat a snack.
Karaoke.
Physical exercise.
Health check-up.
Talk with an Artificial Intelligence.
Other.

7 - Would you be willing to physically share the vehicle space with other users?

Watch current news.
Watch a movie.
Attend a concert.
Talking.
I do not share experiences with people I do not know.
Other.

Consider de following scale

Please consider the following statements using the scale provided.

8 - Traveling in an autonomous vehicle with other people with the same interests as me makes me comfortable.

1 **2** **3** **4** **5** **6** **7**
Totally disagree Agree

9 - Traveling in an autonomous vehicle with other people who also go to work or college makes me comfortable.

1 **2** **3** **4** **5** **6** **7**
Totally disagree Agree

10 - I feel the need to have the option of having a private space in a vehicle of this type.

1 **2** **3** **4** **5** **6** **7**
Totally disagree Agree

Demographic data

11 - Age:

12 - What country are you from?

13 - What are your main hobbies?

14 - Education:

Associate's degree.

Undergraduate/Bachelor's degree.

Master's degree.

Doctoral degree.

Other.

15 - Occupation.

Consider the following scale

Please consider the following statements using the scale provided.

16 - I consider myself.

	1	2	3	4	5	6	7	
Introvert	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Extrovert

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17 - I consider myself.

	1	2	3	4	5	6	7	
Cautious	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Adventurous

18 - I consider myself.

	1	2	3	4	5	6	7	
Rational	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Intuitive

19 - I consider myself.

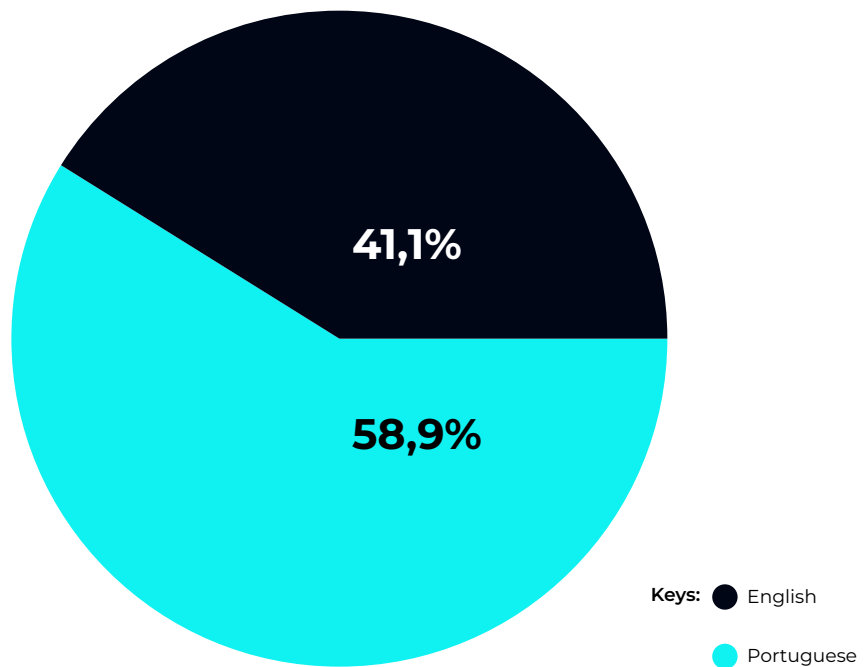
	1	2	3	4	5	6	7	
Conventional	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Imaginative

20 - I consider myself.

	1	2	3	4	5	6	7	
Skeptical	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Gullible

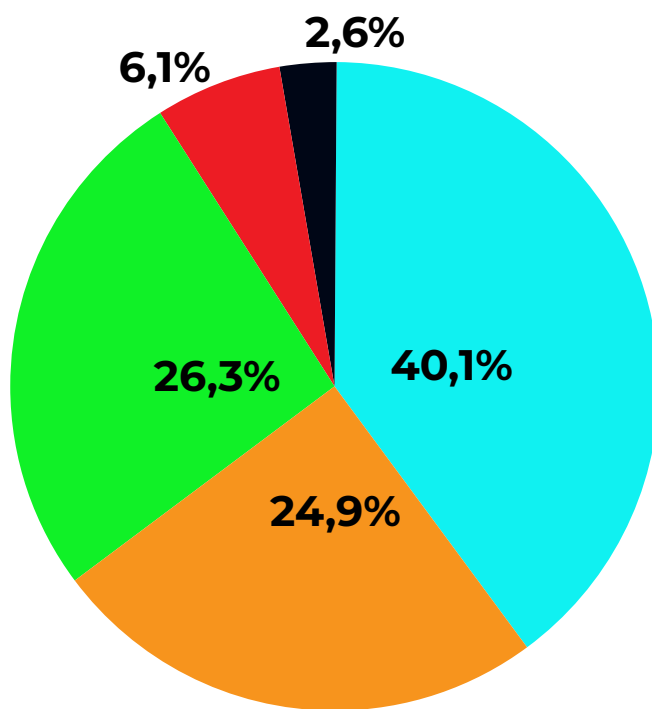
Appendix 3 (A3) - SURVEY DATA

Chosen language



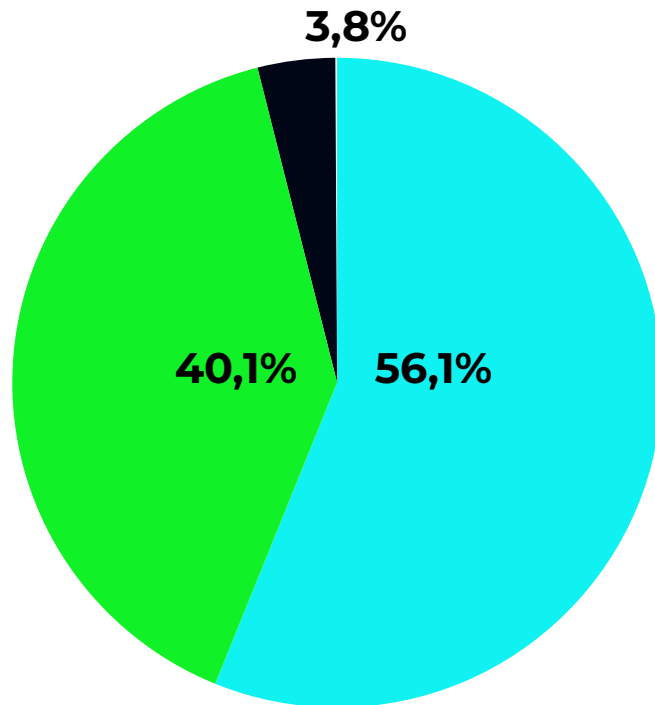
DEVELOPMENT OF AN
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Would you consider yourself a future user of this type of vehicle?



- Keys:
- Yes, totally
 - Yes, but only with people that I know
 - Maybe, but I wouldn't be using it right away
 - I don't know
 - No

Would you be willing to physically share the vehicle space with other users?

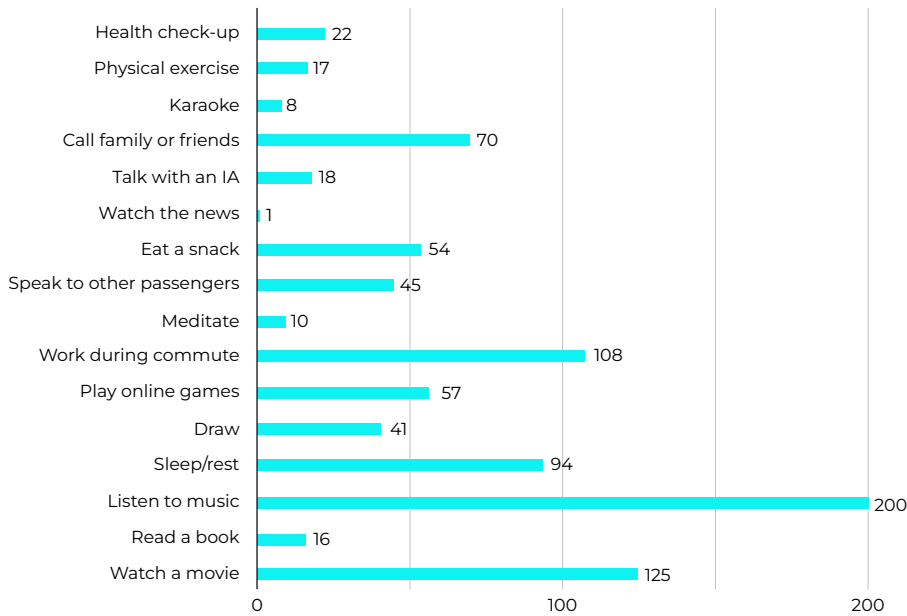


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- Keys:
- Yes, for sure
 - Yes, if they were from my family or friends
 - No, I would prefer to travel alone

in a shared autonomous vehicle before arriving at your destination?

