AI COMPANION

TRUST IN PILOTED DRIVING

MASTER THESIS

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MASTER THESIS

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EXECUTIVE SUMMARY

This report presents the entire design process of the Audi AI Companion from the initial problem definition to the development and evaluation of a fully functional design prototype.

Advances in technology during the last decade have made piloted vehicles a reality. With an increasing level of vehicle automation, the role of the driver changes from controlling and observing the driving environment into becoming a passenger. However, with the introduction of piloted driving, the user has to trust his life to a machine. Therefore, one of the most important factors in the human-car relationship will be trust that the occupant places in the piloted vehicle (Waytz, Heafner, & Epley, 2014). In fact, the feeling of trust will have a major impact on the acceptance of piloted driving and is an important factor in the judgment of autonomous systems (Garcia, Kreutzer, Badillo-Urquiola, & Mouloua, 2015). However, recent scientific surveys indicated that people are interested in the new technology, but hesitate to trust piloted driving vehicles (Schmidt, 2016, Schoettle & Sivak, 2014, Kyriakidis, Happee, & Winter, 2015).

In order to define the future domain and context for this thesis, the target year is based on different expert forecasts on the development of autonomous driving. According to literature, it can be concluded that due to developments in technology, fully autonomous driving will be market-ready between 2025-2030 (ERTRAC, 2015; Rupp & King, 2010). Due to the fact that the next generation vehicles for 2020-2023 are currently under development, the selected target year for this thesis is 2030 in order to create a visionary input for the subsequent fully autonomous vehicle generation of Audi.

The theoretical analysis about fully piloted driving and the related problem of trust in combination with the developed future context scenario of 2030, which will be discussed later in this thesis, led to the following mission statement:

"Design of an AI Companion that evokes the feeling of trust by creating a relationship that is characterised by authenticity and control"

Based on the mission statement, the interaction analogy of ***"using a compass for guidance in unknown territory"*** and the derived product qualities of ***"vivid"***, ***"reassuring"***, ***"familiar"*** and ***"magical"***, the AI Companion was developed.

The AI Companion is an innovative haptic interface concept for a fully piloted vehicle without a steering wheel and pedals with the objective to build trust between the vehicle and the occupants. By simply laying on hands, the AI Companion generates a magical, haptic movement that allows the user to feel the upcoming driving manoeuvres of the piloted vehicle. By actively moving the AI Companion the user has the ability to communicate with the vehicle and therefore shapes its driving dynamics. Through the interaction with the user, the AI Companion creates an individual piloted driving profile based on the needs of each occupant.

In order to make the functions perceptible and to test if the AI Companion concept fulfils the desired product qualities in order to evoke the feeling of trust, a functional design prototype was build. To evaluate the concept, a user test with 47 participants was carried out. The user test revealed that the developed prototype satisfies the desired product qualities to a large extent. That in turn forms the basis for a trustful relationship between the user and the product. Therefore, it can be stated that the AI Companion has a positive influence on the feeling of trust in the context of a fully piloted vehicle.

WORD OF THANKS

At this point I want to express my gratitude for the support, which I received from different sides during the creation of this master project. My special thanks goes to Wouter Kets, who has made it possible at all for me to start my internship at the Audi Ag. Doing my internship and master thesis at the Audi Ag was a great experience and opportunity for me.

Moreover, I want to thank Steffen Ross and Immo Redeker for supporting me during my internship and master thesis. I felt very well supervised during the entire time of the creation of the thesis because they always took a lot of time for me. They shared their knowledge so that I was able to learn so much of them and I always received very constructive feedback and support.

Furthermore, I would like to thank Prof. Jos Oberdorf, the chair of the supervisory team and Wouter Kets, my mentor for their professional guidance, support and useful criticism during this project.

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I hope we will have the possibility to work together on great projects in the future.

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CHAPTER 1
INTRODUCTION

This chapter provides an overview of the organisation and the two departments this thesis was composed with. Furthermore, the thesis background as well as its objective are explained. Finally, the applied methodology and the structure of the thesis are outlined for a clear overview of the chosen approach.

1.1 COMPANY

This master thesis was written within the scope of the master program Industrial Design Engineering at the Technical University Delft (TU Delft) in cooperation with the Audi Ag. The Audi Ag is an internationally operating automotive company, headquartered in Ingolstadt, Germany. Audi has eleven production facilities in nine countries and sells vehicles and services in nearly all countries of the world. Initially founded in 1899 as Horch & Cie. Motorwagen-Werke by August Horch, today the company is a member of the Volkswagen Group. In total, Audi has 88,000 employees, which are responsible for the design, the engineering, the production and the distribution of the vehicles worldwide. Today, more than 60,000 people are employed at the German sites in Ingolstadt and Neckarsulm.

The graduation project is developed in cooperation with the technical predevelopment and the interior architecture design department. Both departments are part of the research and development centre, located in Ingolstadt. The technical predevelopment team is composed of experts from different areas, including amongst others, mechanical engineers, computer scientists, aerodynamic experts, chemists and physicists. The department develops new technological concepts and examines the feasibility of new ideas for future vehicles. It is aimed at anticipating the technical risks from series development projects and can be categorized between the research and the series department. The interior architecture design team is responsible for the interior appearance of production and showcars. They create the interior proportions, shapes and surfaces for future vehicles based on the technical package.

1.2 BACKGROUND & OBJECTIVE

Advances in technology during the last decade have made piloted vehicles a reality. However, the direction that this development will take is not yet clear and car manufactures are trying to come up with new and innovative concepts for piloted driving cars. With an increasing level of vehicle automation, the role of the driver will change from controlling and observing the driving environment into becoming a passenger (SAE International, 2014). When the driver does not need to be in the driving loop anymore, how does the car interior of the future support the needs of its occupants? In contrast to previous innovations in the automotive industry, this new area of driving opens up new possibilities but also includes threats for the automotive brands.

In general, car manufactures aim to develop vehicles that adapt to the driver's needs in terms of pleasurable and authentic driving experiences (Rödel, Stadler, Alexander, & Tscheligi, 2014). However, with the introduction of piloted driving, the user has to trust his life to a machine. Therefore, one of the most important factors in the human-car relationship will be trust that the user places in his/her autonomous car (Waytz, Heafner, & Epley, 2014). In fact, the feeling of trust will have a major impact on the acceptance of autonomous driving and is an important factor in the judgment of autonomous systems (Garcia, Kreutzer, Badillo-Urquiola, & Mouloua, 2015). However, recent scientific surveys indicate that people are interested in the new technology, but hesitate to trust autonomous driving vehicles (Schmidt, 2016, Schoettle & Sivak, 2014, Kyriakidis, Happee, & Winter, 2015).

Today, Audi embodies pure driving pleasure and sportiness. However, in the coming age of piloted driving, Audi might need to change its core values to stay competitive. If customers no longer pilot the car, the current Audi brand values might become obsolete. According to Welch (2017), an important element in the area of piloted driving is the credibility of the brand, which is mainly generated by trust. Without a trustful user experience, the user feels unpleasant and might abandon the piloted driving function. Therefore, people, not technology are responsible for a successful adaption and use of piloted cars. For Audi it will be important to focus, next to the product aesthetics and qualities, more on the interior user experience in order to evoke a feeling of trust and comfort.

The objective of this master thesis is to analyse the problem of trust in the context of a fully piloted vehicle and to transfer this problem into an interior experience that is embodied in a physical product, the AI Companion. Thereby, the challenge is to determine how the AI Companion needs to behave, how and what kind of information it has to present to the passengers in specific situations. Furthermore, it has to be defined how its visual appearance should be in order to create a pleasurable and trustworthy relationship.

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1.3 METHODOLOGY

Due to the fact that this thesis considers the development of a revolutionary future product, it is chosen to use the Vision in Product Design (VIP) methodology developed by Paul Hekkert and Matthijs van Dijk (2011) in combination with additional design methods such as brainstorming, morphological idea development, ideation sketching, user interviews and user testing. In general, VIP is a human-centred design method that puts the meaning of a product or service in relation to a future context. In general, a human or user centred design process is used to achieve products with a high level of usability. It builds on the principle that the design is based in a comprehensive understanding of users, tasks and the environment of use. Fundamentally, the process is characterised by an iterative design approach. The VIP method is a context-driven and interaction-centred approach that offers a way to come up with products that give meaning and value to its users. Especially, for the development of the AI Companion in this thesis, the interaction-centred approach is favourable due to the fact that the interaction will mainly contribute to the feeling of trust in the context of a fully piloted vehicle.

In general, the VIP method distinguishes between a preparation and design phase, as shown in figure 1. The objective of the preparation phase is to get an understanding on the existing product and context. In this thesis, the preparation phase considers the topic of piloted driving in general, the psychological topic of trust and the current Audi interior design language and experience. The focus during the design phase is to develop a human-product relationship according to the future context. Within the VIP method, this process is characterised by the selection of a future domain and the collection of possible context factors. Those factors, which can be for example 'states', 'principles', 'developments' and 'trends', describe the future context of the product that is to be designed. Based on the factors, a future scenario is created that serves as foundation for a mission statement. This statement is the designer's subjective vision for the design of the product. In the next step, the designer defines the desired human-product interaction before defining the look and working of the product to be designed. Based on the defined interaction, preferably by means of an analogy from another domain, product qualities are derived as input and starting point for the ideation, conceptualisation and materialisation phase.

1.4 THESIS STRUCTURE

This master thesis is subdivided into five chapters. The first chapter is an introductory chapter, which outlines the background and objective of the assignment. Within the second chapter, the subject of piloted driving is described and analysed in terms of its constraints and challenges. It builds the basis in order to understand the importance of trust in the context of fully piloted vehicles. Additionally, this chapter describes the future context 2030. Based on the context, the mission statement, the interaction analogy and the desired product qualities for the design of the AI Companion are derived. The third chapter outlines the concept development from the first brainstorm session to the ideation, evaluation and decision on the final design direction. The fourth chapter outlines the detailing process of the selected concept direction. Important topics in this chapter are the development of the mechanism and the final design. Furthermore, it gives an impression of the developed functional design prototype and the interplay between design and engineering. The last chapter covers the evaluation of the developed concept in terms of how good it satisfies the defined product qualities. Finally, the chapter reflects on the whole design process and describes recommendations for the further development of the AI Companion.

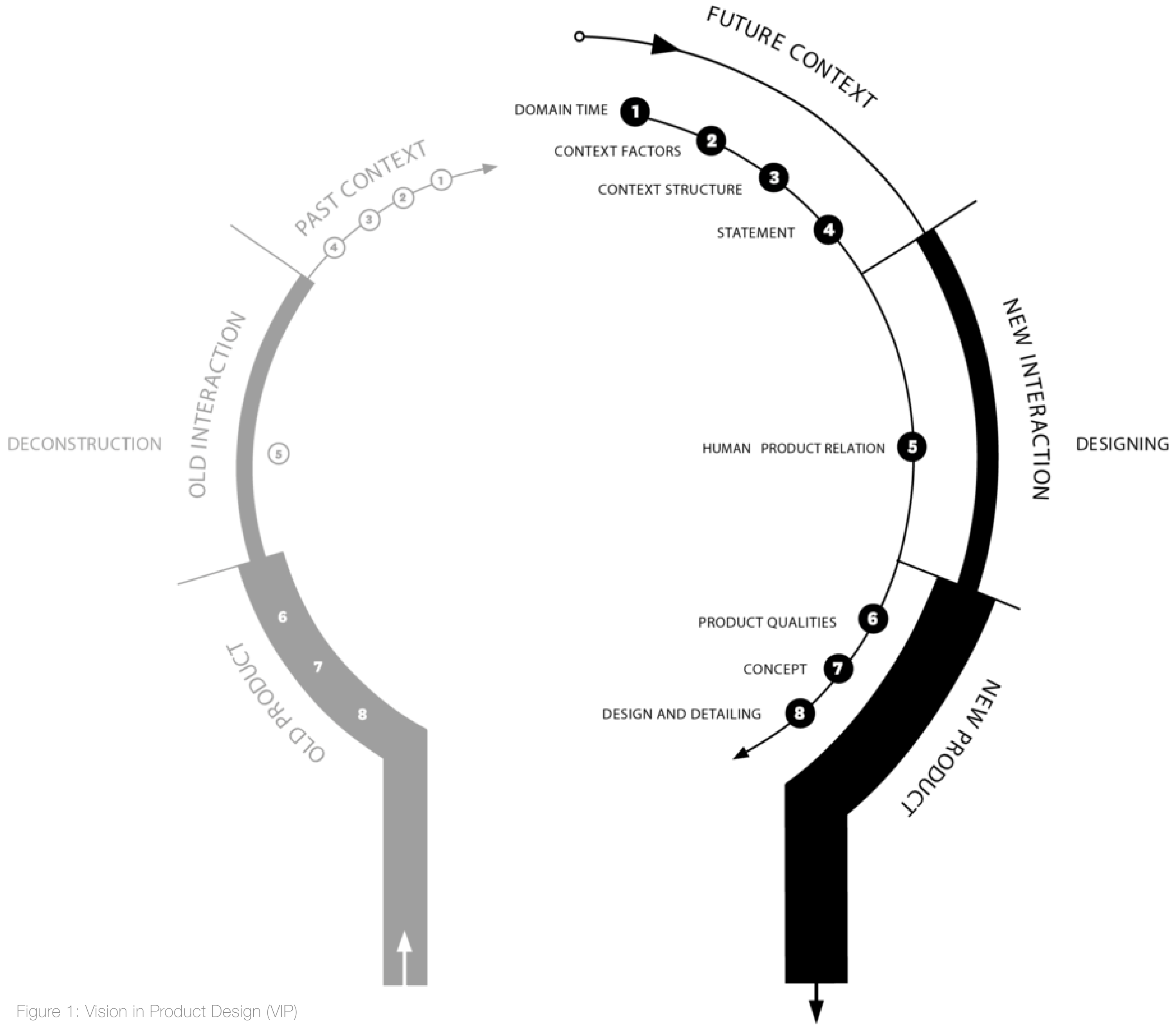

Figure 1: Vision in Product Design (VIP)

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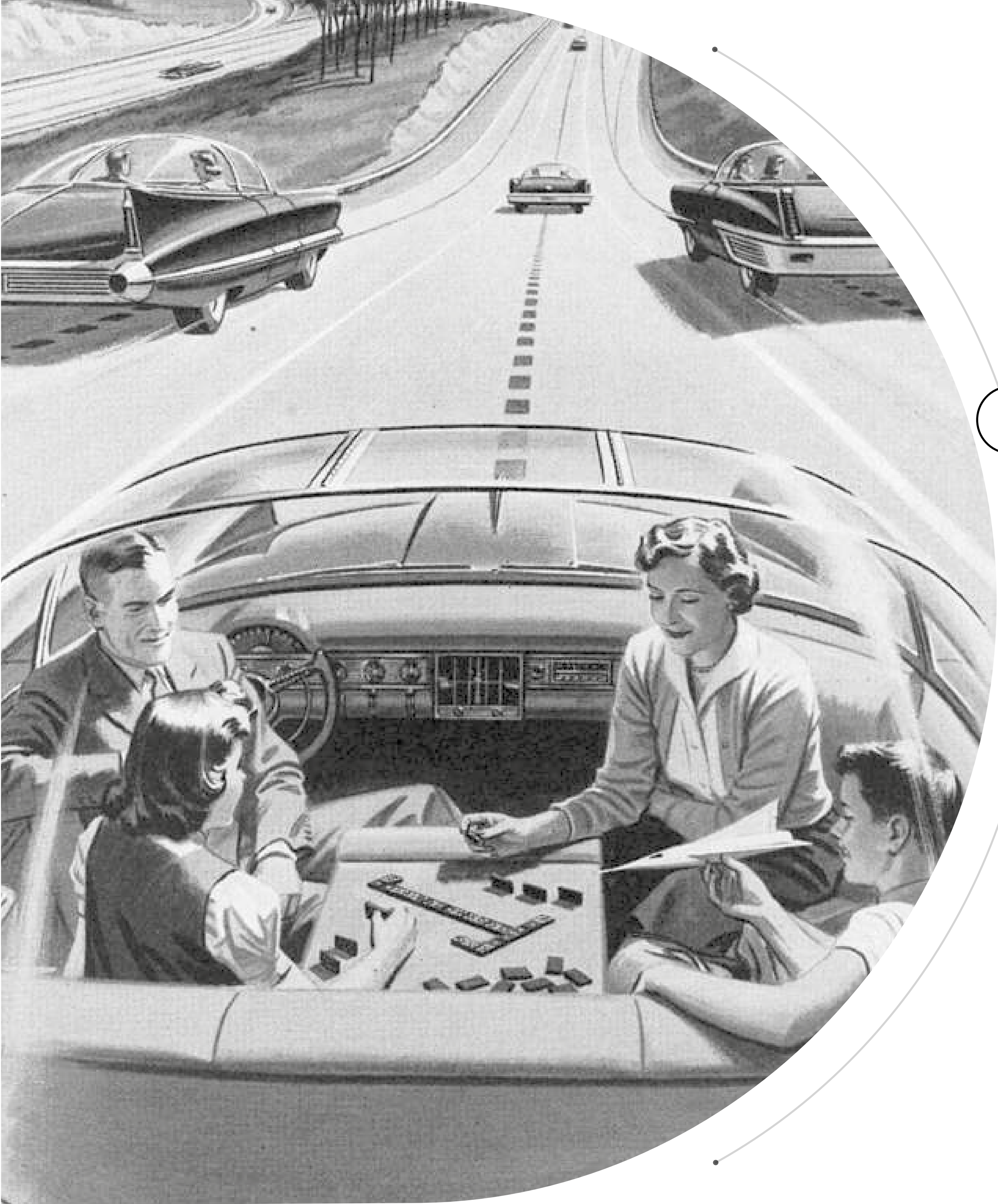


CHAPTER 2
DESIGN RESEARCH

This chapter starts with a brief analysis of the Audi brand values and form language. It gives an introduction into the subject of piloted driving and basic knowledge that is needed to understand what piloted driving is, how it is categorized and how it works. Furthermore, the possibilities and challenges, state of the art technology and future trends regarding piloted driving are analysed to define design opportunities for the development of the AI Companion. The topic of trust in general and specifically trust in automation is addressed for a theoretical understanding. Finally, a future scenario is created that leads to the definition of a mission statement and desired product qualities for the design phase.

2.1 BRAND ANALYSIS

This first part of the analysis chapter gives a short and compact overview about the main brand values of Audi in order to get a clear understanding of the company. Besides that, it is analysed how these values are translated in terms of form language and interaction between product and user.

2.1.1 AUDI BRAND VALUES

The Audi brand has a history that has significantly influenced the automotive industry of the present. Audi's brand identity today is therefore based on values and competences such as innovative developments and successes in motorsport. Audi is positioning itself as one of the sportiest supplier in the premium segment and has a perfect basis for this: motorsport. Sportiness, advanced technology and emotional design can be seen as the base for the success of the Audi brand. In its more than 100-year tradition, Audi has always set milestones in the history of the automobile: the first automobile with front-wheel drive in 1931, the Quattro technology in the early 80s, and the first serial vehicle with an aluminium body. These and other innovations have significantly influenced the brand and its appearance in the past. The genetic code of Audi encompasses passionate automotive engineering combined with the highest technological standards and high quality. The core message of the brand is summarized in the slogan "Vorsprung durch Technik", meaning "Progress through Technology". The slogan not only articulates the pioneering role of Audi in the interplay of technology and design, but also embodies the attitude of the entire company. The strong columns and distinctive features of the brand are characterised by a combination of precision, technology and simple and clean design. In addition to technical advances, Audi is characterised by the core values of sportiness, progressiveness and high-quality.

Sportiness stands for performance, attractiveness, dynamism and youthfulness. The design is athletic and dynamic. Many years of experience and success in motorsports and the resulting innovative technologies form the basis for sportiness.

Progressiveness is the driving force of thinking, discovering and developing innovative solutions at Audi. The brand embodies the passion for the new, which is expressed by the interplay between technology and design. A progressive solution is characterised by the perfect balance of form and function, and is characterised by clarity and simplicity.

High-quality is the expression of style, sophistication and fascination. Audi stands for the highest standards of quality with a commitment to perfection in detail, which is expressed by precision in fit and finish, a high interior quality.

