Reducing the Number of Features while Creating a Rich User Experience

A Study within the Automotive Industry

Master's thesis in Industrial Design Engineering

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Department of Industrial and Materials Science
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Abstract

The continuous evolution of the automotive industry constantly pushes the limits of what is achievable through vehicle design, aiming to enhance the driving experience. However, integrating an excessive number of features can lead to distractions, increased cognitive workload, reduced situational awareness, and decreased usability, ultimately compromising safety. Therefore, this thesis has investigated how a rich user experience could be created while reducing the number of features, where the cluster, steering wheel, display and the centre stack were the four investigated focus areas of the interface. Furthermore, the project concentrated on urban driving contexts, aiming to identify factors that positively affected the user experience and what key features contributed to it. Data about the users (the drivers) and the usage situation (driving in urban contexts) were collected using various methods to generate insights about the driving situation from different perspectives. The collected data was then carefully analysed and resulted in a list of identified factors that could be seen affecting the user experience of driving, and a compilation of features required to fulfil these factors and, in that way, contribute to a good user experience. The insights from the user studies were then used to create various prototypes of the four focus areas. The prototypes were then evaluated by the users to identify the best-performing ones based on set requirements and design guidelines. The prototypes of the four focus areas were then further developed and assembled, resulting in a final concept exemplifying how a good user experience could be received with a reduced number of features. The final concept focused on preventing overstimulation and distraction caused by the interface, as well as providing good usability where redundancy of features was avoided, since these were the general identified factors contributing to good user experience in urban contexts, in particular. The evaluation of the final concept revealed that a "less is more" approach to car design, focusing on essential features, can create a rich experience and address safety and usability concerns efficiently, which supports a shift towards more simple and user-centred designs in the car manufacturing industry.

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Contents

1
Introduction

Over the last two decades, the number of cars has increased significantly. Currently, Europe alone accounts for approximately 412 million cars (Stumpf, 2023). This increase raises concerns about sustainability, particularly the environmental impact. According to Pipitone et al. (2021), the push in car sales has led to a significant increase in emissions, contributing notably to global CO2 levels.

Furthermore, cars also significantly influence our routines, social structures and cultural norms due to their seamless integration into daily life. Beyond environmental sustainability, cars profoundly impact urban living and mobility. Cars have evolved from simple modes of transportation into complex environments that engage users on multiple sensory and emotional levels. This evolution underscores the increasing complexity of human-machine interactions (HMI), which are crucial in defining the relationship between drivers and their cars.

The automotive market is competitive, with manufacturers continually striving to outdo one another by adding features designed to enhance the overall product experience. Consequently, the market is characterised by cars that boast excess features and intricate interior trims, all aimed at elevating user experience and satisfaction.

This competition makes the user experience critical as a differentiator; users dissatisfied with one brand easily find alternatives. Among the frameworks guiding experience design is Patrick W. Jordan's model, which categorises the pleasures associated with products into four types: physio-pleasure, psycho-pleasure, socio-pleasure, and ideo-pleasure. Jordan (2000) broadly defines pleasures, covering products' emotional, hedonic, and practical benefits. This broad definition captures the subjective nature of pleasure, which varies widely among individuals due to their diverse interactions with products.

However, the pursuit of feature-rich cars often leads to consequences. The Association for Safe International Road Travel reports an alarming 1.35 million traffic fatalities worldwide each year, prompting extensive safety measures. These include the incorporation of advanced driver assistance systems (ADAS), intended not only to enhance security but also to potentially reduce drivers' mental workload, thereby allowing them to concentrate better on driving tasks (Biondi & Jajo, 2024) and (Placek, 2023). However, there exists research which points out that automated systems might lead to such a reduced level of workload, leading to drivers becoming bored and thus seeking entertainment from elsewhere, often from entertainment features within the car (Biondi & Jajo, 2024), or the possibility for drivers to create an over-reliance in the automated system and thus find it difficult to take over control of the vehicle when necessary (Merat et al., 2012).

Despite these advancements, the abundance of features can overwhelm drivers, impacting their usability and situational awareness. Present research extensively documents the adverse effects of complex and numerous product features, including excessive or insufficient mental workload, decreased situational awareness, and diminished usability. Yet, there remains a significant gap in understanding how reducing features might alleviate these issues and lead to improved outcomes. This gap underscores the need for further investigation into the balance between features and user-centric designs in automotive UX.

Given the essential role of the car's front interior, where many features are centralised and designed for use while driving, this project will focus on this surrounding covering the areas cluster, steering wheel, centre stack and display, which are important areas shaping the driver's interactions with the car.

1.1 Aim

This research aims to investigate user experience in cars and assess whether a reduction of features can create a rich user experience.

1.2 Research Questions

- Q1: What factors affect user experience in a human-machine interaction with a car whilst driving?
- Q2: What features are essential for a positive user experience of a car whilst driving?
- Q3: How can a rich user experience be created while reducing the amount of features?

1.3 Objectives

This study will develop a requirement list of the user's needs and preferences for a car's interior involving the four mentioned areas. Based on the requirements found, concepts will be developed to evaluate the relationship between features and the user experience of the car. A final concept will be developed, representing an example of how a composition between reducing of features and rich experience can be designed to evaluate the aim of the project.

1.4 Demarcations

The project will consider the urban context of driving, and since it is conducted in Europe, the focus will be on this market.

This thesis project will specifically focus on automation levels 0, 1, 2, and 3, where human control of the car is retained, but partial automation functions can be present (Riener et al., 2022).

This project will not consider users with cognitive and physical disabilities that can affect driving since physical and cognitive disabilities might affect their needs and abilities.

2

Literature Review

This chapter presents a literature review that delves into user experience and human-machine interaction. These areas are considered important for an in-depth understanding of the overarching project because they directly influence how users interact with and respond to the system. These interactions are fundamental in shaping the effectiveness, efficiency, and satisfaction derived from using any system, making them critical components in developing and evaluating user-centred designs.

The theoretical findings were systematically extracted using a structured five-stage methodology proposed by (Wolfswinkel et al., 2013). This methodology facilitated the organisation of relevant theories and the creation of theoretical syntheses for the project, enhancing the efficacy and coherence of the literature review process.

2.1 User Experience

User experience refers to a person's overall experience and perception when interacting with a product, system, or service. *"User experience encompasses all aspects of the end-user interaction with the company, its services, and its products"*, aiming to make these experiences as positive as possible (Norman & Nielsen, 1998, first paragraph). Good user experience fulfils the user's needs, providing easy, efficient and enjoyable interactions, fostering loyalty to the product or brand. *"If people have delightful experiences with a product, they are more willing to buy the next product from the same company"* (Kujala et al., 2011, p. 474). A well-designed user experience is crucial in determining a product's success and can differentiate it significantly from its competition by enhancing user experience (Kujala et al., 2011).

The automotive industry, involving cars, is on the cutting edge of technological innovations and presents unique challenges and opportunities in designing for UX. Cars are not only a mode of transportation; they provide complex environments that engage users on multiple sensory and emotional levels (Bengler, 2017).

Cars are among the most complex and costly products, generating a lot of power in various public settings. Therefore, designing cars needs to consider safety and user-friendliness and meet customer expectations while following rules and regulations. Balancing these different needs is considered a challenge (Bengler, 2017).