Consider that this concept offers much wider opportunities than conventional cars currently provide.
(Select 1 or more options)



Keys: ● Absolut number of answers

DEVELOPMENT OF AN
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Criteria	Weight	Lg Connected car	Total	BMW i Interaction EASE	Total	Audi Urbansphere	Total
Comfort	1,6	5	8	1	1,6	2	3,2
Engagement	1,4	4	5,6	5	7	5	7
Co-experience	1,2	5	6	2	2,4	3	3,6
Immersion	1	4	4	5	5	3	3
			23,6		16		16,8

DEVELOPMENT OF AN INTERACTIVE SYSTEM FOR SHARED AUTONOMOUS VEHICLES

Criteria	Weight	DuMont Discovery Dock	Total	Yacht Cloud interactive system	Total	Disney: Star wars galactic cruiser	Total
Comfort	1,6	5	8	2	3,2	5	8
Engagement	1,4	5	7	4	5,6	5	7
Co-experience	1,2	4	4,8	2	2,4	5	6
Immersion	1	5	5	4	4	5	5
			24,8		15,7		24,5

Criteria	Weight	Lg Connected car	Total	BMW i Interaction EASE	Total	Audi Urbansphere	Total
Comfort	1,6	5	8	1	1,6	2	3,2
Engagement	1,4	4	5,6	5	7	5	7
Co-experience	1,2	5	6	2	2,4	3	3,6
Immersion	1	4	4	5	5	3	3
			23,6		16		16,8

Criteria	Weight	DuMont Discovery Dock	Total	Yacht Cloud interactive system	Total	Disney: Star wars galactic cruiser	Total
Comfort	1,6	5	8	2	3,2	5	8
Engagement	1,4	5	7	4	5,6	5	7
Co-experience	1,2	4	4,8	2	2,4	5	6
Immersion	1	5	5	4	4	5	5
			24,8		15,7		24,5

DEVELOPMENT OF AN INTERACTIVE SYSTEM FOR SHARED AUTONOMOUS VEHICLES

Appendix 4 (A4) - COMPARATIVE ANALYSIS TABLE

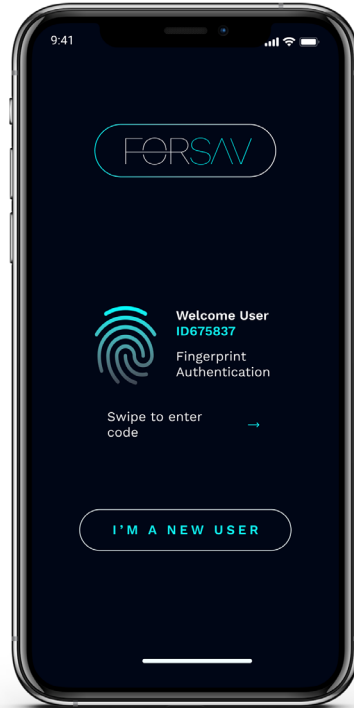
DEVELOPMENT OF AN INTERACTIVE SYSTEM FOR SHARED AUTONOMOUS VEHICLES

	Lg connected car	BMW i Interaction EASE	Audi Urbansphere
Comfort	<p>Since LG connected car was designed for neighbourhood passengers, we could assume that passengers will feel comfortable sitting aloside each other because they know each other. Some problems may occur because neighbourhood relations are not always successful, but we assume that this is similar to any social context.</p>	<p>As discussed in the previous criteria, BMW i Interaction EASE was developed to a maximum of two passengers. In this regard, we assume that these two passengers feel comfortable around each other, but the project fails the "comfort" criteria since we could not consider this solution in social contexts. In fact, the solution is not clear about multiple users interacting with the vehicle at the same time, which for the specific case are two passengers.</p>	<p>Audi Urbansphere focuses on two backseat passengers and their interaction with the interior of the vehicle. However, the solution was not developed for social contexts, in fact it focuses on single usage or with known people.</p>
Engagement	<p>LG Connected car is a solution that was developed towards the interaction between multiple users and a single vehicle system. The ammount of possible interactions engages users into the environment created inside the car. The large screen to watch different movies or TV Shows and the snacks machine are features provided to entertain the passengers and make them feel comfortable in the environment.</p>	<p>Although BMW i Interaction EASE was not developed for more than two passengers, we acknowledged that the whole system holds the attention of its users with the possibilities it provides. The HMI is done through eye movement, making it easy to interact with it. Possibilities as opaque windows to hide vehicle's interior for quick naps or laying seats are perceived as good options to provide in such systems.</p>	<p>Audi Urbansphere is focused on physical comfort and relaxation, as a vehicle to recharge bateries and escape the city stress. The features provided as the in-vehicles screens are meant to connect with family and friends during the ride or just enjoy the ride to work. We believe this approach is suitable and engaging.</p>
Co-experience	<p>LG Connected car has some features developed for multiple usage as the snacks machine and the interaction with the interface. In this regard, we considered the co-experience as a positive advantage of this solution, that relates to the context of use.</p>	<p>As previously mentioned, BMW i Interaction EASE was not developed for more than two users. In this regard, the features provided are not clear when multiple users interact with it which affects the co-experience criteria.</p>	<p>Some features were presented in this solution that enhance the perception of a pleasant co-experience between the passengers. However, as mentioned before, Audi Urbansphere was developed focusing on two backseat passengers which brings limits to the experience scope.</p>
Immersion	<p>We understood that LG Connected car immerse passengers in the social context through the voice commands and the large screen. However, there are limitations in this immersion levels because of the involvement the system can provide to its passengers.</p>	<p>From the three solutions evaluated within the mobility field area, BMW i Interaction EASE is the most immersive mostly because of the widescreen on the front of the car, the eye movement interaction and the windows flexibility that adjusts to the passenger needs. The laying backseats, as comfort providers in the vehicle, also enhance this sense of involvement which immerses users in this new environment.</p>	<p>Audi Urbansphere was developed to only two passengers and since the solution is much focused on the physical comfort of its passengers, the immersion criteria was left aside in comparison to the other solutions. We realized that the features provided hold the users attention and entertain them in a short time frame.</p>