Figure 2: Audi Brand Values

2.1.2 FORM LANGUAGE/INTERACTION

The current Audi Form Language can be described as dynamic, highly functional and technical yet aesthetical, as shown in figure 3. The design embodies a high visual clarity by means of uncomplicated and clean surface treatments where every line is comprehensible. It is the interplay of new technologies and design and the way technology is made visible and attractive that characterises Audi. In the interior, the aim is to combine the visual appearance of simple and clean individual components in a way that the user has the feeling that it is made all of a piece (in German: “Aus einem Guss”). High attention is paid to the perfection of every detail. Split lines, highlights, chamfers and stitching perfectly merge with the architecture and underline the premium-quality of Audi. The interaction between user and technology in the interior can be defined by playfulness, surprise and novelty. The pop-up display or the B&O loudspeaker create a welcome gesture that is comparable to human character traits. Finally, high quality materials and finishes are used at the interaction touch points between user and product in order to create a feeling of quality and comfort.

Figure 3: Audi Form Language

2.2 PILOTED DRIVING

Highly automated, autonomous, piloted, driverless, self-driving - there are many terms that describe the future vision for the automobile. In order to have a common understanding of the term "piloted driving", first of all, it is defined. In general, a piloted car describes a vehicle that is able to sense its environment and to navigate to a specific destination without human input. According to the National Highway Traffic Safety Administration (NHTSA),"piloted driving vehicles are those in which operation of the vehicle occurs without direct driver input to control the steering, acceleration, and braking and are designed so that the driver is not expected to constantly monitor the roadway while operating in self-driving mode" (SAE International, 2014). However, between manual and fully piloted driving there are different levels of automation that describe the allocation of tasks between system and driver.

2.2.1 LEVELS OF AUTOMATION

The degree to which a task is automated is referred to as level of automation. In order to define the level of automation more precisely, the Society of Automotive Engineers (SAE) developed a harmonized system, describing six levels of autonomy: from zero automation (Level 0) to full automation (Level 5), as shown in figure 4. The classification describes both, the tasks the system itself performs as well as the requirements to the driver.

At level 0, there are no automated driving functions. The driver alone is responsible for longitudinal (holding speed, accelerating and breaking) and lateral (steering) guidance. There are only warning systems but no systems that intervene.

Level 1 means that the system can either take over the longitudinal or transversal guidance of the vehicle, while the driver permanently performs the other task. An example of an assistance system that operates at level 1 is the adaptive cruise control (ACC).

At level 2 one speaks of semi-automated systems, since the driver can transfer both the longitudinal and lateral guidance to the system in particular situations. However, the driver continuously has to monitor the driving environment in order to take over the control when the system reaches its limits. An example of a semi-automated assistance system is the AUDI traffic jam assist.

At level 3, the system is able to recognize automatically its limits, thus the point where the environmental conditions no longer correspond to the functional scope of the system. In this case it requests the driver to take over the driving task. At level 3, the driver no longer has to monitor the longitudinal and transverse guidance of the vehicle. However, the driver must be able to take over control in a certain amount of time. As an example, the next generation Audi A8 (D5), entering the market 2017, will be capable of level 3 autonomous driving (Krok, 2017).

From level 4 on, the driver can transfer the complete guidance to the system. The system is able to manage all situations automatically for a specific application. The applications include road type, speed range and the environmental conditions.

The final stage of development, level 5, is fully piloted driving. The vehicle can completely carry out the driving task on its own on all types of roads, at all speed ranges and under all possible environmental conditions.

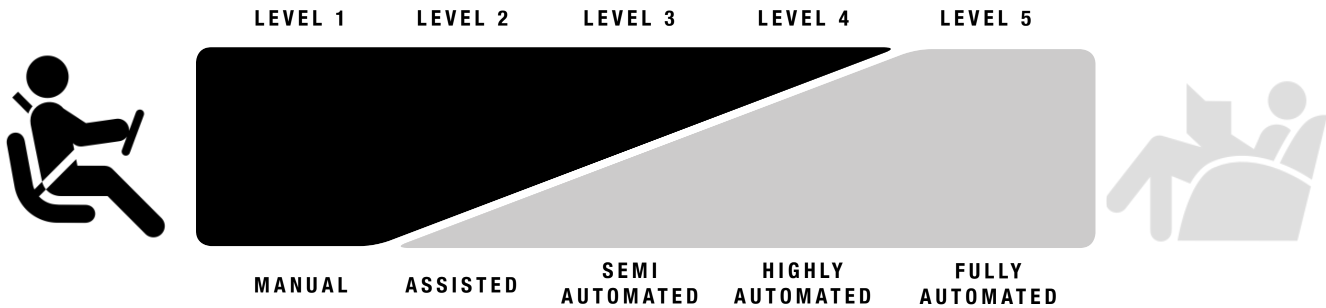


Figure 4: Levels of Automation

2.2.2 PILOTED DRIVING MOTIVATION

Piloted driving has the potential to provide solutions to different transportation challenges, both for the society as a whole and for the individual user. Those include amongst others improving road safety, optimizing traffic flow, allowing more efficient transportation and new mobility models as well as generating additional comfort for the passengers (Esser, 2015). In the following part, first of all the general key benefits are discussed, followed by the specific reasons why piloted driving is important for Audi.

Improving Road Safety

According to the Federal Statistical Office in Germany, around 2,6 million traffic accidents were recorded in 2016, of which 90% are caused by human error (Fagnant & Kockelman, 2015; Fraedrich, Beiker, & Lenz, 2015; Statistisches Bundesamt, 2016).

The most common reasons for accidents are failing to look properly, being distracted or misjudging other road users' movements. According to different experts, the implementation of piloted driving will be more reliable than the human driver (Blanco, Atwood, & Russell, 2016). The system can make decisions within milliseconds without any distraction. Therefore, piloted driving should be able to dramatically reduce the number of road accidents in the future.

Reduction of emissions

Piloted and connected vehicles have the potential to improve the energy consumption by means of forward-looking driving. According to Fagnant and Kockelman (2015) a piloted vehicle is able to accelerate and brake more smoothly than a human driver. Additionally, connected vehicles are informed about the traffic volume and carry out driving actions such as braking and accelerating early and synchronously. Furthermore, the reduction of accidents will allow producing lighter vehicles, which has a positive impact on the energy efficiency of the vehicle (Anderson, 2014).

Traffic congestion

That piloted driving will have a positive influence on the overall traffic flow cannot be clearly stated. On the one hand, driverless vehicles make better use of the road space by travelling closer together. Additionally, a lower accident frequency will lead to less traffic jams in general (Fagnant & Kockelman, 2015). However, the overall number of vehicles on the roads also influences the expected traffic congestion. More efficiency and safety could lead to a high acceptance of piloted vehicles and therefore increase the traffic level. Especially in a mixed environment where piloted and vehicles with lower levels of automation share the road, the traffic flow could even increase due to the fact that piloted cars are driving strictly according to the traffic regulations.

Creating more free time

Another key benefit of piloted driving is the fact that it allows to transfer the attention to other activities while driving such as reading, surfing the web, watching a film, working or communicate with other passengers (Sommer, 2013; Fraedrich, Beiker, & Lenz, 2015). It allows the occupants to use the travel time either productively or to relax.

Increasing access to vehicles for everyone

Piloted vehicles also provide individual mobility to groups that have no access today due to physical or age related constraints. For example, teenagers or children who are not allowed to obtain a driving license or elderly people who are afraid or not able to use personal mobility means anymore. Providing independent mobility to those groups generates a major benefit to their social life and enhances their quality of life (Anderson, 2014).

Motivation for Audi

Compared to other trends in the automotive industry, piloted driving has the capability to completely change the automotive industry. In order to stay competitive and build up on the discussed benefits of piloted driving, it is important for Audi to be a key player in this new area of mobility. Today, Audi embodies pure driving pleasure and sportiness. In the coming age of piloted driving, in order to stay competitive, Audi might need to change its core values. If customers no longer pilot the car, Audi's actual brand values might become obsolete. According to Welch (2016), an important element in the area of piloted driving is the credibility of the brand, which is mainly generated by trust. Therefore, it is important for Audi to build on the current credibility of the brand and improve it for the new area of piloted driving by creating novel brand specific customer experiences.

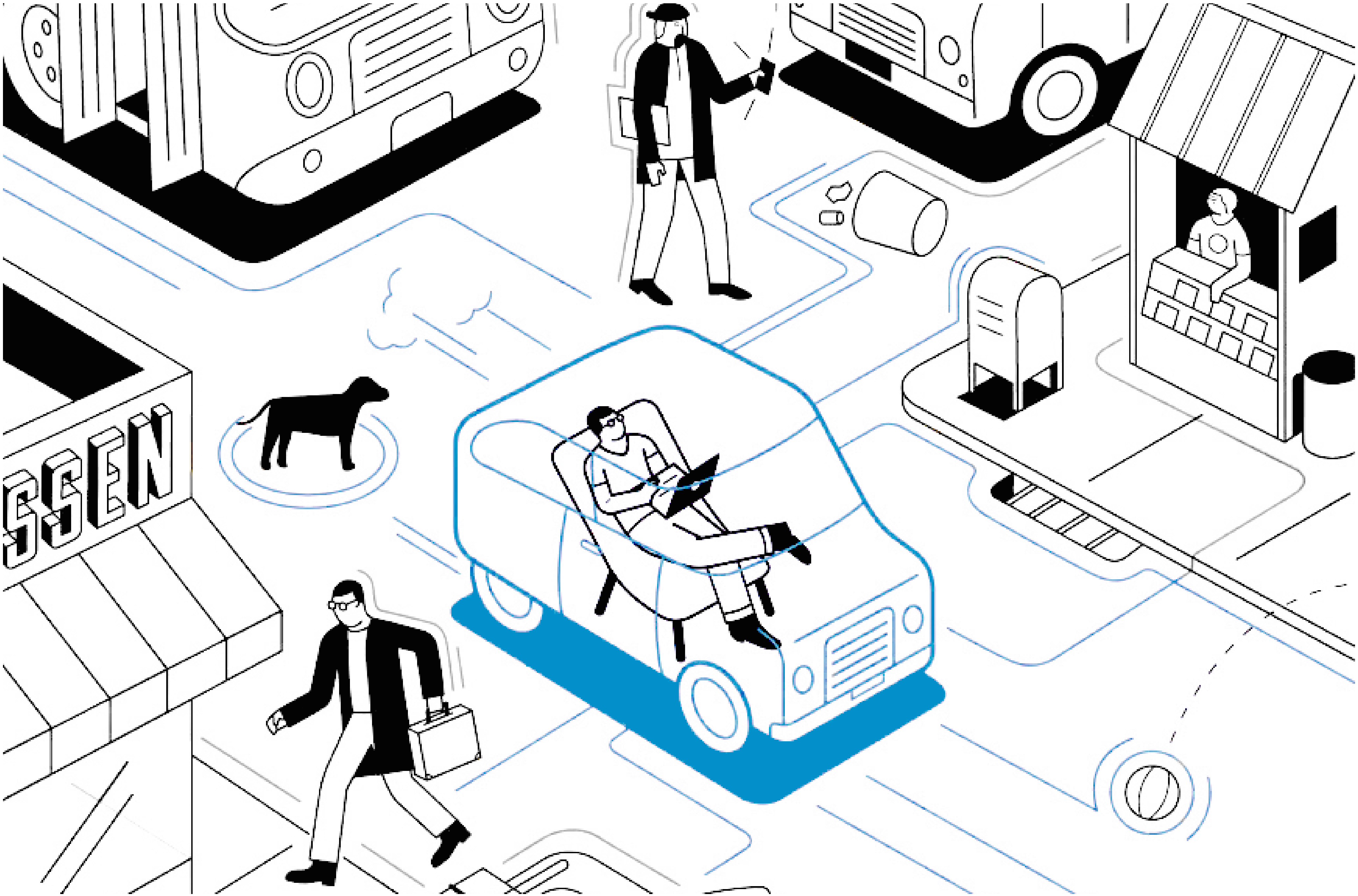


Figure 5: Piloted Driving Illustration

2.2.3 STAKEHOLDERS

Considering the technical realization of piloted driving, there are two main industries involved (Brauck, Hawranek, & Schulz, 2016). On the one side there are the traditional car manufacturers such as Audi, BMW, Daimler and other well-known automotive brands. On the other side, new players from technology and IT sectors like Google, Apple, Tesla and Uber are entering the market. Those tech companies had nothing to do with the traditional automotive industry, however, are making rapid progress in the development of piloted cars. Elon Musk, CEO of Tesla recently announced that Tesla plans to offer fully piloted driving (level 5) in about two years from now (Greene, 2017). Whether this is possible remains questionable, however, it shows the high ambition of the new automotive players to enter the market of piloted driving even before the traditional car manufacturers. Waymo, the result of Googles self-driving car project, also shows this rapid progress. The project started in 2009 and up to today, Google has test driven their fleet of vehicles, in autonomous mode, a total of 2,8 million kilometres (Waymo, 2017) . This quick development and the high ambition to bring the new technology of fully autonomous driving to the market makes companies such as Google, Tesla and Apple a major threat to traditional OEM's.

Therefore, it is important for Audi to step up efforts to defend the position in the automotive value chain. Otherwise, Audi might be downgraded to a platform provider on which the tech companies might place their technology (Brauck, Hawranek, & Schulz, 2016). In contrast to the new players from the technology and IT sectors, the advantages of Audi are their experience and knowledge of building premium and high quality cars. Even in the area of piloted driving, the overall driving experience will remain important in order to evoke a feeling of comfort and safety. However, the current strong bond to the brands heritage, makes radical innovation more difficult for Audi compared to Tesla and Google. Therefore, it is important for Audi to rethink areas of differentiation regarding piloted driving.

Figure 6: Piloted Driving Stakeholders (Audi, Google, Smart, Uber)

2.2.4 STATE OF THE ART AND FUTURE DEVELOPMENTS

In order to define the future domain and context for this project, the state of the art and future development regarding piloted driving are discussed in this paragraph. The defined target year will be used as input for the analysis of the future context, the definition of the vision statement and the creative design solution in the next chapter. For a structured approach, first of all it is analysed which levels of automation are available today. Based on different expert forecasts and statements of various automotive brands the future development of autonomous driving is deduced. Finally, a closer look at autonomous design concept studies is taken to define key aspects regarding the interior design.

State of the art

Today, many vehicles on the road are equipped with level 1 driver assistance systems that take over either the longitudinal or transversal guidance of the vehicle such as cruise control, automatic breaking or parking assists, as shown in figure 7. Besides those basic assistance systems, many established manufacturers offer advanced driver assistance systems, referred to as level 2. Those systems take over both the longitudinal and lateral guidance of the system in particular situations. An example of a current level 2 assistance system is the Audi traffic jam assist. It takes over the guidance of the car in the speed range of 0 to 65 km/h on well-paved roads as long as the traffic is moving slowly. Today's most advanced semi-autonomous features on the market are the Highway Pilot offered by Tesla and the Driver Pilot developed by Mercedes-Benz. Those systems allow drivers to take their hands off the steering wheel on a highway for a defined amount of time and offer autonomous lane change manoeuvres after tapping the turn signal. However, the driver still needs to monitor the system at all times. Whereas Daimler's Driver Pilot requires the occupant to touch the steering wheel or pedal after 60 seconds, Tesla's warning signal depends on the driving environment, allowing to drive several minutes without driver input.

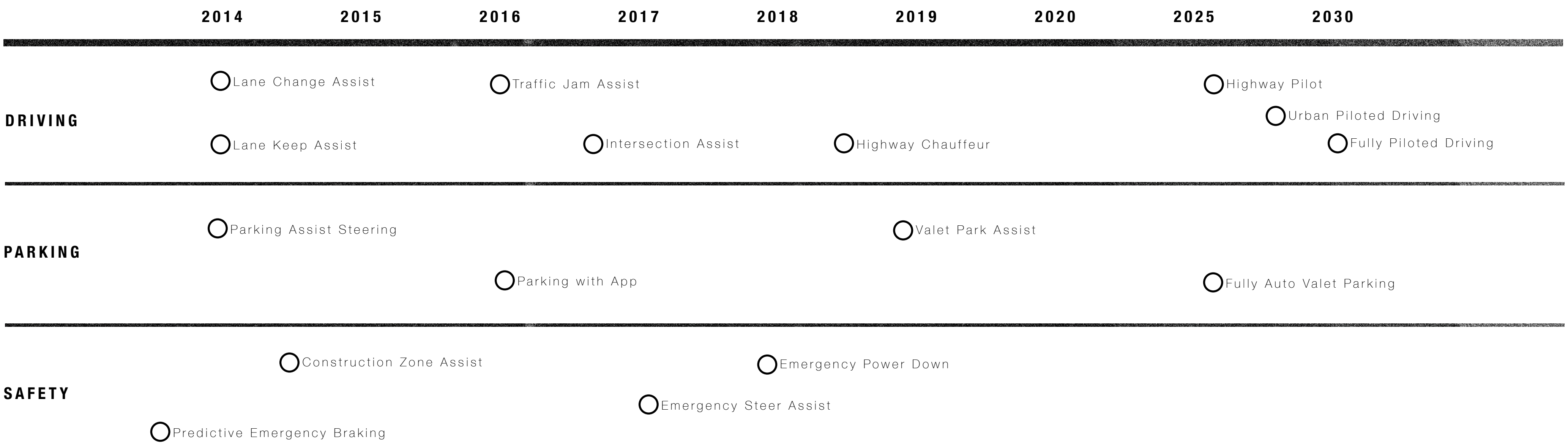


Figure 7: Future Developments Piloted Driving

Future Developments and Target Year

Looking forward, the next evolution towards fully autonomous driving are assistance systems that operate at level 3, namely highway chauffeurs. Those take over all relevant driving tasks, such as overtaking, changing highways and driving in tunnels. The driver does not have to take over control until exiting the highway. As an already named example, the next generation Audi A 8 (D5) entering the market in 2017, is capable of Level 3 autonomous driving (Krok, 2017). In comparison to Tesla's Highway Pilot, it allows to delve into other tasks than controlling the system due to the fact that any intervention would be preceded by eight to ten seconds of warnings.

In general, two different introduction strategies in terms of piloted driving can be observed. On the one hand a step-by-step approach, where the users are guided from level 2 to level 3 and further with the desire to get them used to piloted driving (Davis, 2017). On the other hand, a growing number of automakers such as Volvo and Ford are skipping level 3 autonomous driving technology and take the user out of the driving loop entirely in order to avoid the critical take over moment when a level 3 vehicle reaches its limits. Google was the first company that was convinced that full autonomy (no steering wheel, no pedals, no human backup) was the best way forward.

According to the forecast of different experts and statements by various car manufacturers, it can be concluded that due to developments in technology fully autonomous driving will be possible between 2025 and 2030 (ERTRAC, 2015; Rupp & King, 2010). In a survey with nearly 150 experts of the automotive industry, 48% expect fully autonomous driving within the next 10 to15 years. Even though fully piloted driving will be available between 2025 and 2030, it is assumed that a significant penetration of the entire fleet and thus a noticeable effect on safety and traffic flow, will be realized between 2040 and 2060.

Due to the fact that the next generation vehicles for 2020 to 2023 are currently under development, the selected target year for this thesis and the design of the AI Companion is 2030 in order to create a visionary input for the subsequent fully autonomous vehicle generation of Audi.

Interior Context AI Companion

The AI Companion will be designed for a fully autonomous (Level 5) vehicle. It can completely carry out the driving task on its own on all types of roads, at all speed ranges and under all possible environmental conditions. In order to avoid a direct driving intervention of the occupants, who might not have been paying attention to the road and rather impulsively grab the steering wheel to override the autonomous system, it is chosen that the vehicle has no pedals and no steering wheel.

The actual size of the vehicle and number of occupants is not defined in the scope of this project due to the fact that the objective is to design the AI Companion in a way that it is not depended on a specific car model. Rather it is a component that can be integrated in different kinds of fully piloted cars of the Audi portfolio in 2030.