There is a difference between driver experience and driving experience. While driver experience refers to the driver's general perception and emotional states, driving experience especially focuses on what the driver feels and encounters during the negotiation of the driving task (Bengler, 2017).

Ux in cars is essential as it directly impacts users' feelings about their cars. A good user experience ensures that all interactions with the car, from the actual driving to interacting with the built-in features, are intuitive, satisfactory and safe for the users. A well-designed user experience can enhance safety by making sure that the controls of the car are easy to use so the drivers can focus on the road, thereby reducing the risks of accidents (Bengler, 2017). The concept of UX in cars goes beyond functionality and usability, delving into deep emotional and psychological connections with the users. As the car industry advances, the significance of UX also grows, incorporating safety, comfort and emotional engagement. Pleasure and Usability are two interrelated areas of importance to UX, which are reviewed below.

2.1.1 Pleasures

In the realm of user experience, understanding and integrating the multifaceted aspects of pleasure can enhance the interaction between users and products (Jordan, 2000). The Four Pleasures framework provides a valuable model for classifying different types of pleasures. It involves four conceptually distinct categories: physical, psychological, social, and ideological pleasures. This framework facilitates a comprehensive analysis of how each type of pleasure contributes uniquely to user experiences. Pleasure-based approaches within product design can be seen as approaches that consider all of the potential benefits a product can deliver, whereas "good design" is considered to contain all four categories (Jordan, 2000).

One of Jordan's four categories is physio-pleasure, which refers to physical sensations and comforts associated with using a product. Physio-pleasure encompasses tactile, ergonomic, and sensory aspects contributing to the user's physical comfort and satisfaction (Jordan, 2000).

Human-factor approaches often focus on the physical aspects of product use, such as whether the product's dimensions are suited to the user's anthropometrics, whether the product is light enough to carry, and whether it is accessible to people with disabilities. These issues relate to the physiological aspects of product use. Poor design in these areas can lead to user dissatisfaction. Conversely, if these aspects are well addressed in the product design. In that case, users may feel relieved by the absence of problems or might not even notice them, indicating a seamless user experience (Jordan, 2000).

In driving, physio pleasure is influenced by various design elements that impact the driver's physical interaction with the car. Factors contributing to physio pleasure include the ergonomic comfort of the seats, which support proper body positioning for long drives, the strategic placement of controls and displays for easy reachability and visibility, the tactile responsiveness, such as the feel of the steering wheel or the texture of the controls, climate control systems maintaining a comfortable and pleasant temperature, and the olfactory senses a new car can generate, as new cars often are associated with a particular smell, might leading to pleasure for the owner (Jordan, 2000).

Socio-pleasure refers to the enjoyment derived from relationships with others, friends, loved ones, colleagues, or like-minded people. Besides those relationships, socio also includes the relationship with society, where factors such as status and image may play a role. Socio-pleasure is centralised on the connections and relationships that a product helps to build or maintain, influencing user satisfaction through social experiences (Jordan, 2000).

Products can facilitate social interaction in various ways. For instance, a car can serve as a focal point for social gatherings by enabling a driver to transport passengers, or a particularly distinctive car might attract positive comments, enhancing the owner's social identity. In this way, a person's relationship with a product, such as a car, becomes an integral part of their social interactions and identity (Jordan, 2000).

Connectivity features of the car, such as Bluetooth, Wi-Fi, and integrated systems, can lead to socio-pleasure as they can help the passenger play music or share media. They can also work as a tool to connect with others over phone calls, enhancing the communal experience (Jordan, 2000).

Ideo-pleasure refers to the enjoyment derived from peoples values. In the context of products, Ideo-pleasure relates to the values that a product embodies. This aspect of pleasure focuses on the deeper, ideological satisfaction derived from products that resonate with the users personal and cultural values (Jordan, 2000).

Within the context of driving, Ideo pleasure can manifest through various factors related to values:

A driver who values environmental sustainability may experience high ideo pleasure from driving an electric car due to a lower carbon footprint than other cars. This aligns with their commitment to environmental conservation and responsibility (Jordan, 2000). In the same way, safety features contribute to ideo-pleasure for drivers who play high importance on security and family safety, where different ADAS, such as adaptive cruise control or lane-keep, assist not only in enhancing safety but also align with the driver's value of protecting themselves and other passengers.

Ideo pleasure can also be related to design and aesthetics as a visually appealing design reflecting the driver's style can enhance the driver's sense of identity and pride, making the driving experience more ideologically fulfilling (Jordan, 2000).

Psycho-pleasure relates to a product's psychological impact on its user, encompassing cognitive and emotional responses. This dimension of pleasure concerns how well the product aligns with the user's mental and emotional states, influencing factors such as mental engagement, stress reduction, ease of use, and overall satisfaction. Within product design, this involves addressing the cognitive demands of using the product and the emotional responses it elicits. For example, a product designed in a way that frequently leads to user errors is likely to generate a lower level of psycho-pleasure compared to a well-designed product that minimises the likelihood of such errors (Jordan, 2000).

Psycho-pleasure is often interrelated to usability, where products using high cognitive demands may be difficult to use, thus resulting in unpleasant emotional responses. The mental workload is highly important within the driving area as the driving task involves multiple tasks. The product should be well-balanced, preventing challenging or overly simplistic tasks for increased psycho-pleasure. Creating an environment which engages the user without causing cognitive workload or boredom (Jordan, 2000).

Ease of use is also interrelated to usability. By designing intuitive and easy products which the user can easily operate, user satisfaction will be enhanced where the product helps prevent frustration, annoyance or stress by the user. Clear feedback from a product reassures the user that action has been performed, thus enhancing their sense of control and satisfaction (Jordan, 2000).

2.1.2 Usability

Numerous definitions of usability exist. According to ISO/IEC 9241-11, usability is *"the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specific context of use."* The definition is valuable as it provides the users with a coherent message. The three components mentioned in the definition are expressed below (Jordan et al., 1996).

One definition of effectiveness follows *"the accuracy and completeness with which the users achieve specified goals"* (Jordan et al., 1996, pp. 108–109). To improve effectiveness within usability, the focus should be on simplifying user interfaces and streamlining interactions to enhance intuitive use and reduce cognitive load.

Efficiency is defined as *"The resources expended in relation to the accuracy and completeness with which users achieve goals"* (Jordan et al., 1996, p. 109). Efficiency can also be referred to as the time it takes to operate a product. Where the number of errors has an impact. To increase efficiency, the design should simplify the workflow and reduce the number of steps required to complete tasks, enabling the users to achieve their goals faster and with less effort.

Satisfaction refers to *"The degree to which the product meets the user´s expectations, or the level of comfort the user experiences"* (Theofanos & Stanton, 2012, p. 233). Acceptability of use is one factor influencing satisfaction. Reiss (2012) points out that if a product functions well, it will be used; if not, it will not. This direct relationship between usability and functionality underscores its importance for user satisfaction and as a crucial element of the business case for automotive design (v. Kistowski et al., 2015).