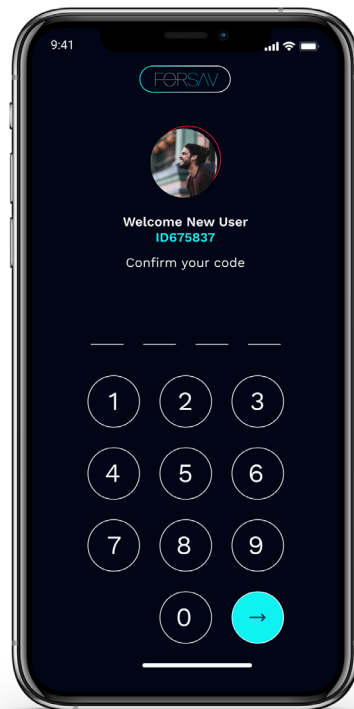
	DuMont Discovery dock	Yacht cloud interactive system	Disney: Star wars Galactic cruiser
Comfort	DuMont Discovery Dock offers many possibilities in the exhibition to participants, since VR glasses to interactive surfaces where it explains the functionality of a german dock not physically accessible to tourists. The features provided are engaging and holds visitors attention in the context created by the exhibition.	Yacht Cloud interactive system is an intuitive solution to yacht owners that provides the possible of accessing the yacht system through a computer or a tablet. The data presentation in such a complex system is one of the reasons that made us choose this project to the evaluation. The presentation is visually appealing and clear, which influences the engagement with the software.	Disney Star Wars galactic cruiser is an immersive experience for children and star wars enthusiasts. In this regard, visitors focus all the attention into this paid experience.
Engagement	DuMont Discovery dock as an immersive exhibition receives different persons at the same time and the environment seems comfortable, welcoming and flexible to this situation. The dark environment with the lights decoration makes the space intimate and overwhelming, inviting the visitors to explore the Dock. We perceive this solution as a success in terms of social comfort.	We do not perceive Yacht Cloud interactive system as a solution with strong characteristics regarding Comfort. Although the interface seems appealing to share with anyone else, the information presented should not be shared due to privacy and safety concerns.	As mentioned before, we believe that most of the visitors are in this exhibition sharing a common interest, their joy for the Star Wars series. In this regard, we consider that Disney star wars galactic cruiser users feel socially comfortable around each others.
Co-experience	DuMont Discovery dock also receives a good score on co-experience criteria for the whole experience it provides for many visitors at the same time. Although it has activities that cannot be done with multiple users, the interactive table is a good way to mutually explore the ships journey paths everywhere in the world until they get to the dock.	As mentioned in the Comfort criteria, the same applies to co-experience. The task of consulting the information within the system with someone close to the user could be pursued as a shareable experience, but our research intends a deeper experience, shareable and cooperative between passengers.	The exhibition was developed to interact and immerse all the visitors in the same history - Star Wars. We perceive Disney Star Wars galactic cruiser as a perfect example of a shareable and enjoyable experience for its users.
Immersion	DuMont Discovery dock is an exhibition focused on immersion and interaction and as previously mentioned, the dark background with the lights not only holds the attention of its visitors, but also immerses them into the environment created by the exhibition.	Yacht Cloud interactive system strongest characteristic is the data presentation regarding wind, velocity of the yacht and all the information ocean related. The way it is presented holds the user attention, involving him/her in the context.	We believe that immersion was a huge focus during the development of this project because of the fantasy and memories that Star wars series provide to the public. As in comfort and co-experience, Star Disney Wars galactic cruiser had a great evaluation in immersion criteria.

Appendix 5 (A5) - MOBILE APPLICATION DEVELOPMENT

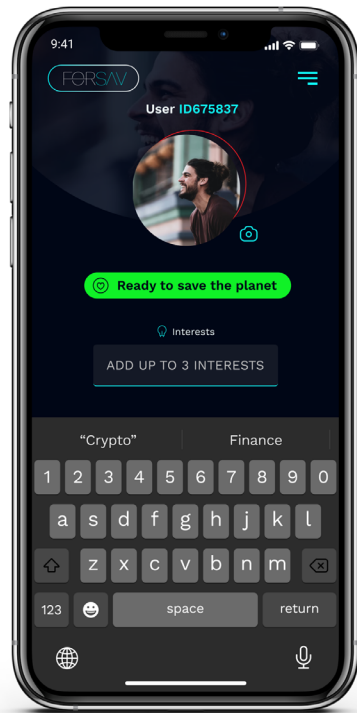
DEVELOPMENT OF AN
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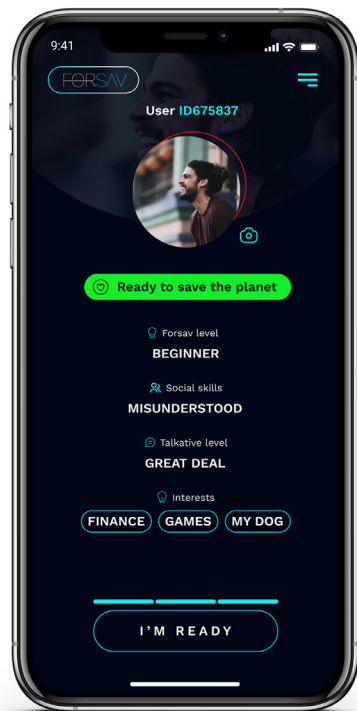
Login



Signup authentication



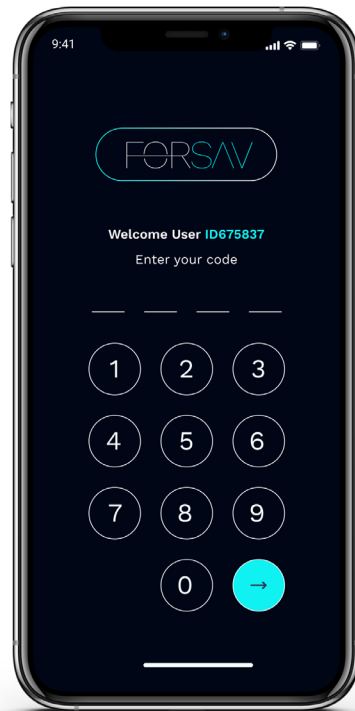
Signup profile completion



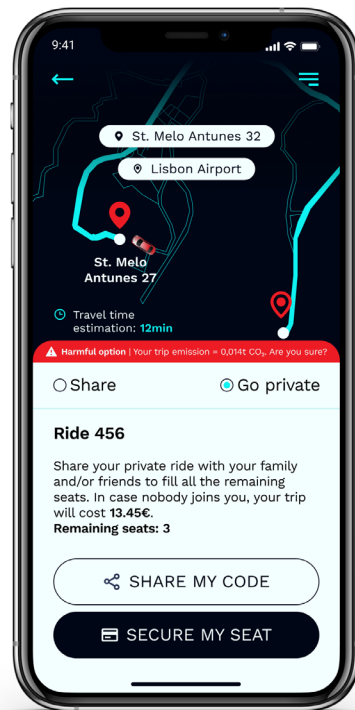
Signup profile completed

DEVELOPMENT OF AN INTERACTIVE SYSTEM FOR SHARED AUTONOMOUS VEHICLES

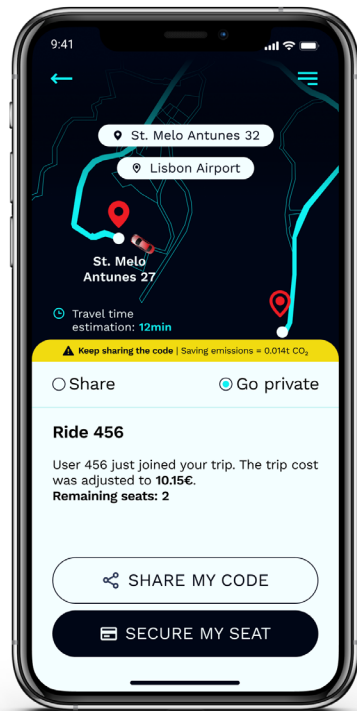
DEVELOPMENT OF AN
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VEHICLES