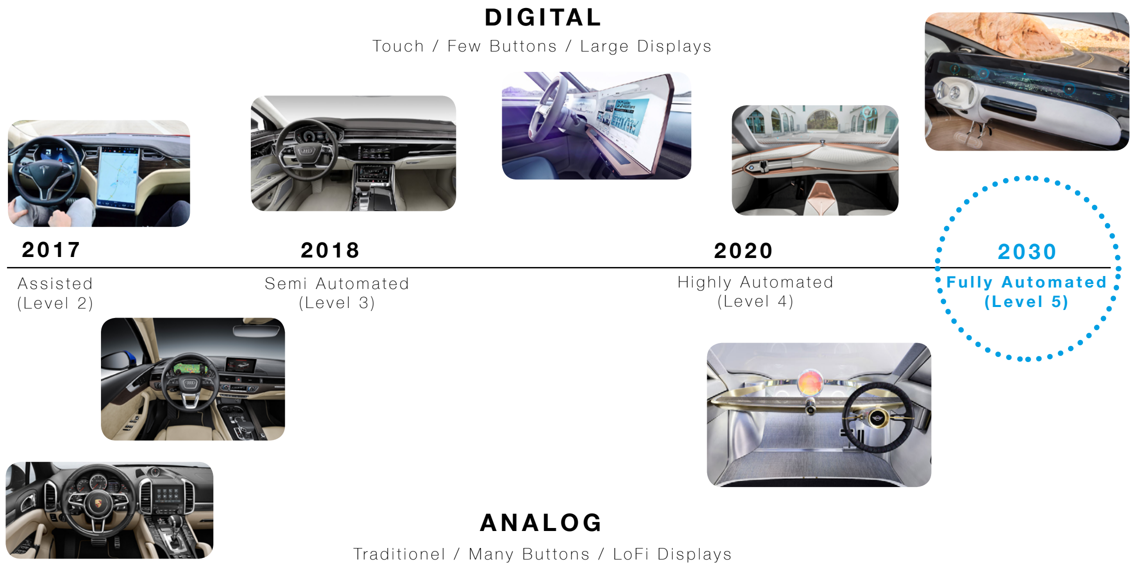


Figure 8: Target year 2030

Concept Studies Piloted Drving

The realisation of level 5 piloted driving offers new possibilities for the design of the car interior. Different concept cars have been presented lately on fairs such as the CES, IAA or Geneva Motor Show. The challenges and possibilities of piloted driving have been explored by various studies such as the BMW Inside Future, Mercedes F015, VW Sedric, NIO EVE and Audi Aicon.

Adaptive and Flexible Interior Architectures

By comparing and analysing those concept studies it can be stated that a major point of interest for fully autonomous cars are adaptable and flexible interior architectures. Allowing the occupants to change the interior layout regarding their personal needs and preferences such as working, relaxing or driving.

Second Living Space

Basically, the interior becomes a second living space that allows doing other activities while driving. In order to evoke the feeling of a second living space, it is noticeable that most of the concepts make use of wood and of high quality fabrics.

New Seating Layout

Another important point that a majority of the concepts have in common are rotating seats or seat layout where passengers face each other to enhance the communication and connection inside the car. Another typical feature is foldaway steering wheels that offer more space when driving autonomously.

New Ways of Interaction

The interaction between the vehicle and its occupants mainly takes place via large touch screens located in the dashboard, doors or windows to communicate with the vehicle and connect to the outside world. Other popular ways of communicating with the vehicle is via voice or gesture control. Interesting is also the fact that not all concept cars implement additional large display and touchscreen areas. In BMW's Next 100 study and in the NIO EVE concept no touchscreens can be found in the interior. The only display medium that is used is the windshield.

Figure 9: Piloted Drivng Concept Studies (Audi Aicon, Mercedes F015, VW Sedric, NIO Eve)

Paradigm Shift Personal Mobility

Based on the previous analysis of future mobility developments and concept studies, it can be stated that piloted driving is the biggest paradigm shift in the automotive industry. This development will have a large impact on the way cars are built and evaluated in the future. As shown in figure 10, it can be estimated that vehicles in general will change from a “Driving Machine” that delivers the ultimate driving pleasure to a kind of “Reliable Co-Pilot” and finally to a “Lifestyle Space” in 2030 that offers quality time comparable to being at home. This is also noticeable in terms of the interior and exterior design. Up to today, the car interior is perfectly designed to meet the ergonomic needs of the currently most important person in the car, the driver. In terms of the interior architecture and the exterior design, cars of today symbolise the feeling of speed and create an atmosphere that perfectly supports driving pleasure.

In contrast, piloted driving will be quite different and will challenge Audi not only technologically but also on a sales-oriented level. After all, driving pleasure, speed and brutal performance, which are now central sales arguments, will lose importance in a world of piloted vehicles. Moreover, a main topic will be safety, not the actual safety but the feeling of security because people will leave their welfare directly to a technical machine that is not working transparent. Therefore, it will become one of the most important points for Audi to create trustworthy environments in which occupants feel comfortable. This will require more than the design of fluid interiors with swivel seats, coffee machines, many displays and entertainment facilities. This underlines the need to develop from a product to an experience focused culture at Audi, considering topics like usability, artificial intelligence and flexible individualization next to aesthetics, functionality and ergonomics.

Besides the car in itself, it can be estimated that the complete automotive industry will experience a paradigm shift from car manufacturers to mobility providers. According to different industry experts, it is likely that the car ownership model of today is moving to a subscription model like Netflix and Spotify (Treece, 2017). This means that a range of different vehicles can be accessed for a flat fee, but are not actually owned by the driver. This development also supports the shift from a product to an experience oriented industry that offers its customers the desired experience for their individual needs.

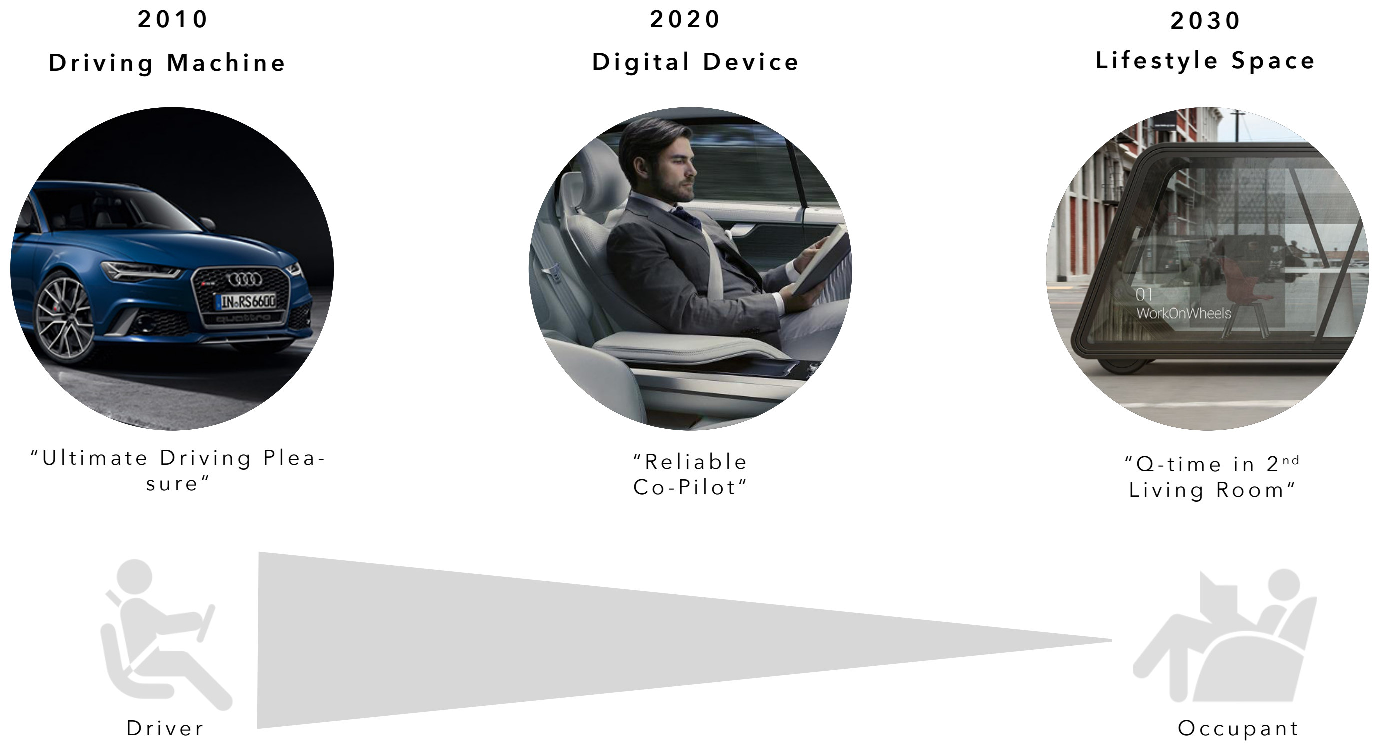


Figure 10: Mobility Paradigm Shift

2.2.5 CONSTRAINTS AND CHALLENGES FOR FULLY PILOTED CARS

Even though car manufacturers and technology companies aim to bring fully autonomous vehicles to the market between 2025 and 2030, there are a number of constraints and challenges that need to be solved. This paragraph discusses the most important issues related to level 5 piloted driving in order to analyse design opportunities for the AI Companion.

Technology

The necessary sensor technology and computing capacity to drive fully piloted is already available today (Hamers, 2016). The technical challenges are mainly in the assessment of concrete traffic situations. Driving in urban settings confronts the system with many unpredictable and difficult to interpret situations. For example, how does the system correctly interpret when another road user makes use of the flash light. According to a given situation it could have different meanings such as warning the driver of a coming dangerous spot or as an indication to give way. Furthermore, the system has to interpret and identify approaching objects in the driving environment under all possible environmental conditions. Even though these systems are working already on a stable level, it is important for a compelling piloted driving experience that the system can cope with every possible situation. In order to be accepted, the fully autonomous system has to prove that it is much better than the human driver because in general, the society is way more tolerant of human errors than of technical errors. (Reese, 2015).

Ethical Issues

Even though fully autonomous vehicles will decrease the accident likelihood and improve road safety, accidents may be unavoidable as a matter of physics (Fraichard, 2014). Especially in the complex and dynamic urban driving environment it is likely that collisions occur. Even if the risk is low, technological errors, misaligned sensors and bad weather conditions could also lead to accidents of fully piloted cars.

However, when fully piloted vehicles are involved in an accident, ethical questions arise (Goodall, 2014). How does the system behave in the case of an unavoidable accident? How does the algorithm of system decide between life and death? Should the system

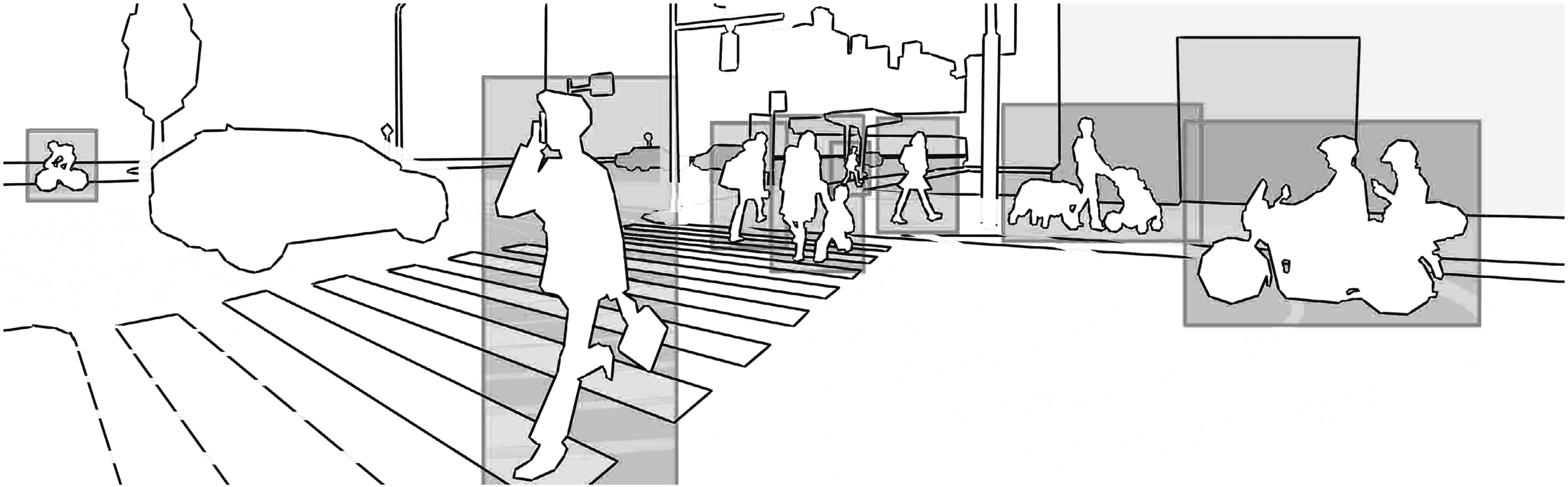


Figure 11: Piloted Drivng Technology Challenge

take the wellbeing of the passengers or of other road users into account? Who will be held liable in case of an accident? The challenge for car manufacturers is to think through ethical dilemmas and set the right expectations with users and the public in general. No matter which answer the automotive industry and politics will decide on, it will not be pleasant for everyone.

User Acceptance

As discussed earlier, the implementation of autonomous driving offers various benefits for the individual passenger. However, with the introduction of piloted driving, the driver has to trust his life to a machine. Therefore, one of the most important factors in the human-car relationship will be trust that the driver places in his/her autonomous car (Waytz, Heafner, & Epley, 2014). In fact, the feeling of trust will have a major impact on the acceptance of autonomous driving and is an important factor in the judgment of autonomous systems (Garcia, Kreutzer, Badillo-Urquiola, & Mouloua, 2015).

According to BMW board director Peter Schwarzenbauer, psychological barriers are now bigger obstacles to driverless technology than legal ones: "I don't think regulation, insurance and those kinds of barriers will hold back this kind of technology. But how do we give humans this safe feeling when they are being driven around by a robot?" (Fairs, 2017).

A survey by Schmidt (2016) showed that 50% of the participants could not imagine sitting in an autonomous driving car. Another survey revealed that 22% of the participants are even afraid of driving in a fully autonomous car (Schoettle & Sivak, 2014). Finally, a survey by Kyriakidis et al. (2015) indicated that 65% of their participants were afraid of the reliability of piloted cars. Introducing fully piloted driving requires considering the various ways people look at human-machine performance. In general, people tolerate human errors much more than errors made by machines. Different studies show that once a user questions the benefits or has doubts about a technology, there is a tendency to avoid it (Reimer, 2014; Frey & Frank, 2001). Without a trustful user experience, the driver feels unpleasant and might abandon the piloted driving function. Therefore, people, not technology are responsible for a successful adaption and use of piloted cars. For Audi it will be important to focus, next to the product aesthetics and qualities, more on the interior user experience in order to evoke a feeling of trust.

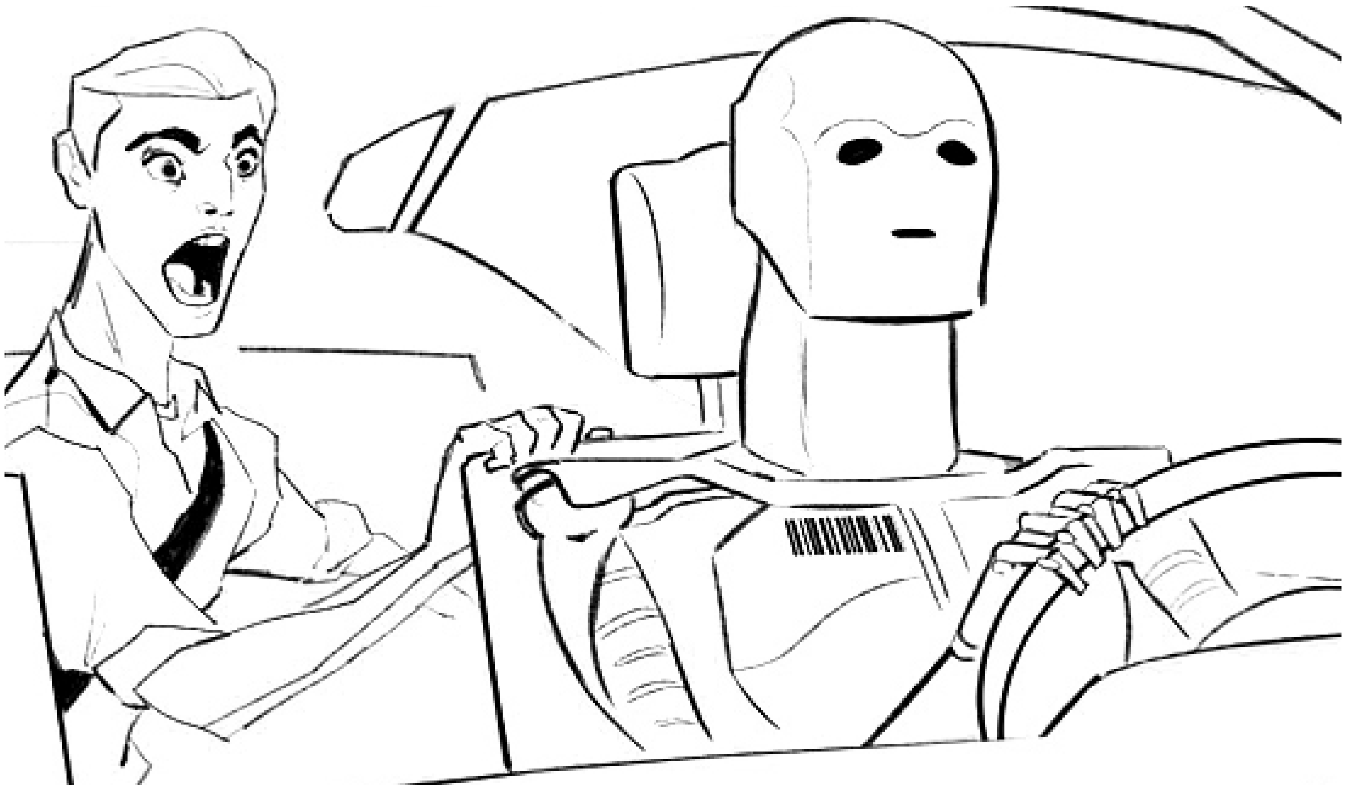


Figure 12: User Acceptance Piloted Driving

2.2.6 PiLOTED DRIVING CONCLUSION

In order to define a design opportunity for the development of the AI Companion, first of all the topic of piloted driving was analysed. Fully piloted driving can be expected between 2025 and 2030. Due to the fact that the next generation vehicles for 2020 to 2023 are currently under development, the selected target year for this thesis is 2030 in order to create a visionary input for the subsequent fully autonomous vehicle generation of Audi.

As discussed in this chapter, piloted driving offers a number of key benefits regarding individual mobility such as improving safety, reducing emissions, improving congestion and generating more free time for the occupants. Current autonomous concept cars show that the trends regarding piloted driving include adaptive and flexible interior layouts with rotating seats, foldaway steering wheels and large display areas.

However, an important design challenge that has barely been addressed until now in any concept car is the feeling of trust when driving piloted. Several studies indicate that people are interested in the topic of autonomous driving but are afraid of it. Without a trustful experience, the occupants feel unpleasant and might abandon the piloted driving function. Therefore, it can be concluded that a main function of the AI Companion is to evoke the feeling of trust when driving fully autonomous.

2.3 TRUST IN AUTOMATION

The feeling of trust is a major factor that contributes to the acceptance of piloted driving, as discussed in the last paragraph. However, up to today the topic of trust in fully autonomous cars has not been actively addressed in any future concept study. A reason for that might be the difficulty of predicting if or to what extent people will entrust their life e.g. in an emergency situation to an autonomous driving car (Grunwald, 2015). Due to the fact that the feeling of trust will be an important part of this thesis, it is analysed in this part of the report how it can be evoked in the context of a fully autonomous car.

The section about trust is divided into three subsections: Fundamentals, Issues and Factors. In 2.2.1 Fundamentals, the concept of trust will be defined and the fundamentals of trust formation will be presented. Subsection 2.2.2 Issues will introduce the problems and issues connected to trust in automation, and in the subsection 2.2.3 Factors, the most important trust factors will be presented that help to evoke the feeling of trust.

2.3.1 FUNDAMENTALS

Here the fundamentals of trust, both interpersonal and human-to-automation, will be introduced to lay a foundation for the rest of the thesis. It contains a definition, a description how a belief turns into behaviour, aspects of trust and how trust arises.