2.2 Human-Machine Interaction (HMI)

Human-machine interaction (HMI) refers to the interaction and communication between humans and machines (Ke et al., 2018). In the context of cars, HMI describes how drivers and passengers engage with a car's internal systems. This interaction includes the use of interfaces such as dashboard displays and physical controls like buttons. HMI includes communication, control, and feedback between users and car systems, which is essential for safe operation. Moreover, the usability of an HMI system can influence the overall experience (Stanton & Young, 2002).

Xu et al. (2022) clarify that contemporary societal developments gravitate towards intelligence, information, and multi-functionality, which also applies to cars. This intelligence manifests in various ways, notably in a trend where manufacturers enlarge in-car displays while removing physical buttons' presence, integrating them into the screen. In line with this, Sladović et al. (2019) describes that the growth of technology and its implementation has led to cars having additional features with the intention to improve the driving experience, raise the level of security and add advanced options to connect the car, such as connect a phone or built-in internet. Kindelsberger et al. (2018, p. 1) characterise the present state *"The current trend in HMI design is toward complexity, toward adding information, not removing it.* Further, Kindelsberger et al. (2018) emphasises that new technology should encourage drivers to focus on the road ahead, where the actual driving is the main focus.

As cars progressively integrate enhanced intelligence and multifunctionality, automation emerges as an influencing aspect within the automotive industry as the driver's roles are changing. The technological landscape rapidly advances towards increased automation, significantly altering the traditional car environment. This evolution necessitates a fundamental transformation in the driver's role from an operator in complete control to more supervisory positions, primarily overseeing the system's operations (Cunningham & Regan, 2015).

2.2.1 Situation Awareness (SA)

Situation Awareness (SA) is a vital aspect of driving, as drivers with low situational awareness have a higher probability of being a contributing factor to accidents, affecting not only their safety but also their surroundings and other humans. SA can be defined as *"The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future"* (Endsley, 1995, p. 36), while Gugerty et al. (2011, p. 265) defines SA as *"The updated, meaningful knowledge of an unpredictably-changing, multifaceted situation that operators use to guide choice and action when engaged in real-time multitasking."* SA is about understanding dynamic environmental elements over time and space, knowledge about their significance, and the projection of their future status.

Driving demands substantial attention as drivers must continuously monitor their route, road position, surrounding traffic, traffic signs, and potential hazards while performing car operations such as accelerating and turning. In addition to these driving-centric activities, drivers frequently engage in secondary tasks like listening to the radio, eating, or conversing with passengers, thereby increasing the multitasking involved. Gugerty et al. (2011) emphasises that effective task management is essential for maintaining a high level of SA, enabling drivers to prioritise tasks based on the demands of the situation and disregard less critical tasks when necessary. Many drivers need help with this aspect of driving, often failing to prioritise tasks appropriately. For example, assigning equal importance to navigating through heavy traffic and talking on a cell phone increases the risk of accidents due to divided attention. One challenge with lowered SA due to multitasking is the possibility that drivers' reaction time decreases, leading to the drivers being unable to act when necessary (Merat et al., 2012).

One factor posing a significant threat to SA is distractions. Distractions can disrupt the coordination of senses and cognitive processes, leading to errors in perceiving the environment, delays in response, and, in severe cases, a complete failure to perform necessary tasks or recognise critical events (Sajan & Ray, 2012).

In the complex ecosystem of road traffic, driver distraction emerges as a critical factor contributing to accidents, accounting for 23 % of all accidents (Sajan & Ray, 2012). Distraction occurs when the driver´s attention is diverted from the driving task to another activity. These other activities can vary, among other things, such as using a phone, daydreaming, or operating the built-in navigation system (Sajan & Ray, 2012).

Distraction can be divided into different categories depending on the way they distract the user, where the categories of interest for the project are Cognitive distraction (mind-off), manual distractions (hands-off) and visual distractions (eyes-off) (Kashevnik et al., 2021). Activities can be a combination of distractions where the driver can be distracted by several factors at the same time, for example, when holding the phone (manual), looking at a previous message (visual) and thinking about how to respond to the message (cognitive) (Kashevnik et al., 2021).

In light of recent studies, it has become increasingly clear that the abundance of features in modern cars, particularly those involving complex user interfaces like touchscreens, can indeed contribute to driver distraction and impact overall vehicle safety. Research has shown that touchscreens, while intended to provide ease of access to various functionalities like navigation and entertainment, actually require significant visual and manual attention from drivers, which can divert their focus from driving task (Grahn & Kujala, 2020).

To maintain safe driving, drivers must understand their surroundings and respond appropriately and accurately, requiring their physical and psychological senses to remain focused. From a human factors perspective, reflecting on car design is essential to aid drivers in comprehending their car's capabilities and limitations. Such design considerations are instrumental in helping drivers maintain situational awareness (SA) and reducing distractions (Cunningham & Regan, 2015).

2.2.2 Workload

Workload manifests in various forms depending on its impact on the user: physical workload involves manual operations; cognitive workload encompasses attention, perception, and decision-making; and emotional workload arises from stress, frustration, or anxiety. Historically, physical workload dominated discussions, but with technological advancements, much of this labour, such as heavy lifting or moving, has been mechanised (Miller, 2001). Consequently, the focus has shifted predominantly towards mental workload in contemporary society (Piechulla et al., 2003). Despite the evolving focus, a universally accepted definition of workload still needs to be discovered. One proposed definition suggests that "Mental workload is related to the amount of attention required for making decisions" (Miller, 2001, p. 4). The workload level a driver perceives is closely linked to their ability to understand and process the events occurring in their surroundings (Hoff & Bashir, 2015). Mental workload is critical in driving safety, affecting a driver's ability to operate a car efficiently and respond to environmental changes. Both too-high and too-low mental workloads present unique risks, potentially leading to dangerous driving conditions and increasing the likelihood of accidents.

Many of today's cars are equipped with partially automated systems, such as cruise control and lane-keeping assist, which manage speed and lane position. According to Placek (2023), it is estimated that 60% of cars sold in 2025 will be partially automated. These automated systems enhance safety by reducing the driver's mental workload and improving car operation. For instance, they assist in maintaining a safe distance from the car ahead, which is particularly beneficial in poor visibility or congested traffic conditions.

Research indicates potential risks associated with operating partially automated systems despite the intended safety benefits. Studies have shown that the shift in workload from active operator to passive supervisor can reduce driver engagement once the system is activated. This reduced workload might diminish the driver's ability to maintain attention on the driving task, leading to boredom and a tendency to seek distraction through other activities like using a phone or listening to music, a phenomenon known as proactive self-regulation (Biondi & Jajo, 2024). Consequently, drivers may spend less time monitoring the driving process and more time on non-driving tasks. This loss of focus and engagement raises the risk of difficulty regaining car control when necessary, potentially resulting in accidents (Biondi & Jajo, 2024). However, other studies, such as those by (Lohani et al., 2021) and (Strayer et al., 2020), suggest that there are no significant differences in workload between using partially automated systems and manual driving.

If the driver experiences too low a mental workload, there is an increased risk of reduced alertness, complacency, drowsiness, and overreliance on automation. On the other hand, if the mental workload is too high, it can lead to decreased situational awareness, delayed reactions, cognitive fatigue, and elevated stress and anxiety. For example, studies suggest that heightened stress and cognitive overload can impair a driver's ability to make quick decisions, affecting reaction times crucial in dynamic traffic environments. Similarly, a low mental workload often results in drivers losing focus, which can be especially dangerous in scenarios requiring sudden manual intervention in semi-autonomous cars (Biondi & Jajo, 2024).