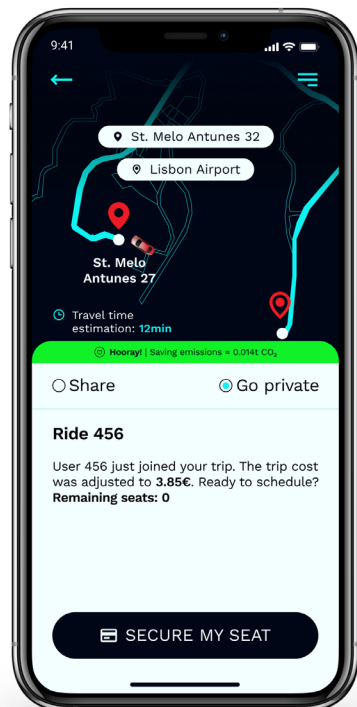
Login code



Private ride



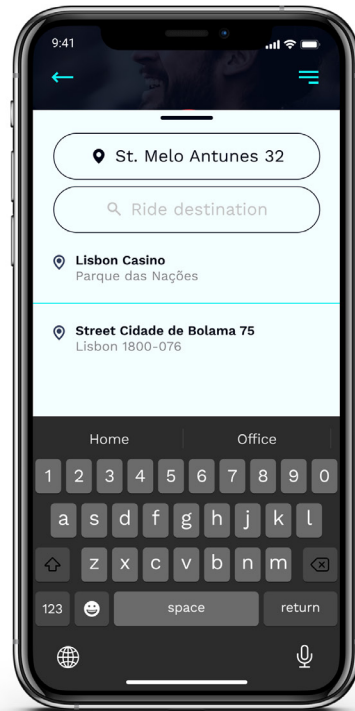
Private ride - sharing code



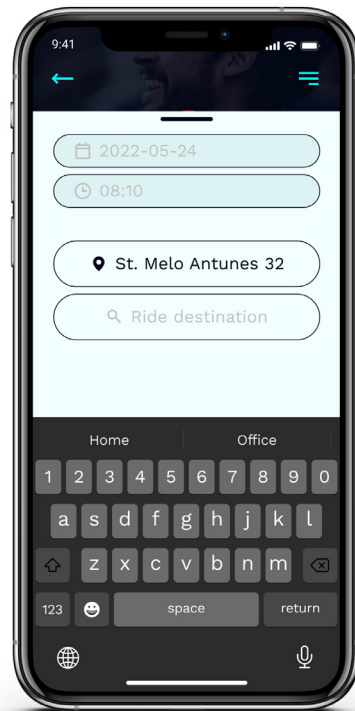
Private ride - full car

DEVELOPMENT OF AN INTERACTIVE SYSTEM FOR SHARED AUTONOMOUS VEHICLES

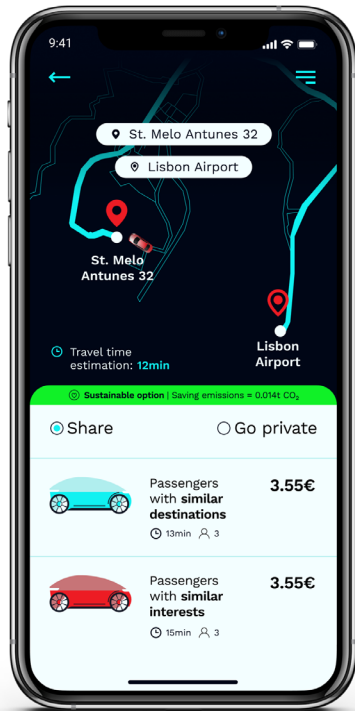
DEVELOPMENT OF AN
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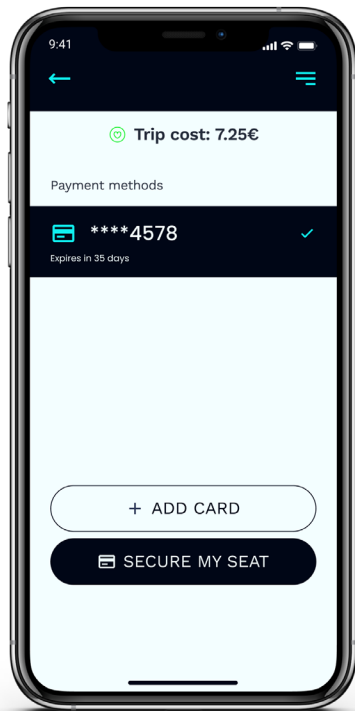
Set destination



Scheduling a ride

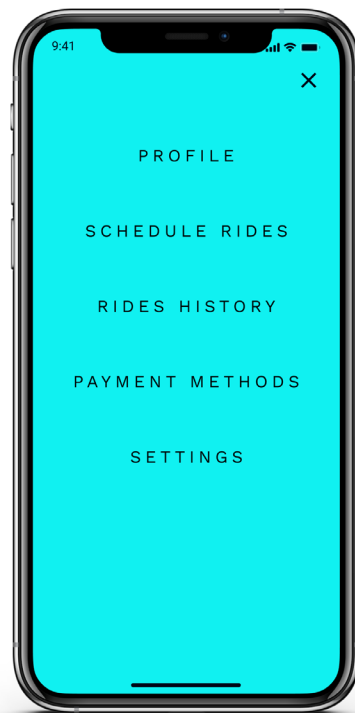


Vehicles' possibilities



Payment

DEVELOPMENT OF AN INTERACTIVE SYSTEM FOR SHARED AUTONOMOUS VEHICLES



Menu

Appendix 6 (A6) - THINK ALOUD TEST DATA

Think Aloud test 1

M: "... So during the usage, tell me what are you seeing and expect to see in further steps."

U: "... I think that I'm registered here because it's saying "welcome" but I'm a new user. In this regard, I'll click "I'm a new user". The characters are low for old people.

M: "How would you go further on your task now and what do you expect to see?"

U: "Well I would click here [I'm a new user] and I expect to see my name, my information and my credit card."

M: "Wonderful. Let's try it."

U: "Ohh it works? WOW. Great, now I understand that I can register through Google or Facebook which is much easier. I would do it with Google because I do not have Facebook. Should I do it?"

M: "Let's try it out. Tell me what you see in the next screen"

U: "Okay.. Now I should type a password here, right? Okay. [next screen] Opa, it says that I'm ready to save the planet."

M: "This is a prototype, but let's imagine that this is your picture in here. Tell me what you can see here."

U: "Well I can see that the application is classifying me and I don't like it. I do not understand what a social skill is."

M: "It's like a soft skill as conversational or kind."

U: "I am the costumer, so I want to be something or ask for something not tell what I am; I control him and not the other way around. It seems that he is in control now."

M: "Let's go further, what do you expect to see next?"

U: "[next screen] Well, now I see that he is telling me an important ecological information about carbon waste for who wants to use this mobility option. Now I would input my destination here."

M: "Great. Let's imagine you're scheduling a ride for Lisbon airport."

U: "Okay.. Well, now I see that I can share my ride or go private. I want to go private [laugh]."

M: "Okay, what do you want to do now?"

U: "I want to go private. Okay.. I can schedule it or share my code with other people."

M: "Let's imagine you are going with your family or your friends and let's share your code with them."

U: "Sure. Okay."

M: "What do you see now?"

U: "I see that the characters are very small. But the application is informing me about carbon emissions and it changed my ride value."

M: "Let's schedule it. What are you seeing now?"

U: "I see that I can pay now. [after payment] Now I see the time that the vehicle is arriving and the estimation ride time. This is very good."

M: "Let's go for the next task? So, let's imagine that tomorrow your scheduling a ride for tomorrow to the center of Lisbon. How would you do?"

U: "First, I would go in the menu. [clicked] Schedule a ride, easy. Now, I see the rides I have scheduled shared, private and my usual itineraries. Schedule a ride again."

M: "What are you seeing now? Which one would you choose?"

U: "Now, I'll go shared. I see that there are other persons with similar destinations and similar interests and you can see other passengers and their interests. This is good."

M: "How do you feel about this information?"

U: "I feel that this is important for younger people, but I do not see much difference in it for me, the persons classification, because I am a bit off about this. Also, It is only 13 minutes, it does not matter that much."

M: "Okay.. Let's move on, what do you expect to see next?"

U: "I see the payment method as in the previous task and now I've the ride scheduled for tomorrow at 08h10am."

Think Aloud test 2

M: "So the first I'll have for you is to signup on the application and schedule a ride. How would you do it? Tell me what you see."

U: "Do I have to enter the code or I am a new user?"

M: "You're signing up for the first time."

U: "Okay, so I am a new user. I have to sign up with.. humm... Google."

M: "Tell me what you are seeing in the screen."

U: "That I have to put like a code. Where do I receive this code?"

M: "What do you think? Where are you expecting to receive the code?"

U: "I don't know, maybe in my email because I chose Google but I don't know because the application is not saying that I received the code in my email. But I'll go on and set-up a code."