Definition

When people are not familiar with and do not know much about new technologies trust is an important factor when it comes to acceptance of the new technology. There are several definitions of the phenomenon of trust because it can be analysed by different specializations. Disciplines like sociology, psychology, philosophy, economics or human factors give definitions of the concept of trust in different ways however with substantive overlaps (Mcknight & Chervany, 2000). Definitions of trust often refer to interacting parties, where the chance that the trusted party, the trustee, will perform a certain task is so high that the trust giver, the trustor, is willing to interact with the trustee (Fishmana & Khanna, 1998). An often-quoted definition comes from Rousseau et al. (1998) who define trust as a psychological state that includes “the intention to accept vulnerability based upon positive expectations of the intentions or behaviour of another”. According to Muir (1994) human-automation trust is comparable to interpersonal trust. In this context Moray and Inagaki (1999) define trust as “an attitude which includes the belief that the collaborator will perform as expected, and can, within the limits of its designers’ intentions, be relied on to achieve the design goals“. In the context of automated systems, also trust in the parties who are responsible for the new system plays an important role. It has been found that the more user trust those that are responsible for new systems, the greater the probability of acceptance (Montijn-Dorgelo & Midden (2008).

In conclusion, it can be stated that there are many ways to define trust and there are overlaps with belief, attitude, intention and behaviour. It also becomes clear that well-known companies with good reputations have a good chance to rather convince people of piloted driving cars.

From a Belief to a Behaviour

The various ways of defining trust show that there is a need of clear distinction. Ajzen and Fishbein (1980) and Lee and See (2004) give a framework for distinguishing these trust definitions and help to explain the influence of trust on reliance. Ajzen and Fishbein (1980) define four steps how a belief can turn into behaviour: it begins with a belief that forms an attitude. This attitude leads to an intention, which in turn can result in behaviour.

Beliefs represent the information and the user's experience about the system. They determine attitudes that are affective evaluations of beliefs, which guide users to adopt a certain intention to rely on the agent. Intentions turn into behaviour according to the environmental and cognitive constraints a person faces.
The framework makes clear that trust affects reliance as an attitude and reliance is equated with behaviour.

Aspects of Trust

There can be identified several similarities in the concepts of trust about interpersonal trust and trust between human and automation. In the following paragraph it will be highlighted, which aspects have an impact on the feeling of trust in order to define how a feeling of trust can be constituted between a user and automated systems.

The feeling of trust is mainly influenced by three factors: a person who trusts, the system that the person should give trust and a certain situation (Hoff & Bashir, 2014).
The first factor, the person who trusts, contains the propensity of a person to trust an automated system. This depends on a variety of factors such as gender, age, opinions, knowledge, and character traits. Hoff and Bashir (2014) describe this as dispositional trust and point out that this factor is quite stable over time because personality traits have the tendency to remain constant.

The personality factor includes several sub factors that have an impact on the intention to trust. One important sub factor is the person's locus of control (Helldin, et al. 2013). It describes a person's tendency to blame external or internal factors at certain events and might have an effect upon performance (Stanton & Young, 1998). The locus of control can bee seen as a predictor with regard to peoples' tendency to blame themselves or to blame automation depending on their perception of an overall controlling of the vehicle or not. If a person has the tendency to believe that his or her own activities are responsible for the behaviour of the car, it can be stated that this person has a high internal locus of control. On the other hand, if a person attributes the automated system for the behaviour of the car, one speaks of a high external locus of control. Studies also suggest that people with an external locus of control take a more passive role in the automated system, whereas a person with an internal locus of control might be in a more active role. The likelihood that people failed to intervene when the automated system failed was higher when the people had a high external locus of control. People with a high internal locus of control (active drivers) were able to take control of the situation.

Regarding the second factor it can be summarized that the feeling of trust in an automated system can be seen as a dynamic construct that is influenced by the experience that the user makes regarding its functionality and performance. Hoff and Bashir (2014) describe it as learned trust. The feeling of trust in an automated system is influenced by its integrity, benevolence, and skillfullness (Hoff & Bashir, 2014). These components can be perceived differently from one individual to another and therefore depend on the perception of the circumstances. The more frequently a system is used, the more experiences about the functionality and performance of the system are collected. This has an impact on trust towards the system, because the feeling of trust can become stronger or weaker, which emphasizes the dynamics in the construct of trust. Hoff and Bashir (2014) also state that learned trust can be divided into initial and dynamic learned trust. Initial learned trust means the pre-existing knowledge before the user interacts with the system and dynamic learned trust means trust that arises during the interaction.
In conclusion, the more a user interacts with the system, the more experiences he or she gains, what on the other hand affects the level of trust using the system.

The third factor, namely the situation, includes the circumstances under which the feeling of trust should be evoked and it implies the perception of the underlying risk of the situation, which can be perceived as threat (Hoff & Bashir, 2014). This factor cannot be seen as stable because it depends on the external as well as the internal environment that can rapidly change. According to Lee and See (2004), external factors are the complexity of the system, its benefits and risks, the user's workload and the organizational context like a positive or negative reputation, and formal or informal roles before the driver had direct contact with the system. Internal factors contain mood, know-how of the subject, self-confidence and attention capacity.

It can be concluded that the aspects of trust are variable because they depend on factors like persons, systems and situations, which have the tendency to change and are therefore difficult to predict.

Trust Formation

In literature there are several models describing the development of trust in automation. In this thesis it is chosen for the model of Muir's (1994) "Two Dimensional Framework for the Study of Trust in Automation" because it represents a qualitative model of trust in automation that includes the relation between automation, the user's trust and predictions about the behaviour of the automated system. In order to study trust in human-machine relationship Muir adapted existing theories and models of trust from Barber (1983) and Rempel, Holmes and Zanna (1985) and developed the two-dimensional framework.

The first dimension represents three human expectations: persistence, technical competency, and fiduciary responsibility. According to Barber (1983) these expectations constitute the basis for developing trust between human and automation.

The second dimension represents the dynamic nature of trust relationship based on Rempel et al. (1985). Muir (1994) states that trust changes because of interactions between the user and the automated system. In the beginning of a relationship, we often base our trust on the predictability or consistency of the automation's behaviour. The more experience the user gains with the automated system, the nature of trust changes and becomes based upon the user's attribution of dependability. Extended experience of the user, which particularly includes risk-involving experiences, leads to generalizations from the specific behaviours of the automated system to a greater set of attributions about the nature of automation. The final and highest level of trust development is faith. It occurs when the user is able to project beyond the observable to a broader attribution about the user's belief in the future dependability of the system.

2.3.2 TRUST ISSUES

In the following paragraph there are the main issues of human factors highlighted that play a major role for designing automated systems.

The main problems about trust in automation are documented in studies about Human Factors and are summarized as "Out-of-The-Loop-unfamilarity" (Endsley & Kiris, 1995). The negative consequences can be summarized into three main aspects: over- or under reliance in automation (Madhavan & Wiegmann, 2007), loss of manual and cognitive skills (Onnasch, Wickens, Li & Manzey, 2013) and problems to maintain an adequate situation and system awareness (Endsley, 2006). If the user shows an inadequate reliance in automation he might not monitor or use the automated systems adequately anymore. If people perform a certain task fairly well but do not continue to perform the task they lose these specific skills.

The consequences of losing manual and cognitive skills only occur when the user is forced to take over an automated function. In a worst case, the motor and cognitive skills would not work effectively anymore. A reason for that could be missing mental models (Endsley, Bolte & Jones, 2003). Therefore, users should at least be able to know the point at which they would have to take over from the system and how to do that (Toffetti, et al., 2009).
If the user loses situation awareness it becomes problematic if the system suddenly malfunctions, which forces the driver to take over the control again (Parasuraman, Sheridan & Wickens, 2008). In such an unpredictable situation the user suddenly needs to understand what is happening and should be able to manually operate the vehicle.

The accuracy of the operator's perception of the system's competence has to be improved in order to reach an optimal level of trust, (Muir & Moray, 1996). According to Merrit and Ilgen (2008) the optimal level of trust correctly reflects the automation's actual competence level. This can be achieved by making sure that the operator gets an adequate picture of the system with regard to its functioning and its purpose.

In other words, it will be a design challenge to make sure that the user understands the automated system and how it makes its decisions. If the user does not fully understand the system, he might distrust or reject the system or is not aware of the system's limitations (Hoff & Bashir, 2014). If he fully understands the system he won't doubt the systems abilities.

In order to understand the system it has to be clear what the system's intention is. The automated system has to give accurate feedback and information to the user. Trust can be increased when the user has an increased feeling of control by being able to predict the system's behaviour (Verberne, et al. 2012). This is comparable to trust between human. If the performance of the system does not match the intended purpose the user can lose his trust in the system (Lee & See, 2004).

2.3.3 TRUST FACTORS

It is important to understand how best to develop trust in automation. In the automation literature several factors can be identified that determine trust in automation and that could counteract the issues with trust. These factors could be helpful in order to achieve an adequate level of trust in automation. In this thesis three important factors are chosen and will be analysed in detail: anthropomorphism, information about next driving manoeuvres and feedback.

Anthropomorphism

In the automotive context trust should be evoked in a more interpersonal way because the system cannot demonstrate its competence in extreme situations (von Bülow, 2015). Therefore, it is quite difficult to create trust in piloted driving by only understanding the system or relying on positive past experiences.

As already argued it is important to improve trust in automation so that the user's acceptance of the automated system will increase. Lee and Moray (1992) suggest that trust in automation can be improved by the use of an agent that creates an emotional bond between occupant and autonomous vehicle. According to McKnight and Chervany (2001), trust in automation can be increased by anthropomorphism, which is a high level of usability, a polite communication and transparent system actions. In general, the term anthropomorphism describes the attribution of human-like features to objects and animals (Waytz, Cacioppo & Epley, 2010). It can be related to the appearance or the nature of an object. People can understand objects by attributing pre-existing knowledge and structures to the automated system. This helps them to comprehend the system and leads to an emotional relation between the human and the system (Epley, Waytz & Cacioppo, 2007). A recent study has shown that piloted vehicles are given greater confidence when they have a name, a voice and a gender. The vehicle in the study got the name IRIS and a female voice that informed the participants about the functioning of the system.

Further findings by Waytz et a. (2014) indicate that anthropomorphism leads to increased trust in fully automated driving because anthropomorphic features seem to be more competent. More precisely, if the autonomous system has human features like a voice and also a personality the chance for trust into the system increases. According to Hoff and Bashir (2014) the human voice should be perceived as patient and without interruption in order to increase trust. Furthermore they state that also human attributes like politeness and anthropomorphic features such as eye shape, its movements and chin shape influence trust in automation.

On the one hand, fully piloted cars break with regard to control with all historical rituals, on the other hand, they are almost predesignated to increase the anthropomorphisation of the automobile. Already today, we treat cars as living beings without finding it weird. A tame but humanized autonomous vehicle could even give the automobile something magical back that is lost with the mass motorization. Another important aspect that should be considered is that piloted driving has to address the needs of various user groups. Although early adopters may like technical visualizations of the system's action, less technological versed users should be convinced to trust piloted vehicles in a more understandable and predictable way without being obtrusive.

Information

In order to develop trust in automated systems it is also important to provide information and knowledge about what the system does in a certain situation. Additionally, it is important that the user comprehends the given information correctly (Adams, Bruyn & Houde, 2003). It is not necessarily that the user brings the information given by the system to bear correctly. Therefore it is important to provide the information in a way that the user is able to understand, interpret and integrate it properly. Consistent information about the system's or the agent's actions also forms an important factor for the user to give trust (Muir 1994). It ensures that he or she gets the feeling of understanding and being able to predict the system's actions.

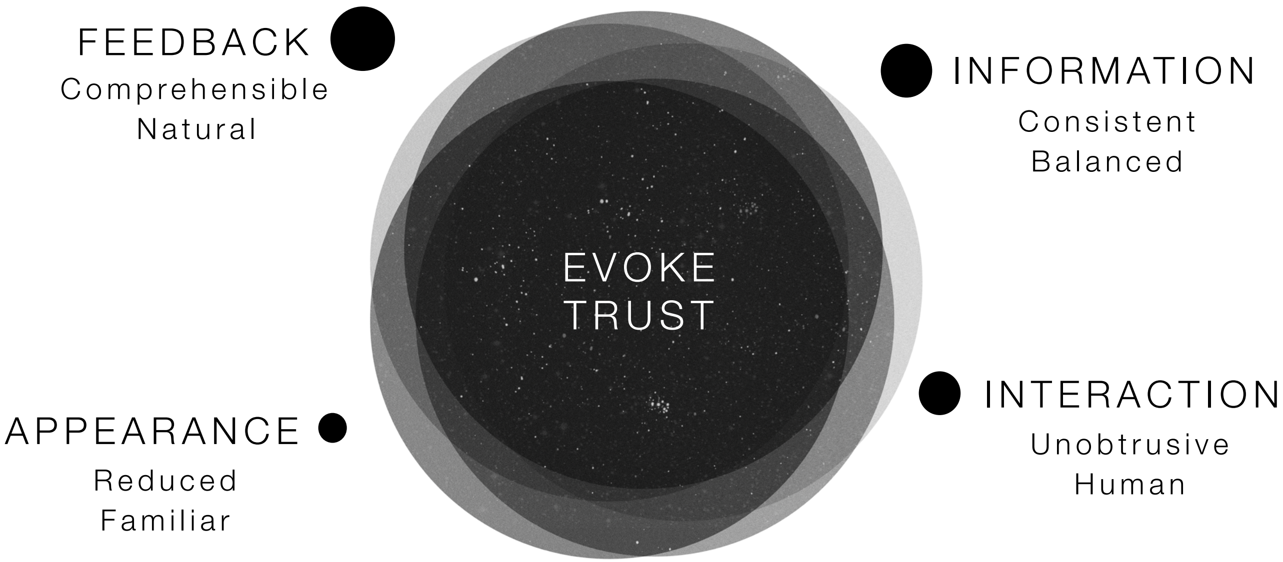
Verberne, Ham and Midden (2012) found that providing information to the user is mainly necessary in the beginning of the system use. More precisely when the

user gathers the first experiences, skills and knowledge about the system. The more experience the user has, the less relevant the information provided becomes in order to keep a proper level of trust.
Nevertheless, it should be ensured that the user has the choice whether to receive information from the system or not because this leads to a greater feeling of control and finally to a higher level of trust.
The same applies for error information. If the system makes an error this could appear untrustworthy to the user. But when he understands the error information the level of trust could increase (Hoff & Bashir, 2014). This is also especially important in the beginning of the interaction with the system (Stanton & Young, 2000).
Studies have also revealed that it is important that the automated system provides uncertainty information in order to increase the user's trust (Helldin et al., 2013). The information about uncertainty should not only be presented through interfaces that only soften up their colours but also through a certain sound or haptic cue. According to Beller, Heesen and Vollrath (2013) only showing factors that influence the problematic situation is not practicable in complex situations including uncertainty. They suggest designing a general warning that presents uncertainty information.

Feedback

Feedback is another important factor to increase trust. According to Normann (1989) people are out of the loop without adequate feedback. This is because they do not know if their requests have been received, if the actions are performed properly, or if problems are occurring.

Feedback can be best processed if it is presented multimodal and stimulates different senses. This is because perception is multimodal, which means that sensory information is perceived through various senses at once (Gibson, 1966; Stein & Meredith, 1993). Furthermore, a combined feedback has the advantage that additional information can be received, which is unavailable for a single modality.
Today mainly acoustic and visual feedback like alarm signals, icons or text messages are used in order to give feedback about the current system state or dangerous situations. In addition to the acoustic and visual feedback, some cars also give haptic feedback in the form of vibrations, forces or discrete signals (Schieben, et al., 2008). Also in driving assistant systems haptic signals like a vibrating seat or steering wheel are used in order to warn and to increase the driver's attention.The challenge in this area is to find a well-balanced way to provide adequate feedback in order to keep the user informed yet not overloaded. The feedback has to be easy to understand so that it does not lead to information overload, channelling of attention or a failure to perceive all relevant information (Billings, 1991).
According to Thill, Nilsson and Hemeren (2014) icons can function as easy and understandable ways of presenting visual feedback because the user can process them faster than written text. In literature it is suggested to use vocal and haptic feedback, in addition to visual feedback (Toffetti, et al., 2009).
Designers should make sure that the acoustic feedback is consisting of a speaking voice and not



only an acoustic signal like a beep. If that is followed, vocal feedback is especially effective regarding reaction time, safety, understanding and distraction. In addition to that users should be able to make changes with regard to the accents because if the accent resembles one's own accent the level of trust can be heightened (Waytz, et al., 2014).
Also an adequate timing of the feedback is important because if it occurs on a wrong time the user might distrust the automated system and in the worst case switch it off (Saffarian, et al., 2012). An adequate and timely correct feedback is important in the beginning of the system use, too, because it then increases trust (Verberne, Ham & Midden, 2012). According to Norman (1990) an automated system should be able to communicate to the user up to the minute about its operation.

Another important factor is the continuity of the feedback. The user should be regularly informed which should further keep him in the loop. That means changes in the system capability should not suddenly surprise the driver. It helps to keep the user in the loop so that he is able to react in case of an emergency situation (Toffetti, et al., 2009). A continuous feedback also leads to an increased feeling of trust because it gives the user information about the predictability of the system.

It becomes clear that also the way the automated system gives feedback will become a hard design challenge because various user might prefer different kinds of feedback, which underlines to use multimodal feedback in autonomous driving cars.

2.3.4 TRUST SCENARIO ANALYSIS

According to the previous analysis about trust in automation it is important that the AI Companion provides feedback in certain driving situations to evoke the feeling of trust. For a better understanding in which situations people mistrust piloted vehicles and therefore have the need for additional driving related feedback, a survey was conducted. In the survey, 30 participants (17 M, 14 F; Age 17-78) were asked to name the three situations in which they would mistrust a piloted vehicle most. It must be noted that none of the participants ever drove in a fully autonomous car. The results could be different if the participants would already have experienced driving fully piloted.

The results of the survey show that there is a wide range of different driving situations in which the participants mistrust a piloted driving vehicle, as shown in figure 13. However, it is striking that there are four situations that were named by most of the participants:

- Construction Area Highway
- Sudden Obstacle (Cyclist, Pedestrian, Animal)
- Lange Change Manoeuvre
- Bad View (Rain, Fog, Night)

Based on the results it can be stated that those four situations are critical to evoke the feeling of trust when driving piloted. Due to the limited scope of this thesis, only the four most mentioned driving scenarios are further considered. In order to gain more insights

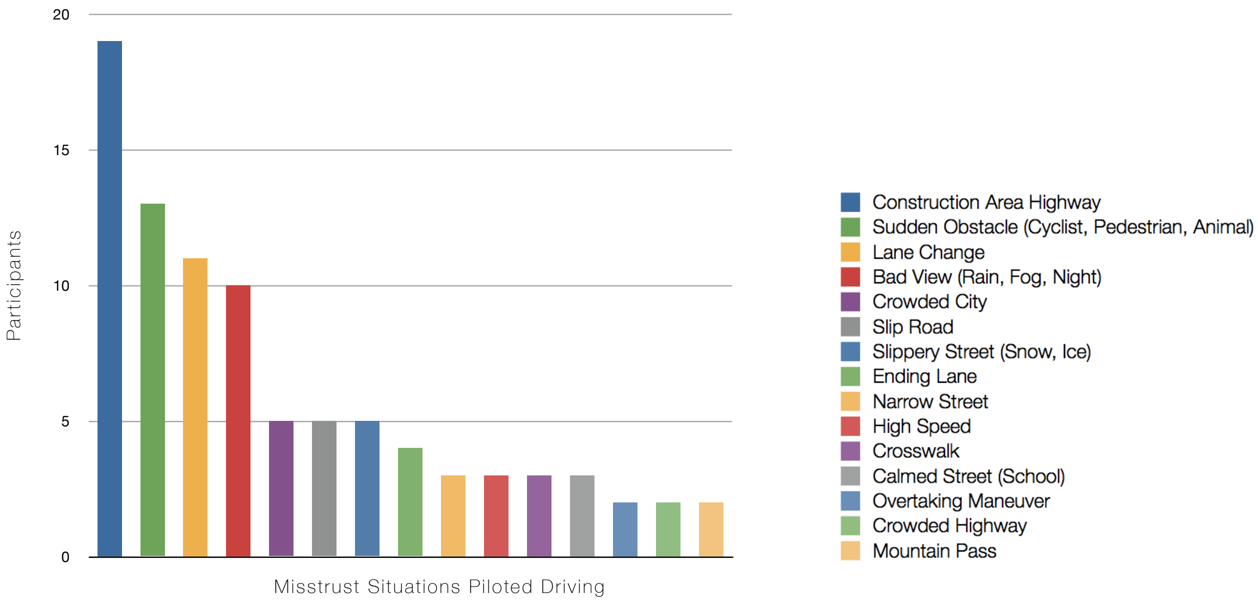


Figure 13: Misstrust Situations

about the desired user needs in the selected scenarios, a subsequent interview session with ten participants was done. The aim of the interviews was to find out, which kind of information users require from the AI Companion in order to increase the level of trust. Additionally, the participants were asked which sensory channel they would prefer to receive the required information or to transfer their intentions to the AI Companion.