Achieving a proper balance in mental workload is crucial, as excessively high and low levels present significant risks. To support the driver effectively, the information provided must be clear, accessible, and easy to comprehend. This supports enhanced usability and reduces the mental effort needed. Managing the extensive information that drivers encounter requires using straightforward, intelligible cues. Utilising familiar pattern-based cues such as icons and imagery not only helps minimise cognitive workload but also enhances the overall usability of the information system (Dekker & Woods, 2002). By adopting this approach, drivers can understand and respond to the information, promoting safer and more efficient driving.

2.3 Synthesis

The synthesis of the presented literature covers various essential aspects of user experience (UX) and human-machine interaction (HMI) and their broader implications for car design. The purpose of the synthesis is to establish a basis for the project. By connecting the theoretical insights to the project's objectives, the synthesis helps determine the feasibility of the project aim, provides insights for further research, and, in the end, ensures the results of the project are informed by theory.

The theory highlights drivers' and passengers' emotional and psychological connections with cars. A good UX is essential as it ensures that all interactions are intuitive, enjoyable and safe for the user, enhancing their overall experience.

Understanding the aspects of UX is essential when designing new interfaces, not only for intuitive and safety but also to enhance the pleasure and satisfaction of using the system. In this context, the pleasure framework by Patrick W. Jordan is relevant. Jordan identifies four distinct types of pleasures that products can evoke: physio-pleasure, related to the body; psycho-pleasure, associated with mental and emotional responses; socio-pleasure, involving social interactions; and ideo-pleasure, concerning values. By integrating these dimensions of pleasure into UX design, products can deliver more comprehensive and satisfying user experiences (Jordan, 2000).

A well-designed UX can enhance safety, for example, by making car controls easy to use, enabling drivers to focus on the road and reducing the risk of accidents. The knowledge collected helped guide the development of features, ensuring the new design meets user expectations without compromising safety or usability. This approach utilises Jordan's framework to ensure that the car performs its functional role and delivers a richer, more engaging user experience that resonates on multiple levels of human interaction.

The literature review reveals that cars involve complexity, and the interaction between the system and the driver is paramount. In the current state, cars often consist of a great number of features, intended to give the users everything they need or want. However, the inclusion of numerous features, while designed to enhance convenience, often comes with potential consequences. These features, ranging from infotainment systems to advanced control interfaces, can lead to cognitive overload, where the driver must process too much information simultaneously. This complexity can detract from the essential task of driving by increasing the mental workload required to operate the vehicle effectively (Grahn & Kujala, 2020).

Many modern vehicles are equipped with built-in safety systems intended to reduce the driver's mental workload (Placek, 2023). Yet, other sources indicate that these automated systems can sometimes make drivers bored, leading them to seek entertainment from other built-in systems like phone connectivity or music streaming (Biondi & Jajo, 2024). Engaging with these entertainment features can divert attention from the task of driving. Research suggests that this shift in focus diminishes situational awareness, potentially increasing the risk of accidents due to reduced attention.

Moreover, the abundance of features can complicate the user interface to the extent that even basic operations require more driver input and interaction, which can be particularly distracting during critical driving situations (Grahn & Kujala, 2020). For example, adjusting fan controls or navigating through complex menu systems for media settings can divert the driver's eyes and concentration away from the road for extended periods. This underscores the need for car designers to prioritise simplicity and intuitiveness in the interface design to mitigate the risks associated with feature overload and maintain driver focus on the primary task of driving safely. This can be achieved by simplifying user interfaces and ensuring that the essential driving-related tasks are easily manageable without unnecessary complications from additional features (Grahn & Kujala, 2020).

The main takeaways from the literature review follow:

- *User-centric design:* When designing to create a rich driving experience, the design should have a high level of Usability, aligning the four pleasures to create a comprehensive experience.

- *Balanced Cognitive load:* The design should manage mental workload efficiently to avoid overload and prevent underload, as those states can impair decision-making and lead to decreased attention.

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3

Method

The Method chapter will describe the project procedure and explain taken steps. The process started with data collection, executed to understand users' requirements for the car and the driving situation, aiming to answer the two first research questions. The following part of the process was the creative part, resulting in a final concept based on found requirements, aiming to answer the last research question.

3.1 Process

The project process is represented below (see Figure 3.1). The process flow follows from the top left corner (Initial data collection) down to the bottom left corner (Senario of future User Experience). The method chapter involves all 12 steps, while the result chapter involves the eight steps with underlined titles. Belonging to some of the steps, associated subcategories are represented, and those are placed under the steps concerned.

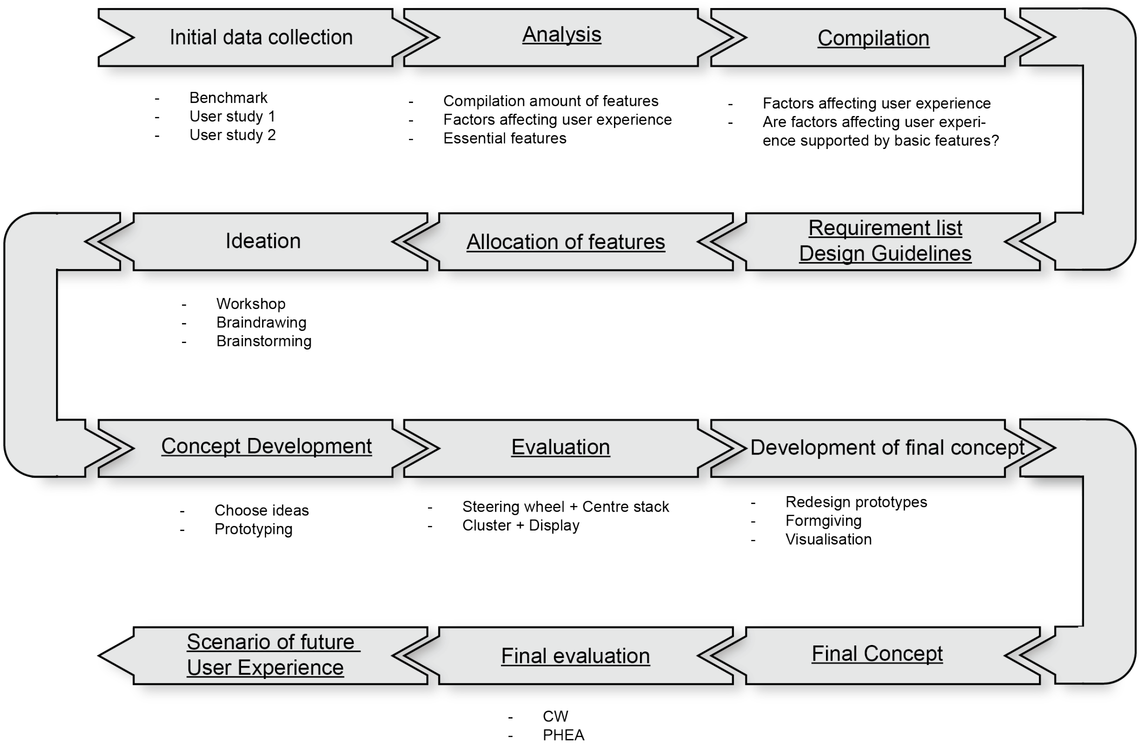


Figure 3.1: Illustration of the process

3.2 Initial data collection - Identification of requirements

The project started with an initial study to explore the current situation in the automotive market and understand the users and the driving situation in relation to an urban context. The initial study aimed to collect insightful data that, at the end of the project, could generate answers to the research questions. The initial study consisted mainly of a benchmark and a user study, where the user study could be divided into User Study 1 and User Study 2.