M: "What are you seeing now?"

U: "I think this is my profile. I don't know what I'm supposed to put on social skill. Maybe my personality, I don't know."

M: "Okay."

U: "humm, ready to save the planet. Maybe if I click here [ecological information], I'll have more information about the ecological information. But I'll just skip the profile completeness. Now, if I want to use it, I'll put my destination here."

M: "Okay, let's imagine that you're going to the airport."

U: "Okay, sure. Now I'm seeing there are 2 options, shared or private. Sustainable option, saving emission, harmful option... Oh okay, I understand I wasn't sure about which one was the sustainable option but now I understand it's every vehicle in the shared mode. Why are the ride times different? I'm thinking that maybe these persons are from different parts of Lisbon and the trip will be longer but I'm not sure. But I think I would choose this one because it's faster."

M: "So you would choose similar destinations, great. What are you seeing now and how do you feel about the information being presented?"

U: "I see the different passengers on my ride. I like it, I feel more secure. Maybe when I go out during the night I feel more safe to know who's going with me, otherwise probably I wouldn't use this mobility option. I feel better this way. There are 3 woman and 1 man and if I don't like I can choose other options, however it's stupid because it is just a photo, but okay."

M: "Okay, now what would you do?"

U: "Secure my seat and I have my card already here, secure my seat again. I think that's it, Hooray."

M: "Okay, wonderful! Let's go on the second task, you signed up and you scheduled a ride for now. Now you're scheduling a ride for tomorrow to go to the center of Lisbon. How would you do it?"

U: "Okay, I would go on the menu and there is it, schedule a ride. Now I see scheduled rides and okay, this is my usual itinerary."

M: "Okay, go on."

U: "ahhh, okay for tomorrow, at 8h10am sure. Shared mode.. Okay now I realized this, similar interests and similar destinations, now I noticed it."

M: "Which one would you choose in this regard?"

U: "Probably I would choose similar destinations because it's faster, but if I'm going from Lisbon to Oporto I would choose similar interests because there is more time to talk about different things."

M: "Great. Choose the one that better fits you and tell me what you see in the next screen."

U: "Okay, there are different people than in the ride before, good. Now, secure my seat, and it's scheduled for tomorrow. Done!"

Think Aloud test 3

M: "So the task is for you to sign up on the application and schedule a ride for now."

U: "Sure. I think that I can see the branding and it's asking for my authentication, however in this case I am a new user. I have two options to register myself, in this case I'm going to register with google. I'm being identified as a number and it's asking for a code but I'm not sure where I am receiving this code. Not sure if I must put a new code. [clicked] Well now I see that I must put my own code because it is asking to confirm the code."

M: "Okay, let's move on. Tell what you see on the next screen."

U: "Now I see that this should be a profile or something similar. It's clear to me where I should input my information, social skills let's select casual, and I like when the things appear as I am filling it and not overwhelming the screen with information."

M: "Okay"

U: "Now I should put my interests and now I think I'm ready to go on. [clicked] Now I see an information about CO2 emissions, and I imagine I am doing good to the environment. Here I should put my destination."

M: "Let's imagine you're scheduling a ride to the center of Lisbon."

U: "Okay... [after destination input] I see that the application is telling me how much emissions I am saving with this mobility option and I see that there are two different options described as similar destinations or similar interests, it is clear to me."

M: "Okay, tell me which one would you choose and how do you feel about the information presented in the following screen."

U: "Okay, I would choose similar destinations... Uhhh, I see more importance in this [ForSav level] than in interests and I think interests are more important to me. Also, I think that passengers with no picture would not be desirable for me, because I would not trust them. [clicked to advance]. Now I see that I can add other credit cards but I've already one set up, so I'll just click to pay, and It's scheduled."

M: "Thank you very much! You're amazing in these tests. Ready for the next task? Let's imagine you're scheduling a ride for tomorrow to the center of Lisbon."

U: "I imagine that the first is menu. Okay, it's clear here it's the schedule option."

M: "What do you see in this screen?"

U: "I see that I've already two rides scheduled and an usual itinerary but I'm not sure if

I'm being suggested instead."

M: "Okay.."

U: "I'll schedule here, [clicked schedule] now the date, hour and destination. Okay, I see that he's telling me about the emission savings. [clicked private option] Okay, I like it because it tells me that I'm doing damage to the environment here and I see that this is my rides' number. However, it seems a bit inconsistent since I'm chose private instead of shared, but I still can share my code. It's weird."

M: "Okay, let's go on shared mode again, and continue the task."

U: "Okay... I think that similar destinations will always be first and not interests because of time concerns. Also, I don't see how passengers with similar interests could go on the same ride with different destinations. Now I would go on secure my seat, and it's scheduled."

M: "Thank you, you were great!"

U: "No problem."

Think Aloud test 4

M: "So, you're a new user, I'll ask you to sign up on the application and schedule a ride."

U: "Okay, I'm seeing the button I'm a new user and the information for returning users. Now I would sign up with google. Enter your code, okay... Confirm your code..."

M: "Okay, what are you seeing now?"

U: "It seems like the home screen. A picture, a number for a user. I'll assume that this is to setup my account. Okay... Add a social skill, misunderstood. Interests, okay."

M: "Okay, what do you see now?"

U: "I see the map and where I am. The emissions saved with this mobility option."

M: "Let's setup the destination to Lisbon airport."

U: "Okay, airport Lisbon, and now I see the trip journey and the options for shared mode or private mode. Ahh..."

M: "Tell me, why you are choosing that option?"

U: "I wanted to see the other options. I see that I can share my code here with family and friends [private mode] but the ride is more expensive. However, if I fill it up, the ride will be cheaper. But let's go on shared mode because it is cheaper. Similar destinations... I'm curious to see about other options."

M: "How do you feel about this information?"

U: "It's interesting and makes me feel curious to see the other passengers."

M: "So which one would you choose here?"

U: "Similar destinations. Ohh, there are more vehicles here."

M: "Are you interested in seeing the other options below?"

U: "Actually, I am. Specially if I chose similar interests instead, I would want to see the other options."

M: "Okay, let's move on."

U: "Okay, secure my seat and I think that's it. It is my card, so I pay. Done, arriving in 4 minutes."

M: "Thanks! You're being amazing, now the next task which is to schedule a ride now but for tomorrow, to the center of Lisbon. How would you do it?"

U: "Okay, let me try the menu here. Schedule a ride, it's easy."

M: "What are you seeing now?"

U: "I'm seeing a list of my scheduled rides and an itinerary that is usual to me. The rides scheduled are one in shared and the other on private mode. For the task I'm supposed to do, I would go on Schedule a Ride. Date tomorrow, hours sure 8h10am. And now I've the two options again, shared or private mode."

M: "Do you want to try the other option?"

U: "Yes! Similar interests and I assume that these are the passengers that already secured their seats. Secure my seat and it's done. Are there any other tasks? This is fun and makes me curious to explore more."

Think Aloud test 5

M: "So your task is to sign up in the application and schedule a ride. Tell me what you see."

U: "Humm... This is confusing because I know I'm a new user, but the screen shows me the information for returning users too. But I'll click on the button for new users. Now I see that I can sign up with Google or Facebook and I have no other options."

M: "Are you sure? What do you see on the screen?"

U: "I see a fingerprint figure and... Ohhh, I can sign up with my fingerprint, okay. Humm, now I can set up a code for me. Done. Hummm, it shows an information about environment concerns, and it says I'm a beginner, maybe because it's my first time in the application."

M: "What do you feel about this screen?"

U: "It seems that it is my profile. Talkative level I believe it's about conversational abilities or something. Okay... Now I'll just click on ready."

M: "What do you see here?"

U: "I feel that this environment feedback is good for the users. I see a map and a destination field."

M: "Let's imagine that you're scheduling a trip to Lisbon airport. How would you do it?"

U: "So, I would click here and write Lisbon airport. Now I'm seeing different options to choose in shared or private mode and the estimation times to arrive. I see that I can choose also between similar destinations and similar interests."