Construction Area Highway

In the construction area scenario nine out of ten participants named that they would like to have a visual or haptic feedback about the vehicles next driving manoeuvre. In this context, it is important for the AI Companion to give the passengers the sense that they are aware of the vehicle's intention. Additionally, all participants expressed the wish to tell the AI Companion "how" to drive within their comfort zone in this scenario. Even if the vehicle estimated the driving manoeuvre as safe, such as an overtaking manoeuvre next to a semi-trailer truck, people require the option to communicate with the vehicle in order to chose to wait until the road widens again. In this situation, the participants prefer either verbal or haptic communication with the AI Companion.

Sudden Obstacle (Cyclist, Pedestrian)

To evoke the feeling of trust in case of a sudden obstacle in front of a piloted driving car, the interviews showed that people require a feedback that the object has been detected by the system. According to the participants, a visual feedback is preferable in this situation. Another interesting aspect that was mentioned by one person was the desire that the AI Companion should also communicate with the outside world in order to control the situation.

Lane Change Highway

Regarding the lane change scenario, there was a divided opinion among the interviewee about system feedback. More than half of the participants explained that they would prefer a subtle visual or haptic feedback short before a lane change manoeuvre. Furthermore, a visual or haptic differentiation between the intention of a lane change and the execution was required. It was also noted that there should be the possibility to deactivate the function in order to avoid information overflow. On the other side, three participants had no need for additional system feedback regarding lane change manoeuvres.

Bad View (Heavy Rain, Fog)

In the case of a bad view caused by heavy rain or fog, all participants expressed that they would like to tell the AI Companion how fast the car should drive. Even though the vehicle has the situation perfectly under control, people expressed their need to communicate the desired driving style in order to feel comfortable. Compared to the construction area scenario, the participants explained that they would either tell the piloted car verbally how fast it should drive or via a tactile input medium.

Figure 14: Driving Situations

2.4 FUTURE CONTEXT 2030

In a timespan of 13 years a lot of things can change. A look back at 2002 shows how much the world can develop in just a decade. Back then, only 12 percent of people owned a mobile phone. Today, more than 60 percent do. Facebook, which today has almost 1.5 billion users, did not exist. These and other developments have changed how consumers live, think, and perceive their environment.

Since the year 2030 is the selected target year for this thesis project, an understanding of the context, in which the AI Companion will be placed, is necessary. What are the main developments and factors that are going to influence how people live in the future? The description of the future context is separated into two main parts. First of all, emerging trends are analysed in order to get a better insight how people might live in the future. In the second part, the context will be analysed from a more critical point of view by means of the Vision in Product Design (VIP) approach.

2.4.1 EMERGING TRENDS 2030

In this section a brief overview is given about the most important emerging trends that could influence the way of living in 2030. The trends are subdivided in technology, mobility and society trends in order to generate a holistic picture of the future world.

2.4.1.1 Technology 2030

Artificial Intelligence and Machine Learning

One of the main technology trend that will influence the way people work, live and relate to each another in 2030 is artificial intelligence (AI) (Stone & et. al.,

Figure 15: Future Context 2030

2016). From SIRI to self-driving cars, AI is already making rapid progress today. In general, AI describes computer systems that perform tasks traditionally requiring human intelligence and perception. Today, AI is implemented in a number of consumer products from Amazon Alexa and Apple's homepod to smart thermostats and robotic vacuums. However, over the next 13 years, it can be expected that the AI technology will outrun human intelligence and will be highly integrated into the daily life from education to entertainment, healthcare to security (Smith & Anderson, 2014). It can be expected that people will have their own personal AI assistants that fully respond to natural language. In 2030 it will be normal for people to engage in natural conversations with machines rather than just give orders. Those personal assistants will support their users by writing emails, booking appointments, performing mental though tasks and even anticipating human needs.

Wearable technology and Augmented Reality

In 2030 smart wearable technology will be widespread in society and become an inevitable part of modern lifestyle (Bajpai, 2016). In the future, information will become more and more pervasive, overlaying information on reality will be the norm for enhanced decision making. With the combination of wearable technologies with augmented reality a screen-less future will become reality as wearable's will become ubiquitous and any flat surface serves as a screen. In general, touch screens will be replaced by high quality surface projection and three-dimensional holograms.

The combination of wearable technologies and augmented reality will make the visualization of data seamless, as centralized data can be accessed on the go. In 2030, augmented reality devices will allow to obtain information in an unobtrusive way at any time and any location.

Personal Robots

Another technology trend that is closely related to AI are personal robots. By 2030, a large amount of households in the developed world will have personal robots (Niggehoff, 2016). These will have the ability to interact with humans on a personal level and take over tasks like housekeeping and butler services. The great advances in speech understanding and image labelling enabled by deep learning will enhance robots' interactions with people in their homes. Interacting with robots on a daily basis will be common in 2030.

2.4.1.2 Mobility 2030

Connected

In 2030 vehicles will be connected to each other and to the corresponding infrastructure (ACEA, 2016). Especially in dense urban environments the connection of vehicles to each other and their connection to traffic lights, congestion warning systems and infrastructure will be an essential part of urban autonomous mobility. This high connectivity will result in more efficiency, increased safety and more overall convenience.

Seamless Experience

Another trend in 2030 is seamless urban mobility (Forum, 2012). City residents will have clean, cheap and flexible ways to get around in the urban environment. The boundaries among private, shared and public transport will become more and more blurred. City residents will no longer rely only on their cars but on a mix of public transport, shared cars, bikes and above all, on real-time data on their smartphones in order to get from A to B in the most convenient way. The multimodal traffic flows will be managed by smart software systems that deliver individual mobility as a service.

Emotional Companion

In the future the vehicle will become an emotional companion that supports the occupants in their daily tasks. The role of the car manufacturer will change from an object to a service provider with an increasing trend towards personalization (Audi Ag, 2016). More than today it will address the personal needs of the human being and will create emotional experiences. Thanks to the power of AI, the vehicle of the future will be able to engage with people in return and will be able to build up a relationship that is meaningful and human.

2.4.1.3 Society 2030

Urbanization and World Population Growth

In the coming years the world population will encounter a rapid increase. It is expected that the population will grow from about 6 billion to 8.5 billion in 2030 (United Nations, UN, 2015). Already today it can be observed that more and more people are moving to cities (Science Daily, 2015). Currently, about 50 percent of the world population is living in urban areas. By 2030 it is expected that about 5 billion people will live in urban centres. Increasing urbanization in combination with a rapid world population growth will have an impending impact on urban traffic volumes as well as on the infrastructure capacity in general. Additionally, the urban mobility demand is expected to grow by 68 percent in the coming 15 years.

Aging Society

The combination of increasing life expectancy and declining birth rates will lead towards an aging society (United Nations, 2015). Worldwide, the median value of the age between 2011 and 2030 will rise from 19 to 34 years. In 2030, Europe will have the oldest population worldwide with a median value of 45 years. The 50+ generation will differ significantly from earlier ones in terms of consumer habits, values and lifestyles. This aging society will introduce new demands on mobility systems to ensure convenience and stay mobile.

Figure 16: Future Trends 2030

2.4.2 THE VIP APPROACH

The described technological, mobility and social trends already give an insight in the world of 2030. In order to analyse the context more deeply and to get insights in people's desires and needs. The Vision in Design (VIP) method, introduced by Hekkert and Van Dijk (2014), is a helpful means to analyse future scenarios. Due to the fact that the scope of this project is very broad, this method is helpful in order to become user and future focused.

Domain

The VIP design process starts with establishing the domain. Hekkert and van Dijk (2014) define the domain as "a description of the area where you want to make a contribution". In this case, the domain is very broad: "Fully autonomous mobility 2030". Being future focused is crucial for designing a product that is relevant for users in the future.

Context Factors

The VIP approach describes a good way to structure information. All relevant findings are summarized in 'factors', which can be 'states', 'principles', 'developments' and 'trends'. These factors describe the future context of the product that is to be designed and can either describe possible changes or principles that stay the same. For this project, more than 60 factors were gathered. All factors can be found in appendix A. The collected factors are clustered and are used to describe the future context. In the scope of this thesis, three out of five clusters have been s elected to create a vision of the world in 2030.

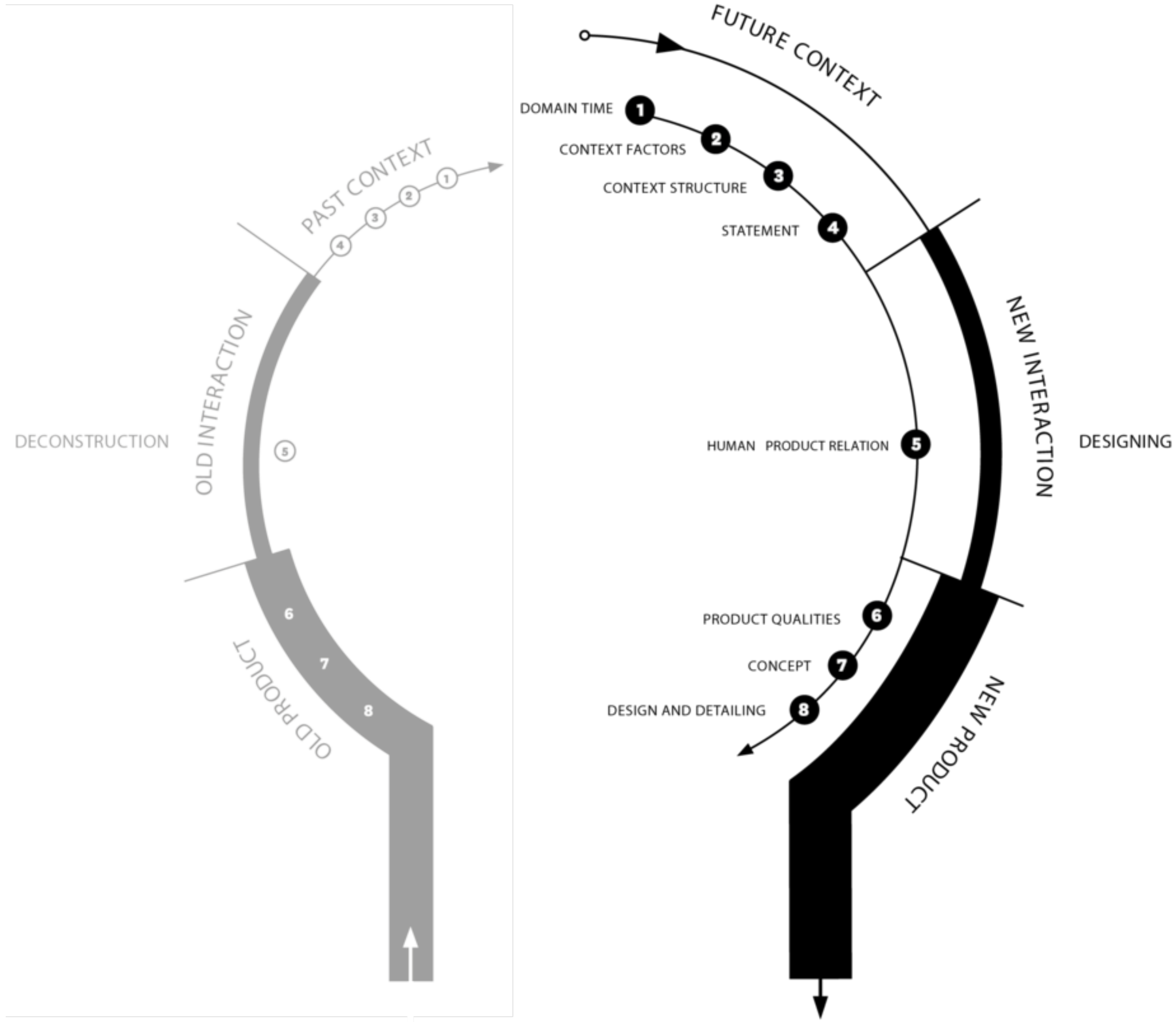


Figure 17: Vision in Product Design

Searching for authenticity

The role technology plays in people's lives is rapidly growing, as they become increasingly dependent and less willing to separate themselves from it. In 2030 information can be accessed from everywhere and in every possible situation. The "real" world gets more and more transformed into a virtual one. In this increasingly fabricated and digital environment people yearn for authenticity. The more high-tech their live becomes the more they value nature and profound, understandable and "real" product experiences.

Losing Control

In 2030, technology will take over more and more tasks that people used to do on their own nowadays. The improvements in automation technology make a lot of jobs redundant and therefore increase the social dependency on technology. People unconsciously hand over more and more daily activities and routines to electronic devices and services. As a result, they become passive observes of their own environment. Due to increasing global problems combined with the rising complexity of technology and amount of information people more and more feel like losing control of their environment.

Optimisation

The combination of smart software and automated technology will increase the everyday efficiency and safety. Seamless mobility and piloted driving will create more time for people to either work or use the saved time to relax and enjoy. Artificial companions will structure people's days in order to be more productive. Improvements in technology will allow people to keep an exact overview of their physical condition at every moment in time. However, in a world where almost everything is arranged and controlled by computer systems, there is no space for unexpected pleasurable experiences. Furthermore, the blurring line between work and private time in combination with the feeling to keep up with the performance-oriented society will create a rising feeling of pressure and stress.

Vision 2030 Summarized

In 2030, life will be increasingly dominated by technology. In this virtual and increasingly fabricated world people will have the desire for authenticity in form of mobility experiences that are profound, understandable and simple. Tactile experiences will be more important than ever to feel the difference between the real and virtual world. As more and more tasks will be taken over by smart computer algorithms people will more often have the feeling of losing control than today. With the introduction of autonomous driving this feeling will even be intensified. Therefore, giving a feeling of being in control of automated systems could be a crucial point in creating positive and valuable user-product experiences in the automotive context. Finally, unexpected pleasurable experiences could lead to positive emotions and feelings in a world that is dominated by efficiency and optimisation.

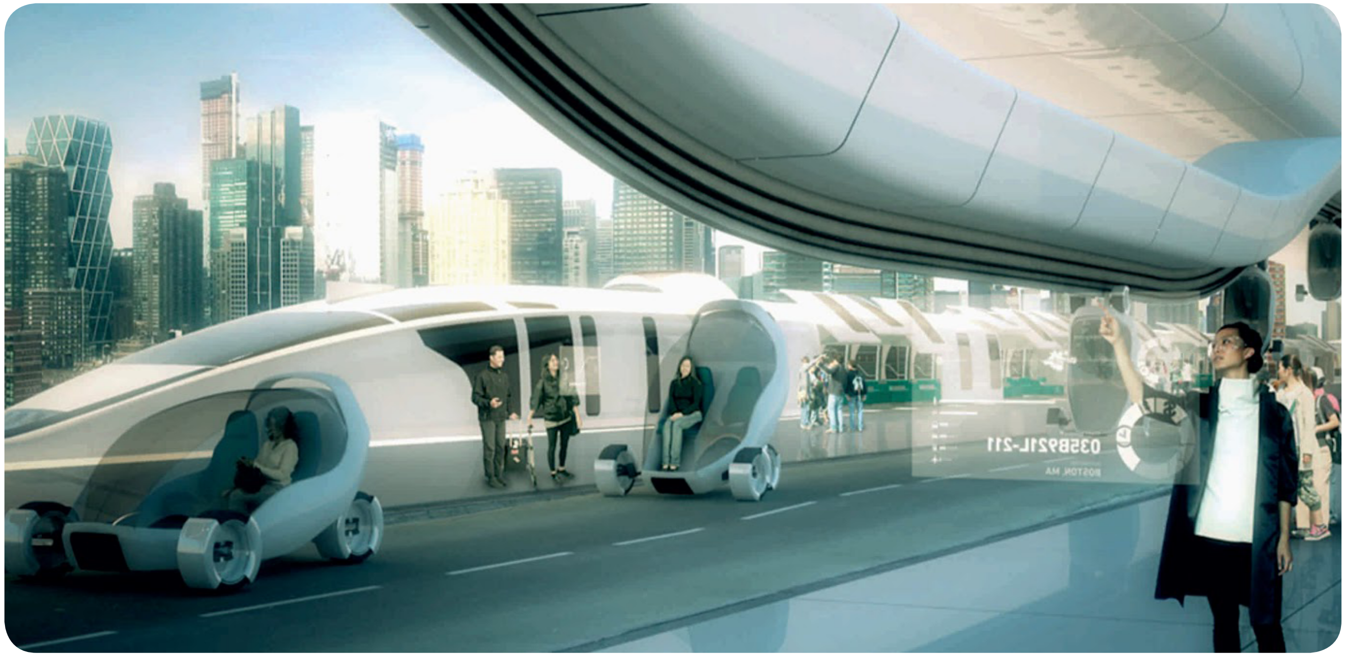


Figure 18: Future Context 2030

2.4.3 DESIGN MISSION

This paragraph represents an important part of the graduation project since it defines the main direction for the subsequent design phase. Due to the fact that the introduction of an AI Companion is a complete new element in the vehicle interior without any reference, the initial assignment definition (the design of an AI Companion for a fully autonomous car) was extremely broad. Based on the gathered information regarding piloted driving and the future context 2030 the assignment is defined in this paragraph in terms of a mission statement.
Summarized it can be stated that the feeling of trust in piloted driving is a main challenge that Audi is facing in the future that has not actively been addressed yet. According to different experts, trust-related problems are the biggest obstacles to driverless technology that need to be solved in the future (Fairs, 2017). Therefore, the main function and the reason of existence of the AI Companion is to evoke the feeling of trust when driving piloted. Trust in the context of piloted driving can mainly be generated by a natural interaction between user and AI Companion, system transparency and situational feedback. On the other hand, the analysis of the future context has shown that giving people a feeling of control in a world that is dominated by smart automated systems is crucial. Therefore, the AI Companion should give the possibility to retain a certain amount of control over the piloted driving car. Finally, the relationship between user and AI Companion should be characterised by authenticity in terms of a profound, tactile and understandable experience. Based on the future context definition and the analysis of autonomous driving the mission statement is formulated.

“Design of an **AI Companion** that evokes the feeling of **trust** by creating a **relationship** that is characterised by **authenticity** and **control.**”

2.4.4 INTERACTION ANALOGY

Before developing what the product is going to be, it needs to be determined how this product is going to be used and experienced. Following the VIP method, the interaction is initially defined with an analogy. This analogy is a situation from another domain, completely different from the project, which captures the desired interaction. In other words, it helps to clarify the qualities of the interaction that is going to be created. Additionally, the interaction is defined with interaction characteristics. These characteristics describe how the relationship between the product and the user is desired to be. The words that will form the interaction serve as supporting framework and describe how the mission statement can be achieved. The result of this is called the 'Interaction Vision'.

Interaction Vision

The chosen analogy that represents the defined mission statement and fits the desired interaction is ***"Using a compass for guidance in an unknown territory"***. This interaction analogy is chosen, since a compass is an object that, no matter in which environment, creates the feeling of being in control of the situation. Compared to electronic devices that could offer the same function, a compass has the huge advantage that it always works and therefore evokes a strong feeling of trust. In other words, a compass might be the first and initial companion that helped people to find their way around the world.