3.2.1 Benchmark

The first part of the initial study was the benchmark, which is a commonly used method for comparison and is defined as a *“Standard tool for the competitive evaluation and comparison of competing systems or components according to specific characteristics, such as performance, dependability, or security”* (v. Kistowski et al., 2015, p. 333).

In this project, the benchmark involved visiting a car retailer in Gothenburg, selling second-hand and new cars, aiming to compare the interiors in terms of the four particular areas across competing car brands. The comparison examined the *number* of features in the mentioned areas, *what* features were represented, and *where* in the mentioned areas they were placed.

Table 3.1: Number of cars studied in relation to brands

Car brand	Number of cars
Audi	3
BYD	4
BMW	3
Citroen	4
Ford	3
Kia	4
Mercedes	8
MG	2
Polestar	1
Tesla	1
Volkswagen	1
Volvo	3

In total, 40 cars and 16 brands were studied (see Table 3.1) where all cars were produced between 2017 and 2024. Due to the lack of car keys in most of the cars at the retailer, the screens were inaccessible. Therefore, only physical features in the area of the steering wheel and the centre stack were studied and compared among the cars. Photos were taken and collected from the steering wheel and the centre stack of all the cars studied.

The objective of the benchmark was to gain insights into the automotive market of sold and used cars in Europe and understand the range of features in these cars, from more minimalistic designs to richer ones. Based on that, what was considered an “average” number of features in cars was concluded since that insight would work as a baseline for the rest of the project. Furthermore, compiled information about *what* features and *where* features were generally placed in cars was used as inspiration for later ideation.

To analyse the benchmark, pictures of the cars’ interiors were sorted and grouped into two categories: one with pictures representing the steering wheel and one with pictures representing the centre stack. The pictures were then analysed to identify trends about what features were usually represented in the cars and where the particular features were placed, either on the centre stack or the steering wheel. This information was further used as an inspiration bank for future ideation.

After that, a new grouping of the pictures was formed, where the pictures of the centre stack and the steering wheel, corresponding to the same car, formed a group. This grouping enabled counting the number of features for each (car). Based on that, a compilation could be made, illustrating how the number of features varied among the cars studied. After that, a conclusion about the “average” number of physical features could be drawn. That insight was then used to select a car as the baseline car for the rest of the project. A future final concept could then be compared with the baseline car to see whether a reduction of features has been made and, if so, to what extent.

3.2.2 User Study 1

User study 1 was a contextual inquiry, which is recognised as an effective method for comprehending user behaviour and usage contexts (Holtzblatt & Beyer, 1997). This approach facilitates a natural interaction between users and the product, service, or system during the study, making it particularly valuable during the initial stages of the design process, where deep understanding is crucial. The objective of utilising the Contextual inquiry method was to have the opportunity to ask questions and discuss directly with the users, thereby creating a deeper understanding of the driving situation and the factors affecting their experience. It was, therefore, complementary to user study 2, which instead focused on self-reflection. Executing the interview in the car, in the proper context, was also helpful since it worked as a mediating tool (Conole, 2009), which was necessary as the complexity of cars is high, which is difficult to imagine.

The Contextual inquiry method was applied to this study and was divided into two distinct parts with partially different aims. However, it still benefitted from having its base in the contextual inquiry method. The first part aimed to identify basic requirements, which can be explained as features in the car that the user usually takes for granted; however, if they are missing or malfunctioning, they can quickly become noticeable and lead to dissatisfaction.

To identify these requirements, the participants assumed the role of a driver in a parked car whilst a driving scenario through the city centre of Gothenburg was read to them. The scenario was read in sections, and after each read section, the participants were asked to mention what features they felt necessary when imagining being the driver for that particular section of the scenario (see Appendix 1, Part A). During this part of the study, the car panel was concealed to prompt participants to identify the most essential features and not get affected by the features they may not need in today's cars.

The fundamental insights about basic features were considered crucial for ensuring that features perceived as essential by users but necessarily contribute to a better experience are not overlooked. Even though basic features might not contribute to an extraordinary experience when being there, they still need to be there; otherwise, the user will become dissatisfied with their drive. When the scenario was finished, the approach was reversed, and the users were asked to specify which features they considered unnecessary and could possibly be removed from the car.

In the second part, the participants engaged in a semi-structured interview, still within the car but with the panel uncovered. This part of the interview aimed to delve deeper into factors affecting users' experience of driving the car, both on a detailed level by looking into single features and on a higher level by discussing general factors affecting their experience. The interview structure was based on Jordan's four pleasures to ensure that insights regarding all pleasures were collected during the inquiry (see Appendix 1, Part B).

The study was executed in a Lynk & Co 01 car model since it was considered to represent an average number of features in the car, which was a preferable baseline for this study. As previously mentioned, the inquiry was executed in a standstill car due to insurance constraints. The duration of the studies varied from about 40 minutes to 1 hour.

A purposive sampling method was applied for this study, which is valuable for qualitative studies when the researcher already has a good idea of what needs to be studied and what kind of data needs to be gathered to generate insightful data (Berndt, 2020). Therefore, the sample for this study was selected based on a few key characteristics of the users. Age was the first selected key characteristic since it is a factor that has a significant impact on driving experience. Gender was selected since it was considered to impact factors affecting the driving experience.

Occupation was considered an essential characteristic since having an occupation involving car usage would likely impact familiarity with cars and their features and, consequently, affect feature preferences. Nationality was also considered essential since it could impact familiarity with the car used for the study and what factors affect the driving experience. Therefore, this study considered the following key characteristics: age, gender, occupation and nationality.

The sample consisted of 6 participants, with a proportion of 66% men and 33% women. The occupations were of varied nature, including students as well. Furthermore, three nationalities also represented the sample (see Table 3.2).

Table 3.2: Sample from User Study 1

ID	Age	Gender	Occupation	Nationality
Q1	25	Female	Student (Interaction design)	Swedish
Q2	28	Male	Student (Interaction design)	Swedish
Q3	37	Female	Administrator	Chinese
Q4	40	Male	Receptionist	Swedish
Q5	40	Male	UX-designer	Swedish
Q6	59	Male	Property manager	British

The analysis of User Study 1 was divided into two sections, aligning with the two parts of the study: the scenario analysis and the interview analysis. These aimed to identify which features were considered basic or indifferent and to collect data on the factors influencing the driving experience. The first part, which aimed to identify basic and indifferent features, was analysed using the Kano model.

The Kano model aims to evaluate and analyse existing products or systems in terms of different types of user needs. The Kano model builds up a two-dimensional area with user satisfaction on the Y-axis and execution on the X-axis (see Figure 3.2). Features of a product or system can then be placed within the Kano model concerning these variables. By employing this model, it becomes feasible to discern the features that users perceive as basic features ("must-be"), those they view as performance-enhancing features and expect to increase linearly, those they do not anticipate but perceive as excitement features, and those they consider indifferent, meaning their presence or absence is inconsequential (Wikberg-Nilsson et al., 2015).