M: "What do you expect to happen if you click on private mode?"

U: "Maybe something like shared. Something like an Uber, a vehicle suggested, time and duration."

M: "Let's try it. What do you see?"

U: "Humm.... It says that it is an inefficient mobility option, it costs more and now I have to decide if I want to pay more and be more damaging to the planet or go on shared mode."

M: "With this information, what would you do?"

U: "I would go for the shared mode. And between these two, maybe choose similar destinations because I feel that if I'm going to the airport I'll be in a rush."

M: "Okay... What are you seeing now?"

U: "Now I can see other passengers that will be on the same vehicle. I'm not sure about the difference between them, since they have different designations as Expert, champion, etc.."

M: "How do you feel about this information? Seeing their photo and interests, how does it make you feel?"

U: "I feel that it can be an interesting way to meet new people. I feel more comfortable with it since I can choose other options if I don't like the other passengers."

M: "Okay, let's move on. How would you move forward?"

U: "Now I must pay here, secure my seat. My credit card is already here, so pay. It's done, arriving in 4 minutes."

M: "Wonderful! Now, the next task is for scheduling a ride now, but for tomorrow to the center of Lisbon."

U: "I go into the menu and schedule a ride. I can also see at the menu, payment methods or my profile, maybe I could see if my level evolved with my first ride. But since my task is to schedule a ride for tomorrow, I would go here."

M: "Okay... What do you see in this screen?"

U: "I can see some rides that I already scheduled and this one that is a usual itinerary."

M: "What did you do now? Guide through your task."

U: "Well, I set a date for tomorrow and the hours for 8h10am and now I have a similar screen to previous ones with the options shared and private mode. Here, since it's same time and in the morning, I don't like to talk much, I'll choose similar destinations too."

M: "Okay, what about next steps?"

U: "Now, I choose the best passengers for me. These ones are okay for me, so I secure my seat, pay and it's scheduled for tomorrow."

Appendix 7 (A7) - THINK ALOUD DATA CODING

Think Aloud data (examples)	Codes obtained	Final code
<p>User (U): "Now I should put my interests first and now I think I am ready to go on. [clicked]Now I see information about CO2 emissions, and I imagine I am doing good to the environment (...)" – P003</p> <p>U: "I would schedule here, [click schedule] now the date, hour and destination. Okay, I see that he's telling me about the emission savings. [clicked private option] Okay, I like it because it tells me that I'm doing damage to the environment here and I see that here is my rides' number (...)" – P003</p>	<p>"I imagine I am doing good to the environment", "Maybe I will have more ecological information here", "Important ecological information", "Carbon emissions", "It tells me how much emissions I am saving", "In private mode it tells me that I am damaging the environment"</p>	<p>"I like ecological information"</p>
<p>U: "Well I can see that the application is classifying me and I don't like it. I do not understand what a social skill is." - P0001</p>	<p>"Well I can see that the application is classifying me and I don't like it", "I do not understand what a social skill is",</p>	<p>"I do not like to be judged" , "I do not know what is a social skill",</p>
<p>U: "I am the costumer, so I want to be something or ask for something not tell what I am; I control him and not the other way around. It seems that he is in control now." - P001</p>	<p>"I control him and not the other way around. It seems that he is in control now"</p>	<p>"I want to be in control"</p>

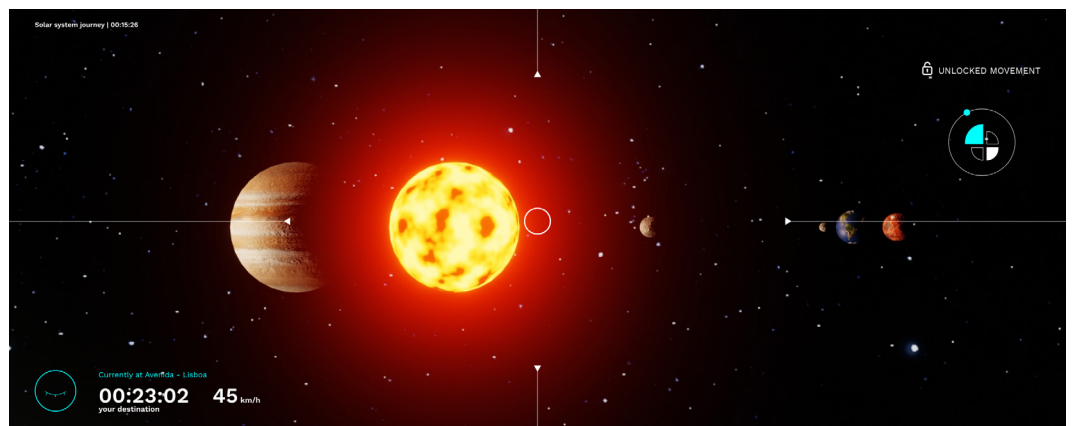
DEVELOPMENT OF AN INTERACTIVE SYSTEM FOR SHARED AUTONOMOUS VEHICLES

<p>U: “[next screen] Well, now I see that he is telling me an important ecological information about carbon waste for who wants to use this mobility option. Now I would input my destination here.” - P001</p>	<p>“Well, now I see that he is telling me an important ecological information about carbon waste for who wants to use this mobility option”</p>	<p>“I like ecological information”</p>
<p>U: “Probably I would choose similar destinations because it’s faster, but if I’m going from Lisbon to Oporto I would choose similar interests because there is more time to talk about different things.” - P002</p>	<p>“I’m going from Lisbon to Oporto I would choose similar interests because there is more time to talk about different things”</p>	<p>“I prefer similar interests for longer trips”</p>
<p>U: “I see the different passengers on my ride. I like it, I feel more secure. Maybe when I go out during the night I feel more safe to know who’s going with me, otherwise probably I wouldn’t use this mobility option. I feel better this way. There are 3 woman and 1 man and if I don’t like I can choose other options, however it’s stupid because it is just a photo, but okay.” - P002</p>	<p>“I see the different passengers on my ride. I like it, I feel more secure”</p>	<p>“Knowing others makes me comfortable”</p>

<p>U: "Now I should put my interests and now I think I'm ready to go on. [clicked] Now I see an information about CO2 emissions, and I imagine I am doing good to the environment. Here I should put my destination." - P003</p>	<p>"I see an information about CO2 emissions, and I imagine I am doing good to the environment"</p>	<p>"I like ecological information"</p>
<p>U: "Okay, I would choose similar destinations... Uhhh, I see more importance in this [ForSav level] than in interests and I think interests are more important to me. Also, I think that passengers with no picture would not be desirable for me, because I would not trust them. [clicked to advance]. Now I see that I can add other credit cards but I've already one set up, so I'll just click to pay, and It's scheduled." - P003</p>	<p>"Also, I think that passengers with no picture would not be desirable for me, because I would not trust them"</p>	<p>"Passengers without a picture are not trustworthy"</p>
<p>U: "Yes! Similar interests and I assume that these are the passengers that already secured their seats. Secure my seat and it's done. Are there any other tasks? This is fun and makes me curious to explore more." - P004</p>	<p>"Secure my seat and it's done. Are there any other tasks? This is fun and makes me curious to explore more"</p>	<p>"I like how quick I can learnt to use the app"</p>

U: "I feel that this environment feedback is good for the users. I see a map and a destination field." - P005	"I feel that this environment feedback is good for the users"	"I like ecological information"
U: "I feel that It can be an interesting way to meet new people. I feel more comfortable with it since I can choose other options if I don't like the other passengers." - P0005	"I feel more comfortable with it since I can choose other options if I don't like the other passengers"	"Knowing others makes me comfortable"