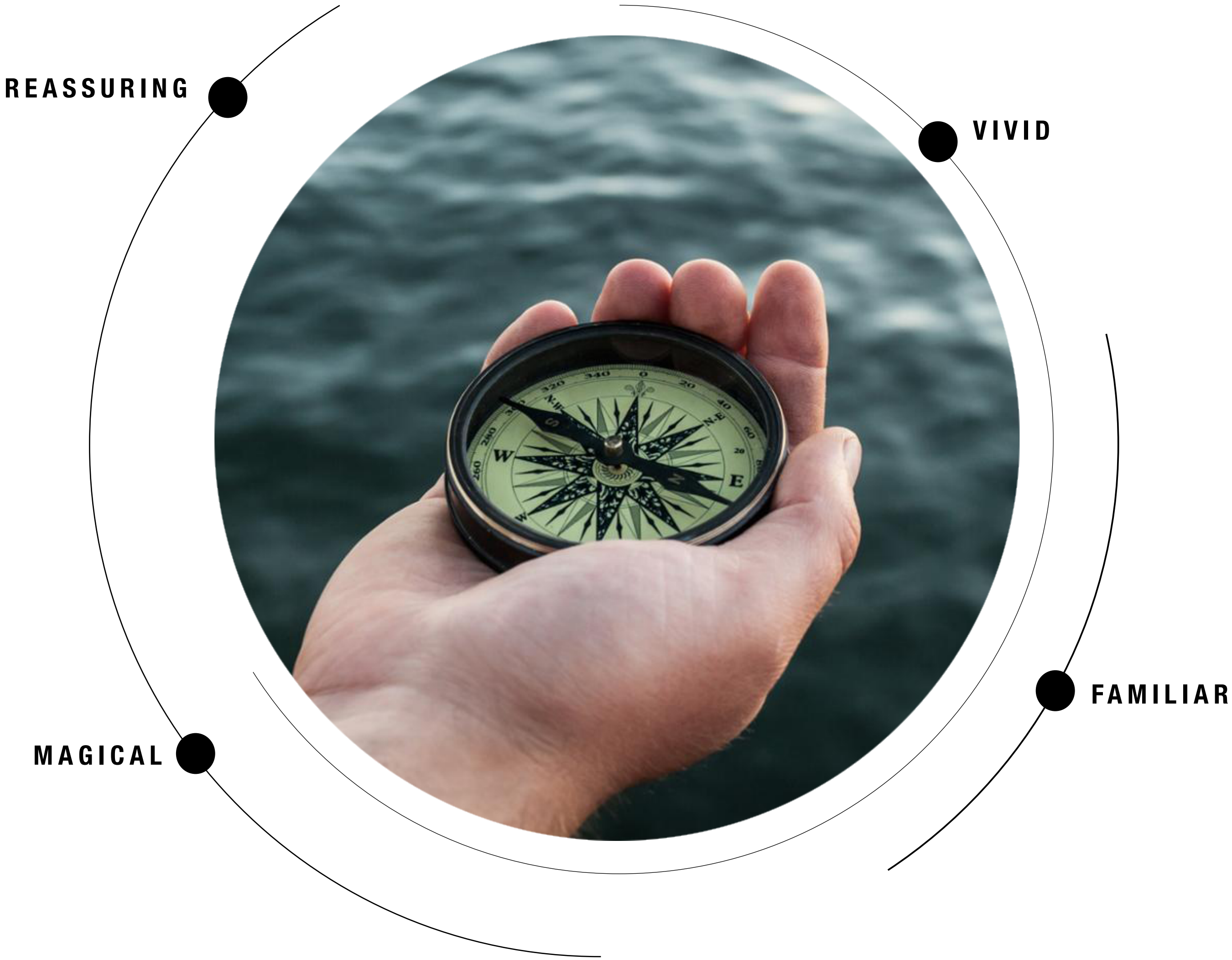


Figure 19: Interaction Analogy

2.4.5 PRODUCT QUALITIES

In order to elicit the desired interaction, the AI Companion has to fulfil certain qualitative characteristics. Those qualities should be similar to the qualitative characteristics of the compass to evoke the desired interaction. The derived product qualities are: ***Vivid, Reassuring, Familiar, and Magical***. Even though the product quality 'magical' is not related to trust, it gives the product a characteristic that makes it interesting to use and interact with it. The derived product qualities are meant to be used during the conceptualisation and materialization phase of the project, as a definition how the product should be like and a guideline for the development. In order to fully understand the defined product qualities each quality is illustrated in form of images of already existing products. The respective interactions are used to clarify the intention.

Vivid

The product quality vivid refers to the response of the AI Companion and the way it triggers the user to interact with it. It also involves that the use can vary between intense interacting and passive background functionality. As shown in the pictures of figure 20, the quality can mainly be evoked by means of a moving structure or object. Another aspect that the AI Companion should cover comes along with the technology that introduces the user to new product experience possibilities through it's capabilities.

Familiar

Within the given context, familiar means that the AI Companion should appear in a way that there is no barrier or fear in using it even without being technical experienced. Even though it introduces new interior functions, its visual appearance should create confidence. Its movements, feeling and shape need to be chosen in a way that they create a feeling of comfort and a desire to interact with it. Like the minimal and reduced round shape of the compass, the AI Companion should be simplified, express timelessness and symbolize the claim of the absolute.

Reassuring

The product quality reassuring is essential for building up a trust relationship between the user and the fully autonomous vehicle. Like the needle of the compass, the AI Companion should create an easy to understand feedback by means of its movement or position in order to inform the occupant and remove his or her doubts and fears. Besides that, it should interact in a way that it puts someone's mind at rest and raise confidence in fully piloted driving.

Magical

Like the magical movement of the compass needle, the interaction with the AI Companion should be designed in a way that it stays interesting and enthuses the user even when it is utilised for a long period of time. Every time the user interacts with the AI Companion it should reengage and stimulate him to think how it works. This could be achieved for example by the way it moves (frictionless), it is attached (floating) or how it knows and addresses the occupant's needs.

Figure 20: Product Qualities

2.5 ANALYSIS CONCLUSION

The analysis part of this thesis identified the most important design opportunities for the development of the AI Companion and is therefore the foundation for the following conceptualisation phase. Within this part, the context for the development of the AI Companion was defined. It was chosen that the AI Companion will be part of a fully piloted vehicle (Level 5) that is able to cope with all possible driving situations on its own without steering wheel and pedals. Based on the expectations of different industry experts regarding the introduction of fully piloted vehicles, the target year of 2030 was selected.

According to the findings of this chapter, it can be stated that piloted driving will introduce a paradigm shift in terms of how vehicles are used and perceived in the future. This shift will challenge Audi not only on a technology level but especially in terms of user experience. Central selling arguments of today like driving pleasure, speed and high performance might lose importance in a world of piloted vehicles. The main challenge that has been identified, is the topic of trust, not the actual safety of the vehicle itself but the subjective feeling of trust due to the fact that people will leave their welfare directly to a technical machine. Therefore, it will become one of the most important points for Audi to create trustworthy environments in which occupants feel safe and comfortable.

By means of a literature study about trust in automation it was found that trust in an automated system can be seen as a dynamic construct that is influenced by the experience that the user makes regarding its functionality and performance. The feeling of trust in an automated system is influenced by its integrity, benevolence, and skillfullness. Moreover, three important factors that help to develop trust in an automated system have been identified, namely, anthropomorphism, information what the system is going to do and adequate, continuous system feedback.

The analysis of the future context 2030 by means of the VIP method revealed that people will have the desire for authenticity in the form of mobility experiences that are profound, understandable and simple. Tactile experiences will be more important than ever to feel the difference between the real and virtual world. As more and more tasks will be taken over by smart computer algorithms people will more often have the feeling of losing control than today. Therefore, giving a feeling of being in control of automated systems could be a crucial point in creating positive and valuable user-product experiences and also the feeling of trust.

The findings about the future context led to the mission statement of **“Designing an AI Companion that evokes the feeling of trust by creating a relationship that is characterised by authenticity and control”**. In the final part, this statement has been transformed into the interaction analogy of **“Using a compass for guidance in an unknown territory”** and the desired product qualities **Vivid, Familiar, Reassuring and Magical**. These qualities are the base for the subsequent idea generation and conceptualisation in the next chapter.

TRUST

AI

“Design of an **AI Companion** that evokes the feeling of **trust** by creating a **relationship** that is characterised by **authenticity** and **control.**”

CHAPTER 3 CONCEPT DEVELOPMENT

This chapter describes the development process from the theoretical findings of the previous part to possible ideas and two concepts for the AI Companion. Thereby, the purpose is to translate the identified product qualities in terms of function, technology and form. In the final part of this chapter, the two concepts are evaluated based on the desired product qualities in order to select the final concept direction for the following detailing and prototyping phase.

3.1 IDEATION

The first part of this paragraph illustrates the methodo logical idea generation process from the initial brainstorm session to the development of two concept ideas. In the second part, the concepts are evaluated and the one with the most potential for the further development is defined.

3.1.1 BRAINSTORM SESSION

In order to define the possible solution space, a brainstorm session was done to diversify and explore possible solution for the design of the AI Companion (see figure 21). The main topics addressed in the session were the potential location of the AI Companion, AI in general, ways to express anthropomorphistic behaviour, how to inform the occupant about upcoming driving manoeuvres, ways of how the user could have a certain control of the vehicle and possibilities for tactile perception. In this phase all possible ideas were collected no matter how good or bad they are. In the following convergence phase, possible solutions were summarized in a morphological chart for a clear overview, as shown in figure 22.

3.1.2 IDEATION OVERVIEW

The morphological chart, presented on the following page, is used as basis for the idea generation. Based on the combination of the solutions for the defined functions, various ideas were generated in an analy tical manner. The blue dots within the chart show, as an example, the systematic approach that is used for combining possible solutions to come up with new

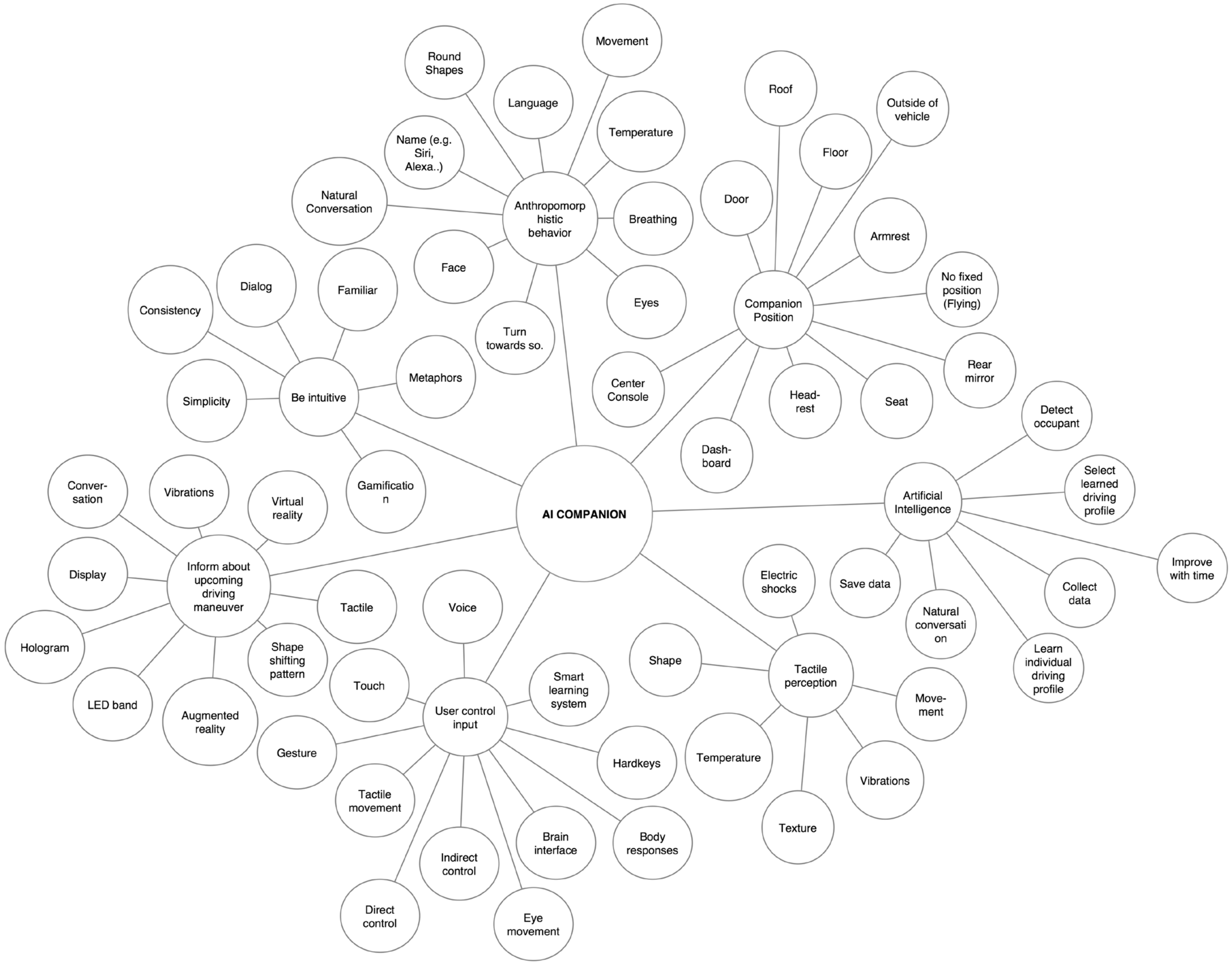


Figure 21: Brainstorm Session

and innovative ideas.
The results of this methodological approach were various ideas of which the most promising ones are illustrated in figure 23. As depicted in the overview, the ideas are clustered in terms of innovation and desired product quality fit. Summarized, the ideas include, among others, a flexible robotic arm with an integrated screen that allows natural conversation between the system and occupants, a kinetic ceiling that informs the user about the upcoming driving manoeuvres with a shape shift, a living eye that responds to the users desires in a humanized manner, a virtual reality bubble that builds up around the occupants head, a robot that informs the user by simple gestures about the movements of the car and a drone that communicates with the occupants. The illustrated ideas have been discussed and evaluated with experts of the Audi Ag. Based on the discussions, the ideas were prioritized as shown in the overview. The two ideas that are on the one hand innovative and that fulfill the desired product qualities best are the "Companion" and the "Ring" idea. Those have been selected for further development and are explained in the next phase in more detail.

Figure 22: Morphological Chart

3.2 CONCEPTUALISATION

In the conceptualisation phase the ideas from the previous phase are further developed into two different concepts. On the following pages the working principles and the appearances of the two concepts are explained by descriptions and illustrations. In the last part of this phase one of the two concepts is selected. To evaluate and to compare their performance, next to the desired product qualities further evaluation criteria are defined.

3.2.1 CONCEPT 1: AI RING

The AI Ring is located centralized in the front of the vehicle interior, replacing the dashboard of today. It represents the main interaction touch point inside the car. Figuratively, the AI Ring aims to create a central humanized focus point all occupants can relate to. The interaction between user and AI Ring takes place via a natural voice dialog instead of an input/output way of communicating as voice control works today. This allows the user to tell the AI Companion where to go and how to drive in order to feel comfortable. Based on the user input and desires, the smart AI Ring learns with time and saves an individual driving mode for each occupant.

The front facing surface of the AI Ring represents a digital eye that responds when talking to the companion in order to create a vivid visual feedback. Additionally, the AI Ring turns towards the occupants when talking to them to evoke a humanized experience.
The shape is selected due to its minimalistic appearance and its advantage of having three possible layers of presenting information in one object. The first layer is the front facing surface that displays the responsive digital eye, the second layer is the inner area that informs about upcoming driving maneuver's and the third area facing to the outside, allows to communicate with pedestrians, cyclists and other road users.

3.2.2 CONCEPT 2: AI Companion

The idea behind the AI Companion concept is to let the occupants of a fully autonomous vehicle feel what the car is doing in a tactile manner. By means of magical, frictionless movements, the Companion translates the upcoming driving maneuvers into a pleasurable tactile feedback. Thereby, the position of the AI Companion mirrors the next actions of the piloted vehicle and creates a comfortable feeling of reassurance.

Next to the tactile feedback, it allows the occupants to express their intention how the car should behave by moving the AI Companion in the respective direction. That allows the user to control the vehicle in an indirect, subtle and non-obtrusive way. By means of the active user input, the smart system learns the desired way of driving and gets smarter with time.

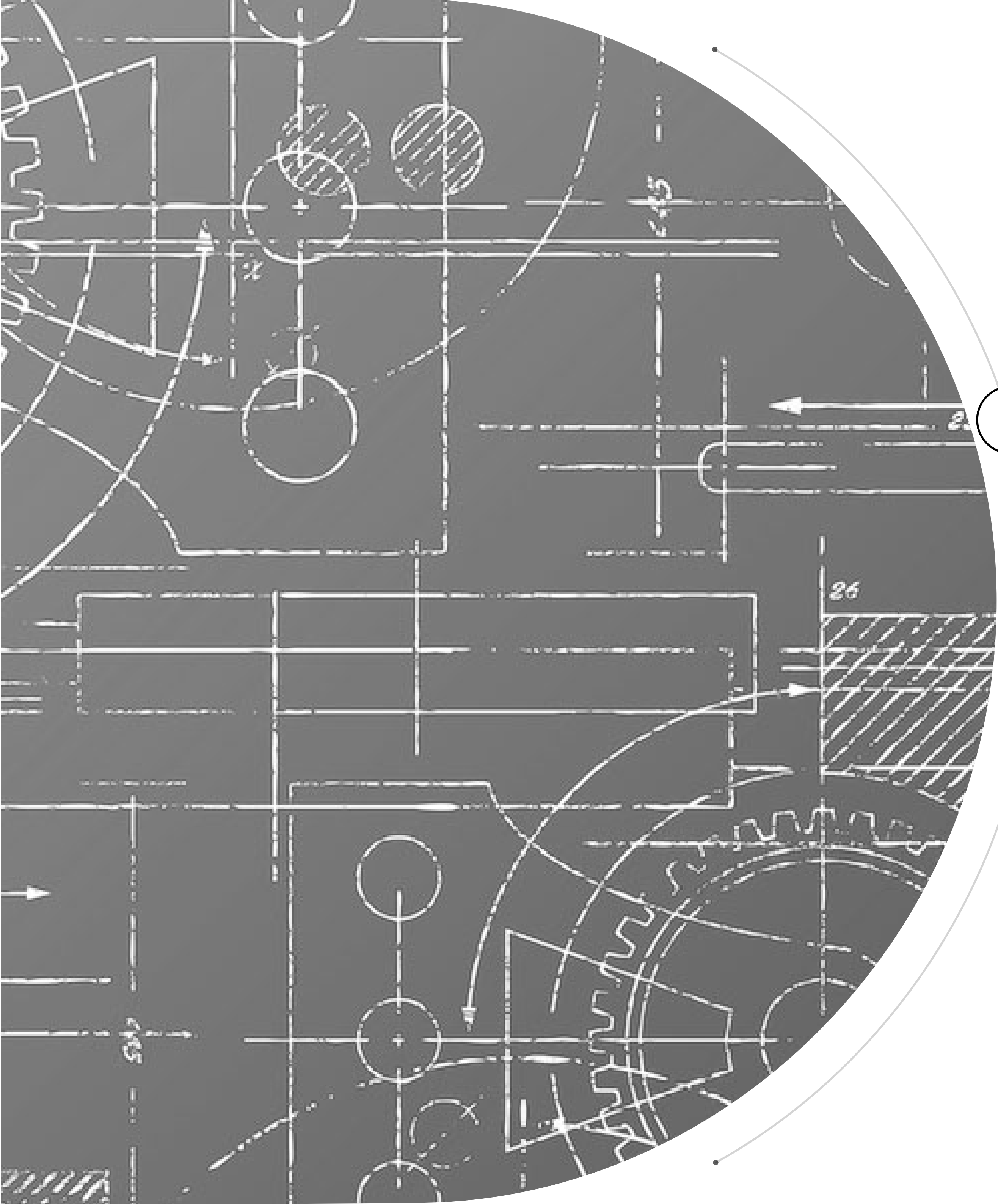
The Companion is integrated in the armrest, as shown in the pictures to allow a comfortable ergonomic handling. The simple and reduced round shape is chosen due to the fact that it feels nice to touch and is familiar for a wide audience. Furthermore, the minimalistic shape makes it unobtrusive when not in use.

3.3 CONCEPT SELECTION

In order to decide which design should be developed into a detailed design, the weighted objective method is used. This method allows comparing the two design concepts based on an overall value per concept. As shown in table 1, next to the defined product qualities, a number of additional criteria is defined. The criteria are of different importance and are therefore weighted with numbers from one (not important) to five (very important). Next to the weighted objective method, the two concepts are evaluated with the Audi experts from the predevelopment and interior design department. Based on the expert feedback and the weighted objective method, it is chosen to develop the AI Companion concept further into a detail design.