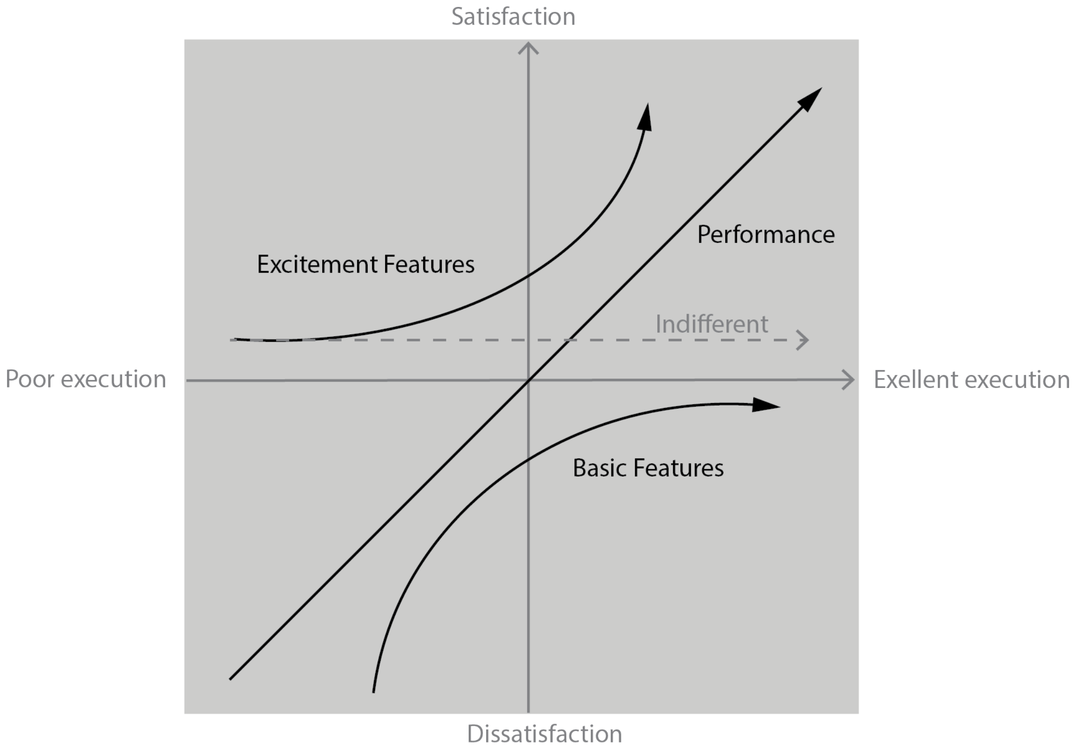


Figure 3.2: Illustration of the Kano model

The scenario part of user study 1 utilised the Kano model to analyse data by organising it into various feature groups: basic, performance-enhancing, excitement, and indifferent. Throughout the scenario stages, participants were prompted to identify the features they felt were necessary for driving. Following the scenario, the approach was reversed, and participants were asked to specify which features they considered unnecessary (indifferent).

All features mentioned by the users during the study were written down on Post-it notes and placed under one of four categories (basic, performance-enhancing, excitement, and indifferent). This classification stemmed from transcripted recordings of the study, where expressions of preferences regarding a specific feature could clarify which of the four categories the feature should belong to.

The second part of user study 1, the interview part, which aimed to collect data about factors influencing the driving experience, was analysed using a KJ analysis method. The KJ analysis is an analysis tool intended to help organise diverse information. It aims to combine diverse ideas or opinions to organise and cluster them into logical themes and groups. Dividing the collected data will help make sense of the amount of information and identify patterns (Bergman & Klefsjö, 2010).

The voice-recorded data from the interview was transcribed and read carefully, and then, the essentials regarding the driving experience were concretised and written on post-it notes. These were then organised and clustered into groups, each group representing a factor affecting the driving experience. An additional dimension to the KJ analysis was the division into Jordan's four pleasures (Physio, Psycho, Socio, Ideo), which enabled the identification of the connection between pleasures and factors affecting the driving experience.

3.2.3 User Study 2

User study 2 was built upon the methods of Reflective Photography and a UX curve, which were combined. Reflective photography is a method that allows users to take photos of their choice based on the task/tasks given to them, where the tasks usually strive to get the user to take pictures of what affects their impressions and feelings related to a specific context (Harrington & Lindy, 1999). On the other hand, the UX curve is a method that focuses on how the users' experience with a particular product or service has developed over time. The experience should then be plotted in a two-dimensional diagram where the Y-axes represent the user experience from negative to positive, and the X-axes represent the time of using the product or service (Kujala et al., 2011).

The objective of using Reflective photography in this project was to enable the users to reflect on features affecting the experience of driving the car and take photos of that. The pictures were supposed to stimulate the users' own reflections but also work as a helpful tool for the researcher when analysing the data later on. The objective of the UX curve, on the other hand, was to identify trends in the time perspective of the trips, for example, if the beginning, middle, or end part of the trips had something in common among the trips studied. Combining these two methods generated an additional objective. When features affecting the experience from the Reflective Photography were also plotted in the UX curve, a number indicating the level of satisfaction/dissatisfaction was given, and a comparison among the various features influencing the experience was enabled.

To summarise, applying a combination of these two methods could answer three main questions: *What* features influence the users' experiences, *when* during the trip does it affect them, and *how* does it affect them? The Reflective photography and UX curve aimed to capture a significant number of features affecting the driving experience, which then can be compiled and analysed to pinpoint which common factors are the most essential affecting the driving experience.

The user's task was to reflect on two everyday trips of their choice when going as the driver of their own car (not as the passenger). While driving, a reflection should be made on factors affecting the experience (negatively or positively), and photos of features that influence the experience have to be captured. The next step of the task was to write up a diagram for the UX curve, either by hand or digitally and plot the photos on the curve. When plotting, they had to consider the two dimensions in the diagram: time (when it happened) and experience (positive or negative). To facilitate the analysis, the users were required to provide brief descriptions of each photo detailing the emotions and thoughts associated with the pictures.