Appendix 8 (A8) - VIRTUAL JOURNEY INITIAL MOCKUPS



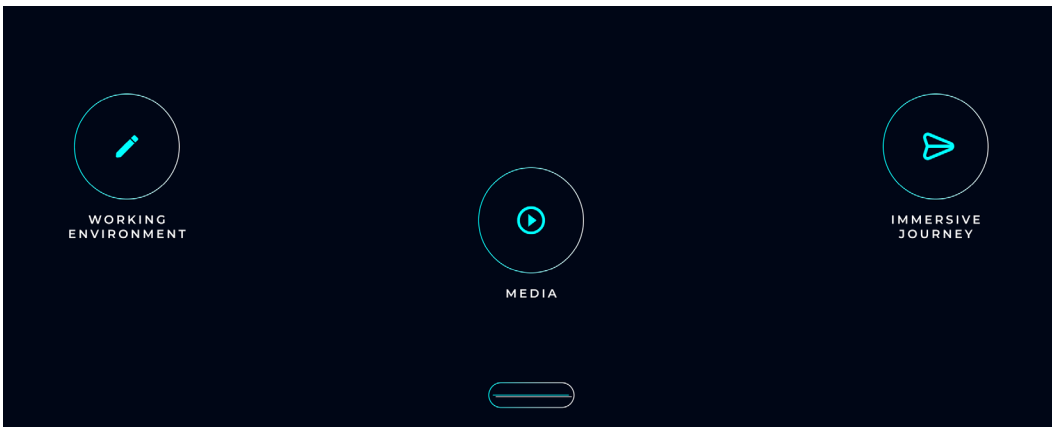
Initial mockups of the virtual journey during the generative phase of IVIS product.