Criterion	Weighting (1-5)	AI RING		AI Companion	
		Score	*Score x Weighting*	*Score*	*Score x Weighting*
Product Qualities					
Vivid	5	4	20	5	25
Reassuring	5	3	15	4	20
Familiar	5	4	20	4	20
Magical	5	3	15	5	25
Additional Criteria					
Feedback about upcoming manoeuvres	5	3	15	5	25
User influence on the vehicle's actions	4	3	12	4	16
Capable of being integrated into different interior designs	4	2	8	4	16
Visual presence when not in use	3	1	3	3	9
Complementable with sub-functions	2	4	8	3	6
Feasibility	3	3	9	3	9
Total			**123**		**171**

Table 1: Concept Evaluation and Selection



CHAPTER 4
CONCEPT DETAILING

This chapter describes the detailing of the selected AI Companion concept. First of all, it is further defined in terms of main- and sub-functions. Additionally, requirements for the detail design are defined in order to meet the automotive design standards. Furthermore, this chapter includes the development process of the mechanism design from the first ideas to the final working prototype. The last part describes the aesthetical design development of the AI Companion based on the technical package.

4.1 MAIN & SUBFUNCTIONS

Due to the fact that the AI Companion is a completely new solution with no reference to already existing products in the car interior, in the first detailing step, the main- and sub-functions are defined in order to have a clear overview. In the following part, first of all, the main functions are explained and illustrated. In the second step, it is analysed which additional interior functions of a fully piloted vehicle could be integrated in the concept. A graphical overview of the different functions is presented in figure 23.

4.1.1 MAIN FUNCTIONS

Tactile Manoeuvre Feedback

The tactile manoeuvre feedback function allows the user to feel in a subtle way what the next moves of the vehicle are. As found in the analysis phase, providing feedback in the context of fully piloted vehicles is a necessity to evoke the feeling of trust. Especially in an environment that is dominated by large screens and therefore mostly visual information, as shown by current piloted driving concept studies, tactile feedback has the advantage to reduce the amount of content on the visual channel.

By gentle movements, the AI Companion mirrors the upcoming manoeuvres of the piloted car, as shown in figure 25. A movement to the front means that the vehicle is going to accelerate, a movement to the back lets the user feel that it is going to break, movements to the left or right symbolize an upcoming lane change and a movement to the front-right or front left inform about overtaking manoeuvre.

In order to prevent that the AI Companion moves even when no manoeuvre feedback is required, the

WHY	WHAT	HOW
Feeling of trust by system feedback	Tactile feedback about upcoming driving manoeuvre	Movements mirror next manoeuvre Laying on hand (>3s) activates function
Feeling of trust by control	Indirect user control on vehicle action	User actively moves AI Companion to influence driving behaviour
Handle situations that are unknown to the system (e.g. double parking)	Direct control vehicle movements up to 20 km/h	User activates function via voice input User moves AI Companion to actively manoeuvre vehicle
Increase level of trust and comfort with time	Create individual piloted driving profile based on user inputs	Detect user with biometric hand-scanner and recall generated profile
Large distance between user and screen in front (e.g. Audi Aicon Concept)	Interact with graphical user interface content (e.g. select music, make call etc.)	Integrated multi-touch gesture touchpad surface on top surface of AI Companion
Voice input is an important means of communicating with the vehicle in the future	Activate / deactivate voice control to decide when system is active / passive	Double tap on touchpad surface to activate/ deactivate voice input
Start the vehicle	Start vehicle and detect user to activate learned driving profile	Laying on hand to start vehicle Integrated biometric handscanner detects user

Figure 23: Function Overview

function is activated when the user puts his hand on the Companion more than three seconds. As soon as the hand is pulled back, the AI Companion stops moving.

User Intention on Piloted Driving Behaviour

The "Intention" function allows the user to have a certain indirect control of the way the piloted vehicle is driving. This function is derived from the results of the scenario analysis about trust in piloted driving, in which the participants expressed the desire to have the possibility to tell the vehicle how to drive in certain situations such as an overtaking manoeuvre next to a semi-trailer truck on a narrow lane.

By actively moving the AI Companion in the desired direction the user has an influence on the behaviour of the car and therefore over-controls the decisions of the piloted vehicle. Moving the AI Companion to the front is equivalent to an acceleration of the vehicle, a movement to the back tells the system to drive slower, movements to the left or right side trigger a lane change manoeuvre and moving the AI Companion to the front left or right starts an overtaking manoeuvre.
However, the active user input does not initiate the desired action directly, rather it is an intention of the user's needs and will be realized by the piloted vehicle as soon as the driving situation allows it. In other words, it is an indirect way of telling the car how to drive and it allows the user to stay passively in the driving loop.

Direct Manoeuvring at slow speeds

In contrast to the "Intention" function, the "Direct Manoeuvring" provides the possibility to control the vehicle in an active manner at slow speed up to 20 km/h. When driving slower than 20km/h the function can be activated via a voice command. In order to create a clear feedback that the function is activated, an additional visual or auditory feedback should be provided.

This "Direct Manoeuvring" function allows the occupants to move the car by means of the AI Companion in situations that might otherwise be impossible to handle without a steering wheel or pedals, such as manoeuvring the vehicle on terrain that is not known by the navigation system or parking the car for a short moment in a second row to pick someone up. However, even when the user has more direct control in this mode, the piloted vehicle still supports, regulates and intervenes in case of a possible accident.

Detect User and Create Personal Driving Profile

As the results of the scenario analysis have shown, the expectations regarding the way a piloted driving car should behave, are quite different. In order to match the expectations and create a convenient piloted driving experience, the AI Companion generates a personalized driving profile based on previous user input. Therefore, the system gets smarter with time and adapts itself to the way the individual user prefers to be driven. By means of an integrated biometric handscanner the system identifies the user and activates the created personal driving profile as soon as the hand is placed on the AI Companion.

4.1.2 SUBFUNCTIONS

Next to the defined main functions it is analysed which additional sub functions could be integrated in the AI Companion. Therefore, first of all the interior functions of current vehicles are analysed as shown in figure 24. In the next step, the functions that get obsolete in a fully autonomous vehicle are determined (indicated in grey) in order to have an overview of possible functions that could be integrated in the concept. Due to the fact that one objective of the AI Companion is to design a product that convinces by its simplicity and ease of use it is important not to overload it with too many functions. Based on the list of possible sub functions it is decided that a meaningful integration would be the following:

HMI Touchpad

The round top surface of the AI Companion is equipped with a multi-touch gesture touchpad, comparable to the Apple Magic Trackpad. This allows interacting with the graphical user interface that is located in the front of the vehicle and might not be reached by the occupant, as in the recently presented Audi AICON showcar. In general, the use of a touchpad is a common way of browsing through graphical user interfaces and therefore it should be convenient for a large group of users. The combination of position and size of the round top surface creates a comfortable means to interact with the digital content of the car.

Activate / Deactivate Voice Control

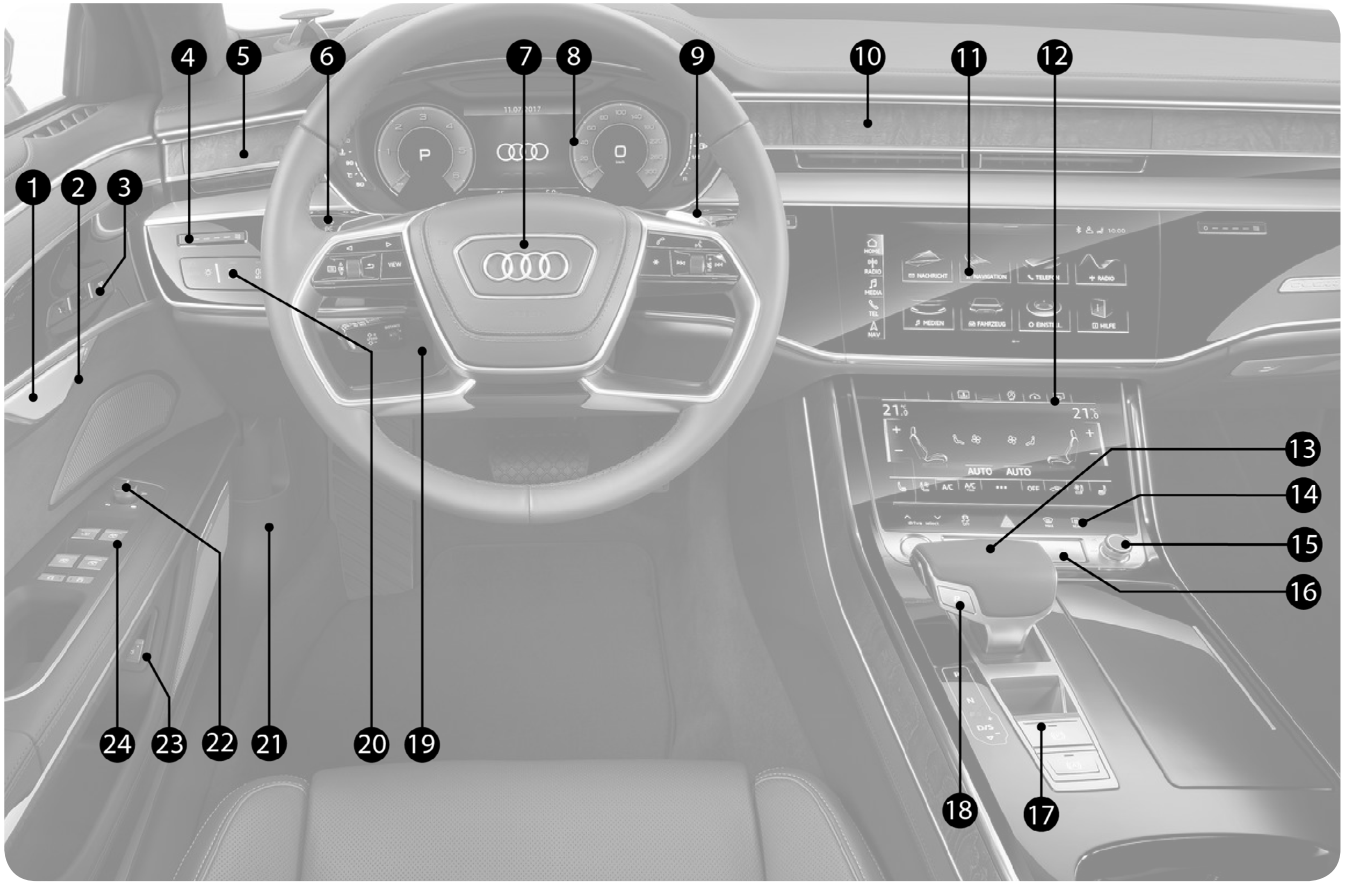
The analysis about concept cars and future technology trends has shown that voice control is an important way of communicating with technology in the future. Therefore, it is chosen to give the user the possibility to activate and deactivate the voice control via the AI Companion. By means of a double tap gesture on the touchpad top surface, the user is able to activate the voice input. According to the analysis about system feedback, the activation should be accompanied by an additional visual or auditory feedback. The deactivation is triggered in the same way by double tapping the touchpad surface. Giving the user the possibility to activate and deactivate the voice control function allows him to decide in which situations the system is listening and when it is not desired.

Start vehicle

The same as vehicles today, it can be estimated that piloted driving cars in the future need to be started when entering the interior. Therefore, it is chosen that the function of starting the vehicle is a meaningful addition to the functions of the AI Companion. Instead of pressing a simple button as in current vehicles, the user can put his hand on the AI Companion in order to awake the vehicle. This has the benefit, that it immediately knows, which person is in the car by means of the integrated biometric handscanner. In that way the AI Companion can select the generated individualised driving profile before the trip begins and it leads to the feeling of a vivid and trustful product experience.

4.1.3 FUNCTION SCOPE

The main and sub functions presented above describe the complete function space of the AI Companion. Due to the limited scope of this master thesis, it is chosen to focus on the tactile manoeuvre feedback function and the possibility to tell the vehicle how to drive by influencing the piloted driving behavior. The aim of this project is to develop a functional 1:1 prototype of the AI Companion to make the two selected functions perceptible and to have the possibility to evaluate those functions.



INTERIOR FUNCTIONS

1. Door handle
2. Central locking switch
3. Buttons memory function
4. Air outlet adjustment
5. Air outlet
6. Control leaver (turn,beam)
7. Steering wheel
   - Horn
   - Audio/Video controls
   - **Speach dialog control**
   - Paddle levers
8. Instrument cluster
9. Lever windscreen wipers
10. Air Outlet
11. **Upper MMI touch dispaly**
12. **Lower MMI touch display**
13. Lever automatic gearbox
14. Buttons drive select
15. **On/Off button MMI system**
16. Buttons parking aids
17. Buttons parking break
18. **Start engine**
19. Steering wheel adjustment
20. Light switches
21. Bonnet lock release
22. Adjuster for exterior mirrors
23. Button for boot lid

Figure 24: Interior Functions Audi A8 2017

4.2 MECHANISM DESIGN

This part of the detailing phase describes the development of the AI Companion mechanism. As explained in the previous part, the focus for the design of the mechanism is to realize the function of the tactile manoeuvre feedback and the possibility to have a certain control on the behaviour of the car by moving the Companion in an active manner. Thereby, the overall aim was to design the mechanism in a way that the desired magical user experience by means of a frictionless and fascinating movement of the AI Companion is achieved. It should be noted that the mechanism that is developed and described in the scope of this thesis is in a predevelopment stage. The main objective is to make the desired user experience perceptible. It can be estimated that a series solution for the desired functional mechanism would require a smaller and more compact package. In general, the development of the mechanism was a process of continuous testing, evaluating and improving to accomplish the desired product qualities. In the following, the design process from the first rapid prototype to the final design is explained.

4.2.1 MOVEMENT DEFINITION

In the first step, the movement of the AI Companion was defined due to the fact that the way it moves is essential for the desired vivid and magical product experience. Therefore, it was first constructed in a digital 3D environment in Catia V5. Based on the data, a rapid prototype was printed. In order to evaluate the movement, the prototype was shown to various employees of the interior design and predevelopment department of Audi to see their responses on the movement. According to the throughout positive feedback it was chosen to go on with the “floating” movement and analyse it in more detail in terms of its point of rotation for the further development.

4.2.1.1 Point of Rotation

The floating and pendulous movement is caused by a point of rotation that is located above the AI Companion. The outstanding aspect of the defined movement is that the point of rotation itself moves in a defined area and therefore creates the floating and magical movement in the desired directions. The knowledge about the point of rotation and its respective movement is essential for the further development process in order to design a bearing that creates the desired motion.

4.2.2 MECHANISM DEVELOPMENT

Overall, there were three main challenges regarding the development of the mechanism. First of all, the selection of the bearing that allows to have the favoured movement with less friction as possible. Secondly, how to actuate the AI Companion with two motors in order to achieve the desired movements to all sides. Thirdly, how to overlay the actuated movement of the AI Companion with the manual intervention of the user. In order to simplify the development of the mechanism, the design of the bearing and actuation was considered individually. In the following, first of all, the development of the bearing is explained, followed by the decision on the way of actuating the Companion.

Bearing Development

Based on the findings from the initial rapid prototype, the desired product qualities and general demands for automotive engineering, a list of requirements for the development of the bearing is created. The following list shows the requirements that the bearing has to fulfil.

- Withstand misuse forces of 800N
- No noticeable sound
- As frictionless as possible
- Protected from dirt
- Create the desired floating movement
- Match the defined point of rotation
- As compact as possible
- As many standard components as possible

According to the defined requirements, possible solutions were generated and evaluated by means of their positive and negative aspects. Inspired by the movement and construction of the SpaceMouse (see Appendix B), the idea arose to generate the desired movement by means of three flexible spring steel wires. Due to the simplicity of the solution and in order to test if the arrangement creates the desired movements, a prototype was build, as shown in figure 30.

The prototype revealed that the arrangement of the three flexible spring steel rods generates the desired movements of the AI Companion. However, to decrease the needed force to bend the spring steel rods for the movement of the AI Companion, a very low diameter of those is required. This low diameter has the effect that the overall stiffness is low and a possible misuse of 800N would permanently deform the rods. Therefore, it was chosen to substitute the three flexible rods with stiff rods and to enable the movements of those by means of six ball coupling bearings, as depicted in figure 25. This composition has the advantage of a high stiffness, very low friction, low maintenance and the use of only standard components makes it affordable to produce.

Actuator Development

This part describes the decisions that were made in order to actuate the AI Companion. The main points that had to be decided on were the type of actuator, the placement, the connection with the Companion and how to generate the desired movement. Therefore, first of all, the most important requirements for the actuators were defined.

- No more than two actuators
- Electric powered actuators
- Actuators are self-impending
- Actuators generate no noticeable sound
- Actuators have enough power to move the AI Companion

Based on the defined requirements it was chosen to use two electric motors for the actuation, one for the transversal and the other for the longitudinal movement. Due to the size of the actuators and the limited space underneath the AI Companion, it was chosen to place them further back in the area under the armrest. Actuator (A1) is responsible for the longitudinal movement (acceleration and slow down) of the AI Companion and actuator (A2) generates the movement in transversal direction (lane change left/right). Both actuators are connected to the drive rod (R1) that is linked to the Companion via a ball coupling. Finally, in order to allow the user to overrule the actuated movements, the connection between AI Companion and the main rod (R1) is a tension spring. The spring makes it possible to move the AI Companion manually independent from the movement that is generated by the two actuators.

In order to test the bearing and actuator set-up, a functional prototype was built, as shown in figure 32. The prototype revealed that the arrangement and placement of the two actuators in combination with the

SOLUTION	Plain	Rolling	Magnetic	Flexure	Ball Coupling
DESCRIPTION	Rubbing surfaces with lubricant	Rollers to minimise rubbing	Faces of bearing kept seperate by magnets	Three flexible spring steel rods flex to give and constrain movement	Three stiff rods beared by ball couplings
FRICTION	Relatively high friction Stick-slip effect	Low friction	Zero friction	Very low friction	Very low friction
STIFFNESS	High stiffness Some slack	High stiffness Some slack	Low stiffness	Low stiffness	High stiffness
LIFE	Low to very high depends on materials	Moderate to high Requires maintenance	Indefinite Maintenance free	Moderate Maintenance free	High Requires maintenance
NOTES	+ Low wear + High stiffness - Stick-slip effect - High friction	+ Low friction + High stiffness - Noticeable sound - Maintenance	+ Zero friction + Maintenance free - Need power - Low stiffness	+ Very low friction + Maintenance free - Low stiffness - Moderate life	+ Very low friction + High lifetime - Maintenance

Figure 25: Solution Space Bearing Development

developed bearing generate the desired movement of the AI Companion. Furthermore, it demonstrated that the stiff steel rods in combination with the ball couplings create the same magical movement as the flexible spring steel rods with less friction. However, the prototype demonstrated that an additional crosslink between two rods is needed in order to prohibit a possible twist and slump down of the bearing.

Based on the insights from the functional prototype the mechanism was further detailed.

4.2.3 MECHANISM CONCLUSION

The mechanism developed in the scope of this thesis allows to make the desired user experience of the AI Companion concept tangible today, even though the defined target year is 2030. However, it needs to be noted that the designed mechanism is in a predevelopment stage that needs additional work to translate it into a solution that is suitable for a future series development. In general, the developed bearing is already quite close to a series solution due to its simplicity, low price, high stiffness and low maintenance. However, the selected actuators and their placement need to be revised. Desirable would be an overall compact package that not larger than the bounding box of the developed bearing. Even though the mechanism allows to move the AI Companion independently from the movement that is generated by the actuators in order to give the user a certain control about the piloted vehicle, this intervention needs to be sensed. Therefore, the integration of a sensor is required, that was not possible in the scope of this thesis.

4.3 DESIGN DEVELOPMENT

This part of the report describes the aesthetical and formal decisions that were made during the development of the AI Companion. Aspects that are addressed in the following are the shape ideation and selection of the keysketch, the development of a 1:1 tape drawing based on the mechanical package and the decisions that were made during the CAD development. Finally, the decisions in terms of colour and trim are explained. Finally, the AI Companion is presented in the context of a fully piloted vehicle.

4.3.1 SHAPE IDEATION

Based on the initial ideation sketches, the desired product qualities and the analysed Audi form language, various shapes are explored as shown in figure 34. The AI Companion is integrated in the armrest for a comfortable ergonomic handling. It is located between the two occupants in order to allow both to interact with it.

For the design of the AI Companion it was important that it embodies a high visual clarity by means of uncomplicated surface treatments. The aesthetical objective was to combine the visual appearance of the different components (Armrest, AI Companion, Pedestal) in a way that the user has the feeling that it is made all of a piece (“Aus einem Guss”). Additionally, it was important that the AI Companion embodies a self-confident and stand-alone stance in order to communicate a trustful appearance within the vehicle. Finally, a reduced and minimal look was desired to evoke a familiar and trustful feeling.