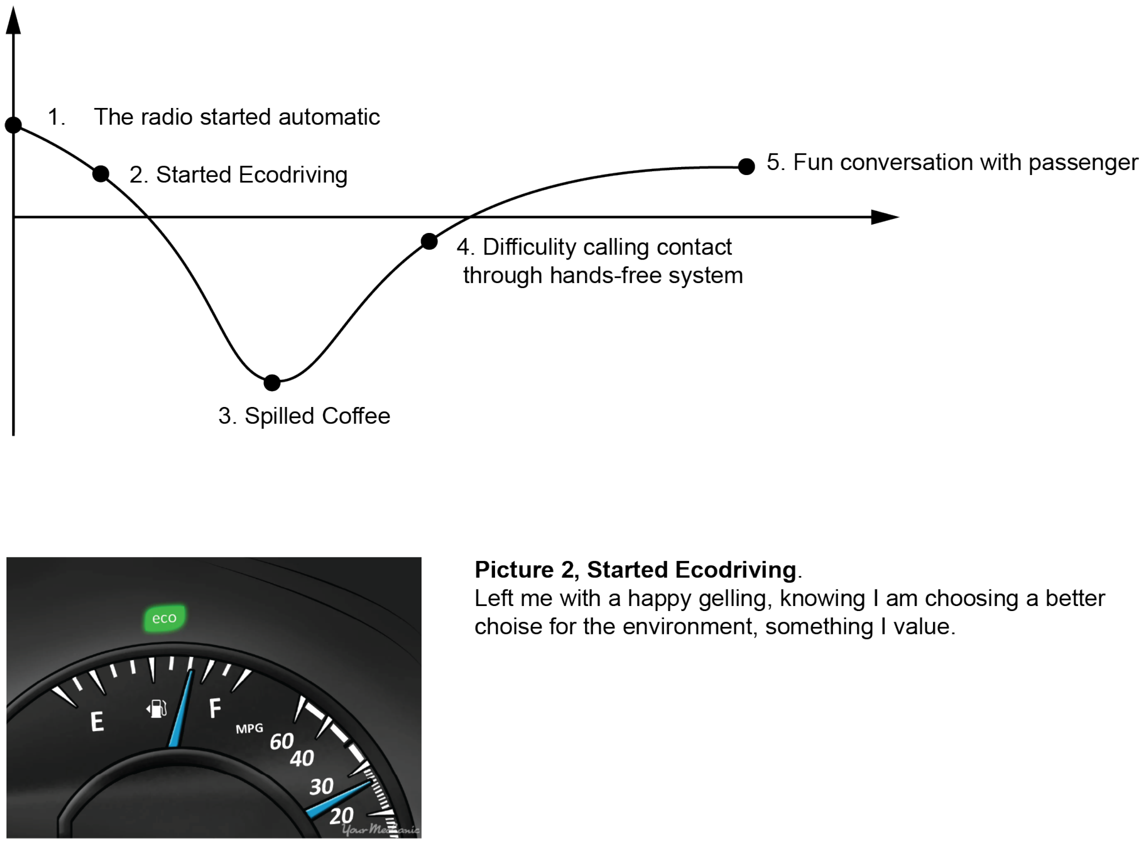


Figure 3.3: An example of the task sent to the users

To better understand the task, the users were given an example of what a completed task could look like (see Figure 3.3), with the only difference being that the users were supposed to deliver photos and a short description of all plots on the curve.

The users had two weeks to complete the task. After that, the UX curves with accompanying photos and describing texts were to be sent in by email. After compiling all received trips, there were 20 trips in total.

As for the contextual inquiry, a purposive sampling method was used even for the Reflective photographs. However, the same key characteristics were only partially applicable to this study. Age and gender remained key characteristics with the same argument as in Study 1. However, car brands and their production year were of interest instead due to the usage of their own car in the study. A broad variation of cars would generate a general representation of the factors affecting the driving experience, which were considered beneficial for the result. In summary, the sample for this study was, therefore, decided to be based on the following key characteristics: gender, age, and type of car driven (brand). The sample consisted of 12 participants and had a proportion of 66% males and 33% females. The sample also resulted in a significant variation of driven car brands, with seven brands represented (see Table 3.3).

Table 3.3: Sample from User Study 2

ID	Age	Gender	Car brand + production year
P1	23	Female	Volvo (2009)
P2	26	Female	Volvo (2015)
P3	27	Female	BMW (2016)
P4	29	Male	Chevrolet (2012)
P5	31	Male	Kia (2021)
P6	40	Male	Kia (2013)
P7	43	Male	Passat (2012)
P8	48	Male	BMW (2019)
P9	48	Male	Saab (2021), bus
P10	54	Female	Volvo (2015)
P11	59	Male	Volvo (2023)
P12	62	Male	Audi (2019)

The analysis of User Study 2 began with writing down the short descriptions written by the users on yellow post-it notes, accompanied by a numerical rating indicating the position of the plot on the UX curve (ranging from -5 for very negative to +5 for very positive). Below are some examples of situations affecting the driving experience written by the users. The example is just a selection of a total of 80 post-it notes (see Figure 3.4).

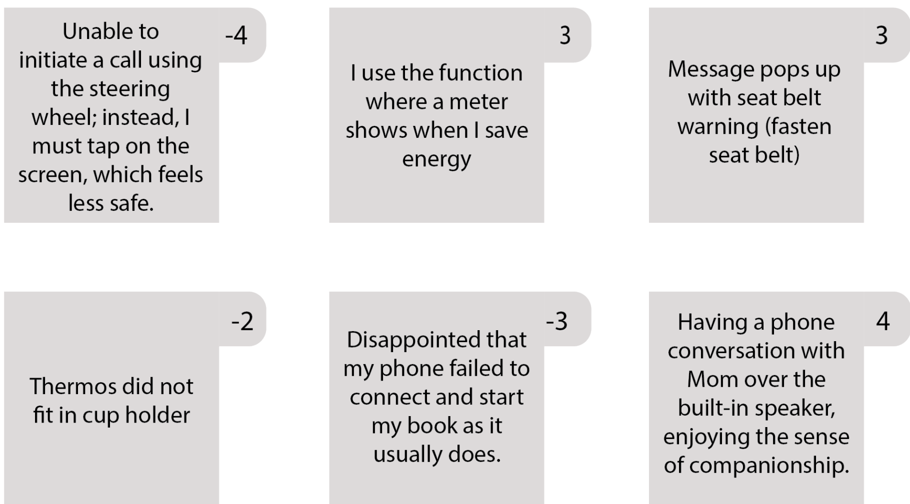


Figure 3.4: Post-its with descriptions of situations affecting the driving experience

Situations that affected the driving experience but occurred outside the scope of the project (cluster, steering wheel, centre stack, display) were filtered to be excluded from the project. Those situations could, for example, have been influenced by external factors such as weather conditions or traffic queues.

A KJ analysis built on the four pleasures (like in user study 1) was then utilised. Each post-it note was placed under a pleasure, and subgroups were created (see Figure 3.5), where each subgroup represented a factor affecting the driving experience.

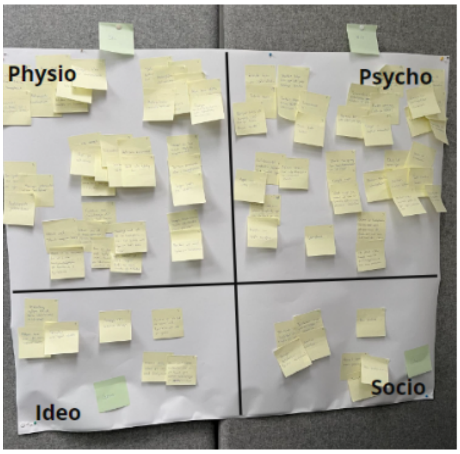


Figure 3.5: KJ analysis divided into the four pleasures

The reflective photographs collected from the study (see Figure 3.6) supplemented the written descriptions and helped better understand the data. In cases where the descriptions were unclear, the corresponding photograph provided a comprehension of the situation encountered.