Appendix 9 (A9) - IVIS DEVELOPMENT

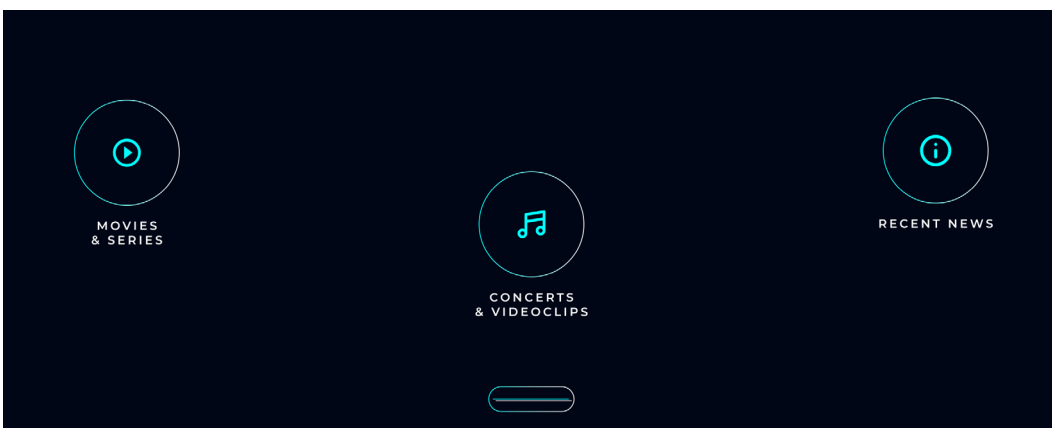


IVIS splash screen

DEVELOPMENT OF AN INTERACTIVE SYSTEM FOR SHARED AUTONOMOUS VEHICLES

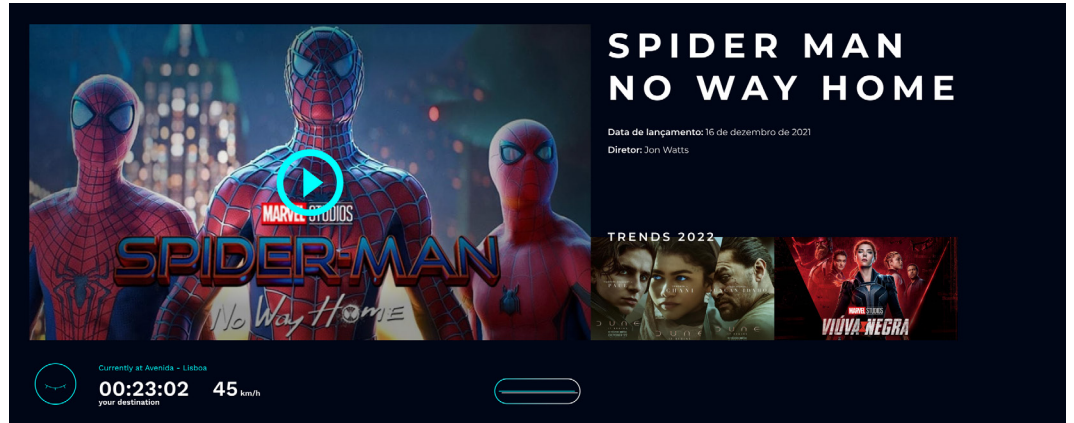


IVIS menu to choose the activity



Different items in Media

DEVELOPMENT OF AN INTERACTIVE SYSTEM FOR SHARED AUTONOMOUS VEHICLES



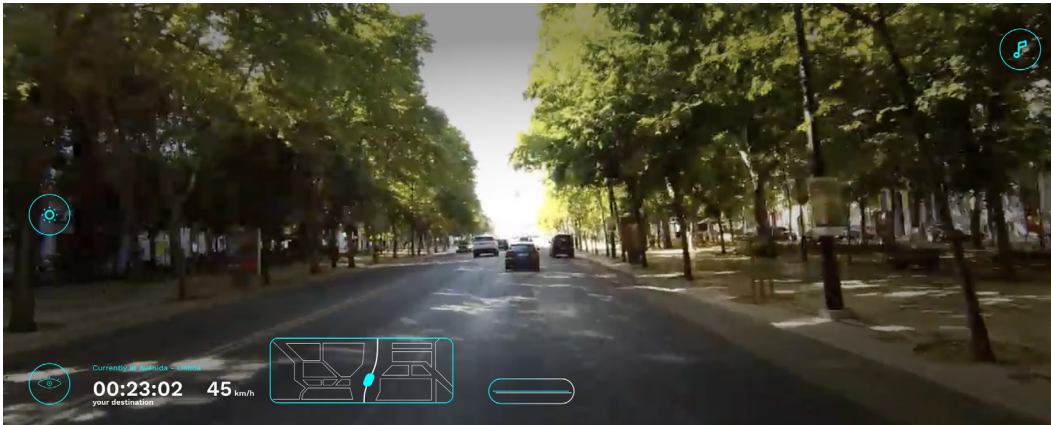
Movies & Series



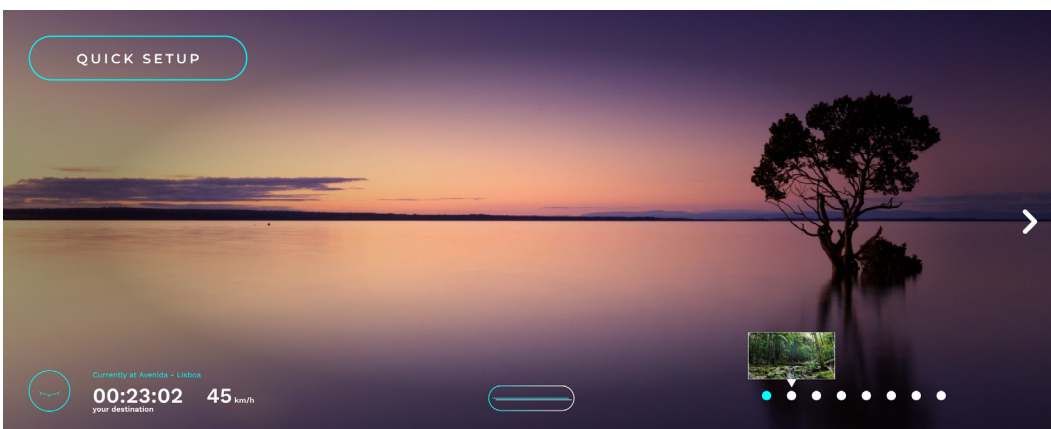
IVIS watch a movie activity



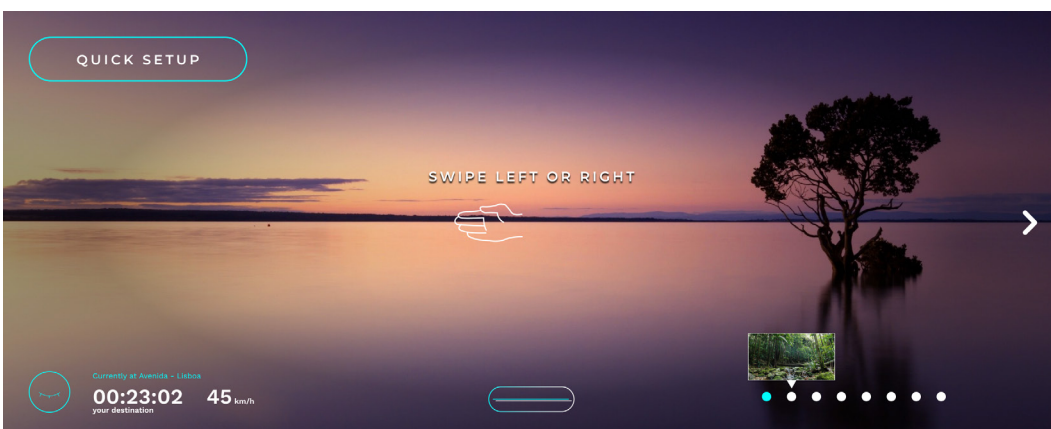
IVIS luminosity component interaction during a movie



IVIS street view



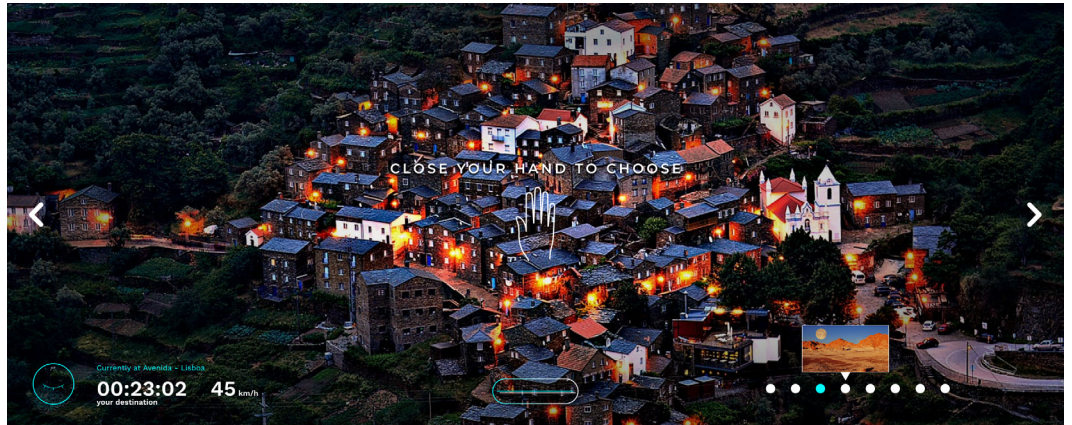
IVIS choosing working environment



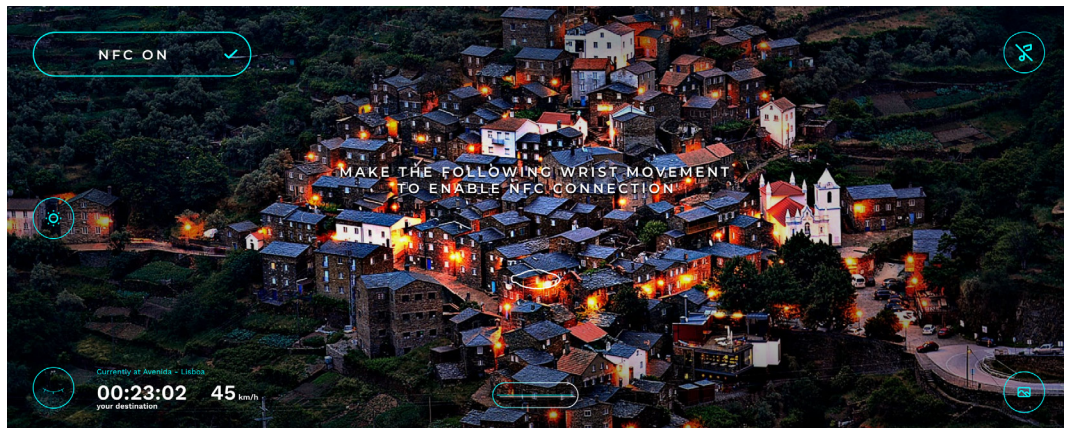
IVIS guide to interact

DEVELOPMENT OF AN INTERACTIVE SYSTEM FOR SHARED AUTONOMOUS VEHICLES

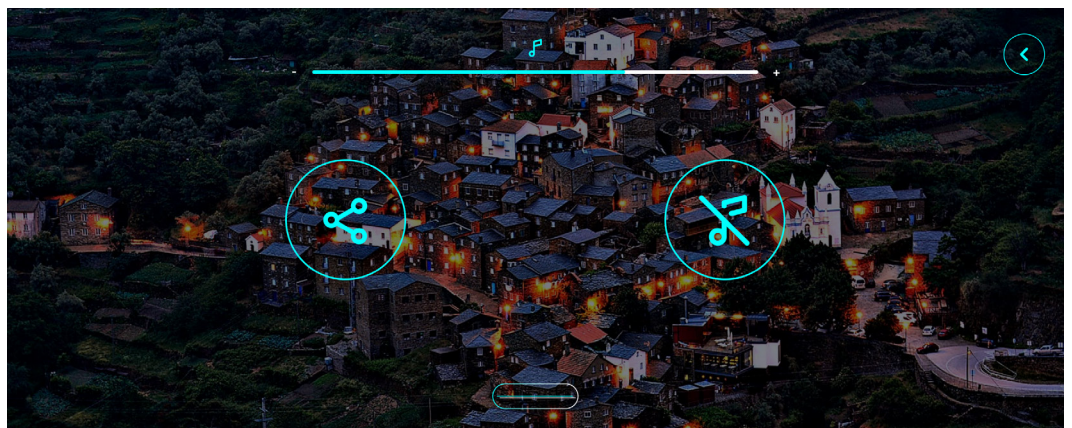
DEVELOPMENT OF AN INTERACTIVE SYSTEM FOR SHARED AUTONOMOUS VEHICLES



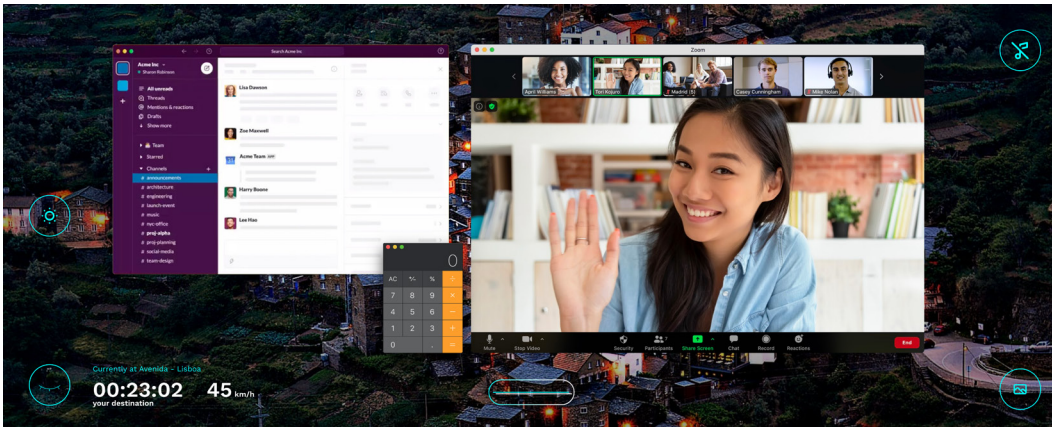
IVIS guide to interact



IVIS guide to interact



IVIS working background sound setup



IVIS working environment

DEVELOPMENT OF AN
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VEHICLES