4.3.2 FINAL DESIGN

This paragraph gives a detailed design overview of the final AI Companion design. As shown in the renderings on this page, the armrest and pedestal are combined in one continuous and flowing form, inspired by the hull of a sailing boat. It was chosen to give the pedestal an aluminium satin finish to underline its premium character. In order to increase the overall contrast, the armrest is made of black leather. To avoid a sharp edge between the aluminium and the leather parts, the armrest surface has a 3mm offset. The transition between the armrest and the AI Companion is designed in a way that the armrest follows the round shape of the Companion. This form feature creates a flowing and clean transition from the armrest to the Companion and minimises the occurring gap between both elements. The centre piece, the moving AI Companion has a minimal and reduced round shape that allows a comfortable placement of the occupants hands. In order to increase its visual appeal, a subtle bend is integrated to create an additional appealing highlight on the surface. Furthermore, this surface bend has a positive impact on the grip when the occupant rests his hand on the element. Due to the fact that the AI Companion is the centre piece, it is highlighted by the use of a high gloss black finish. As shown in the pictures, the AI Companion can either be located in the centre of a bench and therefore can easily be accessed by both occupants. On the other hand, it offers also the possibility to be located between two lounge chairs such as shown in the Audi AICON concept car.

CHAPTER 5

EVALUATION & RECOMMENDATIONS

This chapter covers the evaluation of the developed AI Companion concept. Based on the defined product qualities, a user test was conducted. The objective of the user test was to evaluate to what extent the developed concept meets the desired product qualities and consequently evokes the feeling of trust in the context of a fully piloted vehicle. Based on the results of the user test and general insights during the project, recommendations for further development and research are provided.

5.1 USER TEST AI Companion

The aim of this project was to develop a functional 1:1 design prototype of the AI Companion to make the two main functions (haptic feedback and active user input) perceptible in order to evaluate those functions according to the feeling of trust in the context of a fully piloted vehicle. Due to the fact that the defined product qualities are derived from an interaction analogy that is based on trust, it was chosen to evaluate to what extent the developed prototype matches the desired product qualities by means of a user test. The following paragraph describes the test method, participants, setup and procedure, limitations, results and it ends with a discussion.

5.1.1 TEST METHOD

In order to test to what extent the AI Companion fulfils the defined product qualities (vivid, familiar, reassuring, magical) it was chosen to make use of a four-point Likert scale. In general, a Likert scale has the benefit, that it offers a wide range of answer options and therefore, different degrees of opinion. Likert scales are one of the most reliable ways to measure opinions, perceptions and behaviours and the obtained quantitative data can be analysed with relative ease (Cohen, 2007). The four-point scale was favoured above a five-point scale in order to leave out the neutral position and therefore force the participants to take a clear decision in either direction. Additionally, the questionnaire had a comment field so that the participants were also able to make further annotations if requested.

5.1.2 PARTICIPANTS

In total, 47 participants attended the user test. All participants were Audi employee from different development departments (interior design architecture, interface design, seat design, graphical user interface design, studio engineers, predevelopment engineers and user interface / user experience engineers). The participants were invited to the presentation of the AI Companion and the following user test via an Outlook invitation.

5.1.3 SETUP & PROCEDURE

The developed AI Companion prototype and the driving scenario video were the main equipment used during the user test. The movements of the prototype were adjusted to the recorded driving video in order to let the participants experience how the AI Companion would function in the context of a piloted vehicle. The prototype was placed next to an armrestless chair in order to allow the participants to rest their arm on the armrest of the prototype. The chair and the prototype were located in the centre of the room, facing the beamer projection of the driving scenario sequence. This allowed the participants to rest their hand on the AI Companion and at the same time to see the projected driving video. Due to the fact that the participants attended the preliminary presentation and discussion session, they were familiar with the idea and the working principle of the AI Companion. All participants were asked to participate one at a time in order to have a structured test procedure. At the beginning of the test they had the opportunity to move and manipulate the prototype to get a feeling of its movements. In the following step, the driving scenario video and the movement of the AI Companion were started at the same time. Thereby, the movement of the AI Companion and the manoeuvres of the vehicle in the presented video were time-staggered in order to generate a haptic feedback about the upcoming manoeuvres of the vehicle. In other words, the participants felt via the haptic feedback of the AI Companion what the car‘s next intentions are. Subsequently, the participants were asked to fill in the questionnaire regarding the product qualities of the concept. The questionnaire can be found in appendix C.

5.1.4 TEST LIMITATIONS

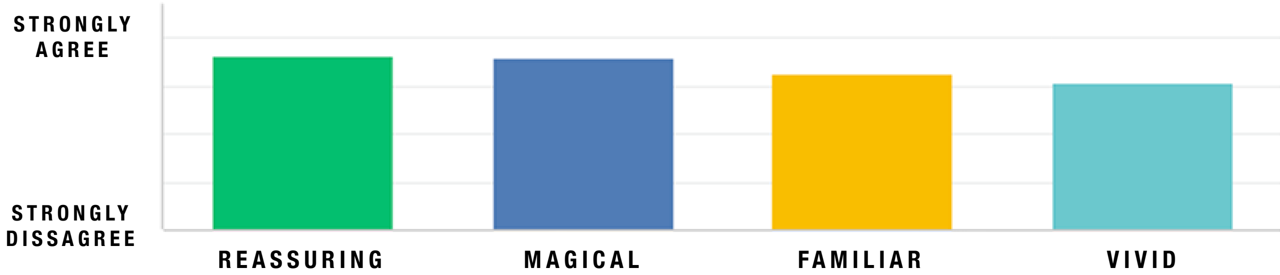
As explained, the prototype was tested in a presentation room environment. A user test in a real driving environment was not in the scope of this thesis. However, testing the prototype in a field study, including the g-forces on the participant's body, might have led to more significant test results. Furthermore, it was only possible for the participants to feel the upcoming manoeuvres of the vehicle. An active user input via the AI Companion was possible, however it had no influence on the behaviour of the vehicle in the video.

5.1.5 TEST RESULTS

As presented in table 2 the results of the user test indicate that the developed AI Companion prototype fulfils the desired product qualities well. The average values in terms of how good the respective quality is fulfilled rank from 3,0 to 3,6 out of 4. However, the results also show that the prototype fulfils some qualities better than others. In total, 66% of the participants fully agreed that the concept has a reassuring impression. Furthermore, 62% fully agreed that the interaction with the prototype is magical. The majority of the participants, namely 53%, somewhat agreed that the prototype feels familiar. Finally, 55% somewhat agreed that the AI Companion has a vivid character. Next to the results from the Likert scale, 12 participants noted that the movement of the AI Companion is counterintuitive in their opinion. They expressed the desire to mirror the movements in a way that it is corresponding to the g-forces that would work on the companion when driving. Furthermore, one participant noted to make the movements more impulsive to generate a clearer feedback. Finally, it was supposed to use more natural materials in order to create a more vivid and familiar appearance.

5.1.6 DiSCUSSION

The goal of this research was to examine to what extent the developed prototype of the AI Companion fulfils the defined product qualities. The observed data reveal that the concept satisfies the qualities on average to a large extent. Due to the fact that the desired qualities are derived from an analogy that is based on trust, it can be stated that the prototype of the AI Companion has a positive influence on the feeling of trust in the context of a fully piloted vehicle. However, it should be noted that a user test in a real driving environment could lead to different test results. Therefore, it is recommended as a next step in the development of the AI Companion, to test the concept in a field study. Thereby, it should also be possible to manipulate the driving behaviour of the vehicle by means of user inputs via the AI Companion. Furthermore, it should be examined if the impulse of the movements should be intensified. Especially in a field study, a more intense feedback could be desirable for a clear haptic feedback. Another important point that needs to be discussed and further evaluated, is the movement of the AI Companion due to the fact that a number of participants noted that it is counterintuitive for them. A possible solution could be a mode that allows users to chose the way the companion moves, compared to the Apple touchpad scroll direction. Finally, it should be investigated if the application of more natural materials, such as wood or fabric, has a positive influence on the desired product qualities. All in all, it can be concluded that the developed concept has a positive influence on the feeling of trust in piloted driving and should be further developed in order to maximise the potential that the AI Companion offers.



	STRONGLY DISSAGREE	SOMEWHAT DISSAGREE	SOMEWHAT AGREE	STRONGLY AGREE	TOTAL	AVERAGE
REASSURING	0,00% 0	2,13% 1	31,91% 15	65,96% 31	47	3,64
MAGICAL	0,00% 0	2,13% 1	36,17% 17	61,70% 29	47	3,60
FAMILIAR	0,00% 0	10,64% 5	53,19% 25	36,17% 17	47	3,26
VIVID	0,00% 0	19,15% 9	55,32% 26	25,53% 12	47	3,06

Table 2: User Test Results

5.2 CONCLUSION & RECOMMENDATIONS

Today, Audi embodies pure driving pleasure and sportiness. However, the coming age of piloted driving mobility will provide opportunities but also challenges for Audi in order to stay a competitive organisation. One challenge that Audi definitely has to consider in the future of fully piloted mobility is how to create a trustful and comfortable relationship between the vehicle and its occupants. Without a trustful user experience, the user feels unpleasant and might abandon the piloted driving function.

In the context of this thesis, a functional design prototype, the AI Companion, is developed that provides a possible solution for Audi to evoke the feeling of trust by means of a physical and tangible interface in the vehicle interior. The AI Companion is a reduced and minimalist tangible interface that allows the occupants to feel the next driving manoeuvres. Furthermore, it allows the occupants to actively determine the driving route and driving dynamic of the vehicle.

The development of the AI Companion is based on an extensive design research including the theoretical background analysis about trust in automation, the generation of a future context 2030 according to the Vision in Product Design methodology, a resulting mission statement and an interaction analogy with derived product qualities. In order to experience the concept of the AI Companion, a fully functional design prototype is developed. To increase the overall experience and to evoke the feeling of driving in a piloted vehicle, the prototype is animated and tuned to a filmed usage scenario. The final evaluation of the prototype has shown, via the paper-and-pencil questionnaire, that all defined product qualities are fulfilled to a high extent. Therefore, it can be concluded that the developed AI Companion has a positive impact on the experience of trust. Even though the concept was aimed at fully piloted vehicles (Level 5) it could also offer a solution for semi-piloted vehicles (Level 4) where the steering wheel moves away from the driver when driving piloted. Due to the use of manly standard mechanism components, an implementation of the concept in an earlier timeframe than 2030 would definitely be possible from a technical point of view.

However, before the AI Companion might be implemented in a series vehicle, it needs to be further evaluated and improved. It should be taken in mind that the concept is not evaluated in a dynamic driving context. The validation of the developed concept in a dynamic driving context should therefore be one of the next steps in the evaluation process. In order to evaluate the AI Companion under real driving conditions, a field study or a driving simulator study would be preferable. The effect of the concept on the occupants could be determined under realistic conditions in order to further optimize the AI Companion. Thereby, it should also be possible to manipulate the driving behaviour of the vehicle by means of active user inputs via the AI Companion. Therefore, the prototype needs to be equipped with additional sensors to record the users input in order to translate it into manoeuvres of the piloted vehicle. Moreover, it should be analysed and tested how many seconds before the actual driving manoeuvre the occupant should ideally be informed by the haptic feedback. Only a consistent feedback in time will evoke the feeling of trust in the AI Companion. Even though the developed bearing of the mechanism is already quite sophisticated, the actuating element needs to be further improved in terms of its package compactness. Furthermore, it should be examined if a mode in order to change the movement of the AI Companion to the individual preference of the occupant is desirable and therefore beneficial for the concept. Finally, it could be interesting to investigate if the application of more natural materials, such as wood or fabric, has a positive influence on the desired product qualities of the AI Companion.

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AICOMPANION

TRUST IN PILOTED DRIVING

APPENIX

APPENDIX A:

CONTEXT FACTORS

Cluster 1: Searching for Authenticity

1. In an increasingly fabricated world, people yearn for authenticity
2. The more high-tech our lives become, the more nature we will need
3. People are looking for more profound experiences
4. An aging society needs simpler products that are intuitive
5. Safety is a basic need for transportation
6. When people feel unsecure they hold on things
7. People feel safe when they feel protected
8. People like to touch and feel objects
9. Vehicles becoming more and more digital
10. Virtual and augmented reality changes the way people perceive their environment
11. It feels good to have something that you can see share with other people
12. In 2030 virtual worlds, and augmented reality are popular network formats
13. In 2030 people don't need to touch anything to get information
14. The line between the virtual world and the real world gets more and more blurred

The role technology plays in people's lives is rapidly growing, as people become increasingly dependent on it and less willing to separate themselves from it. In 2030 information can be accessed from everywhere and in every situation. The "real" world gets more and more transformed into a virtual one. In this increasingly fabricated and digital environment people yearn for authenticity. The more high-tech their live becomes the more they value nature and profound, understandable, simple product experiences.
Relation to the domain:

Cluster 2: Fear of Losing Control

1. Mobility experiences are generated by software companies
2. People have artificial intelligence companions
3. The world will be more open and transparent due to information everywhere
4. AI Companions structure people's lives
5. People get stressed when having the feeling of losing control
6. Time losses, which the driver cannot control on its own are a great stress factor
7. Simplified interactions with digital devices
8. Artificial intelligence goes along with the fear of losing control, jobs and privacy
9. People are highly dependent on technology in their everyday life
10. The role technology plays in human life's is rapidly growing
11. Driving a car evokes a feeling of control
12. Advances in technology make certain skills of people redundant
13. Taking the human out of the loop makes piloted driving safer
14. More and more human tasks are executed by technical systems

In 2030, technology is taking over more and more tasks that people used to do on their own. The improvements in automation technology makes a lot of jobs redundant and therefore increases the social dependency on technology. People unconsciously hand over more and more daily activities and routines to electronic devices and services. As a result, they become passive observes of their own environment. Due to increasing global problems combined with the rising complexity of technology and amount of information people more and more feel like losing control of their environment.

APPENDIX A:

CONTEXT FACTORS

Cluster 3: Optimisation

1. Data driven society: Data used for self-improvement
2. Boundaries between work and private time blur
3. Connected mobility optimizes traffic flow in urban areas
4. Autonomous vehicles will create the “25th hour”
5. People track their activities
6. Every free minute is used for communicating, reading, watching
7. Piloted driving decreases road accidents
8. Artificial Intelligence optimises daily activities
9. People compare themselves to others
10. Seamless mobility to get from A to B faster
11. Piloted driving allows to work while driving
12. Autonomous vehicles only in urban areas to improve safety and efficiency
13. People have the need to improve themselves
14. People feel the need to keep up with the performance oriented society
15. An increased number of employees carry on their work on the move

The combination of smart software and automated technology increases the everyday efficiency and safety. Seamless mobility and piloted driving create more time for people to either work or use the saved time to relax and enjoy. Artificial companions structure people‘s days in order to be more productive and efficient. Improvements in technology allow people to keep an exact overview of their physical condition at every moment in time. However, in a world where almost everything is arranged and controlled by computer systems, there is no space for unexpected pleasurable experiences. Furthermore, the blurring line between work and private time in combination with the feeling to keep up with the performance oriented society creates a rising feeling of pressure

Cluster 4: Use instead of ownership

1. Property thinking changes
2. Decreasing significance of the car as a status symbol
3. A strong commitment to sustainability determine the behaviour of customers
4. Customers expect simple and intuitive access to complex technologies
5. Growing demand for flexible ownership models
6. Evolving customer expectations towards individualisation
7. Personal and public transport will go hand in hand
8. People will use multiple means of transport to reach the desired destination
9. More and more means of transport getting available (e-bike, Segway, etc.)
10. “Car experience“ will continue to be an element of modern lifestyle
11. Means of transport must fulfil the functions of a personal workstation, as well as the desires for privacy, familiarity and intimacy

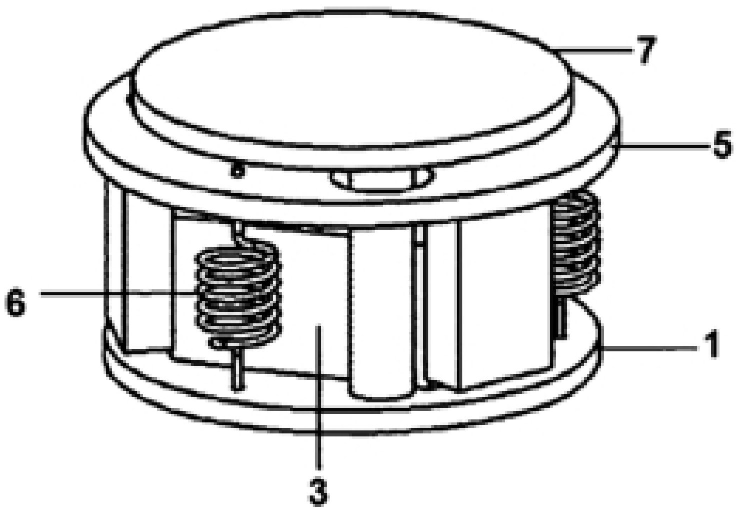
Cluster 5: Privacy and Cyber Security

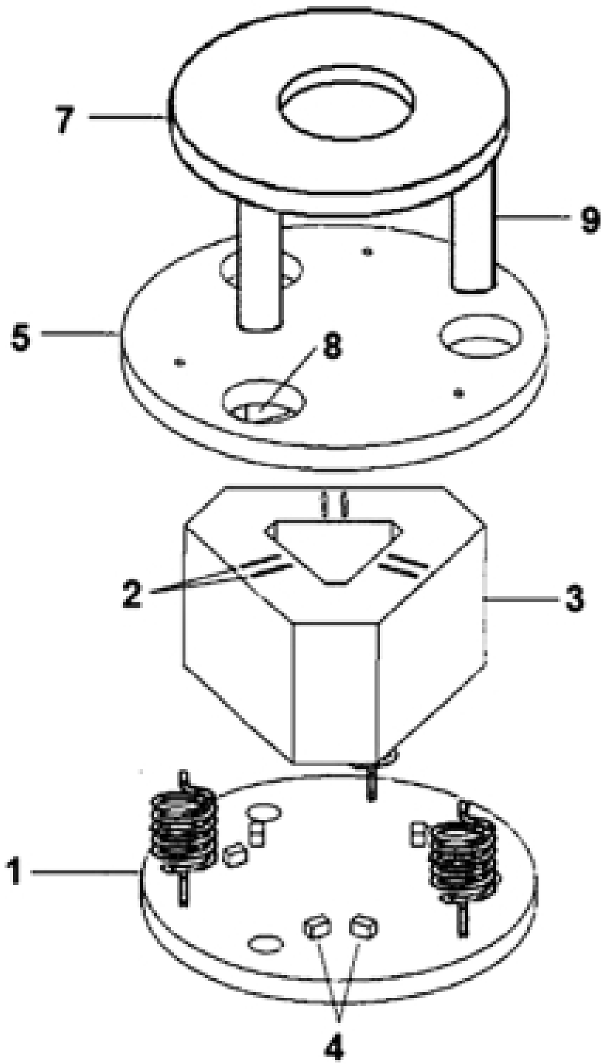
1. People like to share their life on social media platforms
2. Cyber attacks are increasing
3. Protection of individual privacy
4. Increased concerns regarding security of personal data
5. People need privacy
6. Cyber security has an influence on the acceptance of piloted vehicles
7. People are afraid of being hacked
8. Global society driven by digital information

APPENDIX B:

SPACE MOUSE MECHANISM

The working principle of the SpaceMouse was a source of inspiration during the development of the AI Companion mechanism due to the fact that it makes a similar, almost fricionless movement. The pictures show a schematic exploded view of the SpaceMouse. It is mounted on three spings that allow a balanced movement in each direction. The relative motion is measured by optoelectronic components.





Schematic exploded view of the SpaceMouse (adapted from patent EP1850210)

APPENDIX C:

USER TEST (QUESTIONNAIRE)

In order to test to what extent the AI Companion fulfils the defined product qualities (vivid, familiar, reassuring, magical) it was chosen to make use of a four-point Likert scale. The four-point scale was favoured above a five-point scale in order to leave out the neutral position and therefore force the participants to take a clear decision in either direction. The picture on this page shows an example of a filled in questionnaure. Next to the Likert sclare, the participants had the possibility to add additional notes.