Figure 3.6: Example of a photograph taken by a user

In order to examine the UX curves for discernible patterns within the collected data from user study 2, all curves were visualised on a single picture (see Figure 3.7). Each plot on the picture, which represented a factor affecting the experience, was assigned a colour, either blue (physio), red (Psycho), green (ideo) or purple (socio).

The colouring was based on the pleasure they had been assigned in the KJ analysis. Based on that compilation and visualisation of the UX curves, patterns could more easily be found.

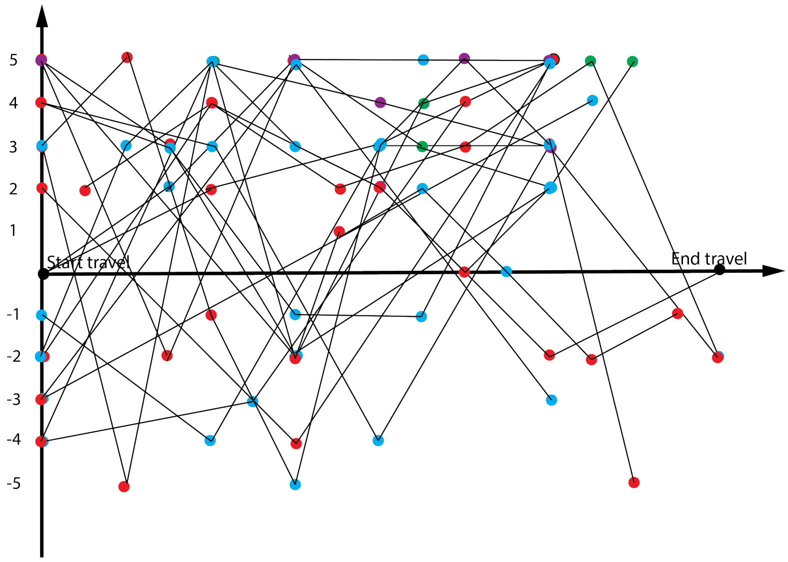


Figure 3.7: A compilation of the UX curves

3.3 Compilation of User Study 1 and 2

The compilation was intended to unify the analysed data from User Study 1 and User Study 2. The compilation was divided into two parts: a compilation of factors affecting user experience and a compilation aimed at seeing whether the required features identified from User Study 1 corresponded to factors affecting user experience found from User Study 2.

Since the factors affecting the user experience had emerged from user studies 1 and 2, a joined list, still divided into the four pleasures, needed to be compiled to get a better overview of them. However, the factors from the two user studies sometimes overlapped. A new title describing all the overlapping factors was created for the compiled list in these cases. The compiled list formed the basis for the final result of the analysis, the requirement list.

The information from the compilation of factors affecting user experience was used to assemble a requirement list. The subjective data collected from the two user studies, which derived the factors, supported when setting the specific requirements. The requirements set in the list were also divided into the four pleasures (Physio, Psycho, Socio, Ideo) to identify the requirements' origin. However, certain factors were considered to belong to two pleasures, which were then clarified in the requirement list.

In addition to the requirement list, four design guidelines were created to support the upcoming concept development. The design guidelines included the major context-specific findings that emerged from the user studies and were therefore highlighted in terms of design guidelines to ensure that the development of concepts was going to be well suited to the city context in which that project worked. The main topics of the design guidelines were distraction, overstimulation and usability.

The second compilation aimed to analyse whether the identified features from the Kano model matched the factors affecting the user experience. The compilation illustrated which features from the Kano model (basic, performance-enhancing, indifferent, or excitement) was required in order to support all the identified factors affecting the user experience. Based on this insight, a decision could be made on which features were required in the car and which could be left out since they did not match the identified factors and were not seen as features contributing to a better user experience.

3.4 Allocation of features in the four focus areas

From the beginning of the project, the cluster, steering wheel, display, and centre stack have been the four focus areas of the interface. These areas became even more essential when the process proceeded to the more creative phase since the ideation was decided to be based on these four areas in particular. That decision was taken due to the complexity of the interface and the high number of features it came with. Considering all requirements during an ideation might have limited rather than stimulated ideas. However, to enable ideation based on the four areas, the required features previously identified in the process also needed to be assigned a specific place in one of the four areas of the interface.

The allocation of features was done using Post-it notes, where each required feature was written on one note. Furthermore, four categories with the headlines, cluster, steering wheel, display and centre stack were created. Then, the notes with features could easily be placed under the category best prioritising the feature based on user insights from the user studies. Besides that, features were allocated in a way that did not challenge the users' mental models, as identified in User Study 1, of where features are usually placed in the cars. Users' preferences, also identified in User Study 1, were considered when allocating the features.

3.5 Ideation

When the features had been placed in either of the four areas, the project proceeded to a new stage, a creative stage, where design ideas for the four categories were created based on the requirements specified in the requirement list. The ideation was built upon a creative workshop with design students, where the focus was on the centre stack and cluster and then ideation within the project team of all four areas.

3.5.1 Workshop

A workshop was conducted as the first part of the ideation. It was used since it is a dynamic approach that enables creativity in a group constellation. Invited participants could be, for example, experts in the field of interest, a specific user group, or just a group without any connection to the project. This method aims to use the group's creative potential and explore areas of interest for the project, depending on what the researcher finds most useful (Wikberg-Nilsson et al., 2015).

This approach was applied in this project to find creative solutions for the cluster and the centre stack since they were considered the two areas with the most potential in exploring the design and composition of the required features and the design of the area as a whole. Six participants were invited to the workshop, all design students, which meant a certain amount of creativity and experience in similar situations were expected, which was considered to contribute to a better workshop result.

The workshop was divided into two parts: the first investigating the centre stack and the second investigating the cluster. In the first part, the six participants were divided into three groups, with two participants in each group (see Figure 3.8). Each group got pens, white papers, and papers with a pre-sketched car panel excluding features. Their task was to develop ideas for a centre stack that should fit electric cars, which is an assumption of how most cars will be powered in 2030. That meant they were not limited to the layout of today's centre stack; instead, the space between the front seats in the car could be explored and used in other ways. During the session, the participants were shown inspirational pictures of futuristic car concepts of the centre stack to stimulate their creativity regarding the topic.

Figure 3.8: First part of the workshop, ideation in group of two

The participants received a list of the features required for the centre stack to be represented in their concepts. The required features were:

- Shifter (with the modes R, N, D, P)
- Regulation of climate (seat heat, heat in steering wheel and air temperature)
- Start/Stop of engine
- Storage of mobile (charging possibilities), keys and drinks.

Some of the required features placed in the centre stack, such as the hazard warning light, were left out of the workshop to narrow its scope and let the participants pay attention to the features that were considered to have the most potential to generate new creative ideas of its design.

When creating the concepts, the participants were supposed to consider two main aspects: the placement of features and the design of features, which needed to be physical. Furthermore, they were given three guiding words to keep in mind to strive for in the design: minimalistic, reachable, and understandable. The time limit for the session was 20 minutes, followed by a group discussion in which all groups presented their concepts and got a chance to comment on each other. The participants were also given written instructions for the session, which they could read as many times as they wanted to recap their memory of the task during the session (see Appendix 2, Part 1).

As previously mentioned, the second part of the workshop investigated the cluster. However, the cluster was ideated using another method, Braindrawing. Braindrawing is an ideation method that can generate many ideas in just a few minutes. The method stimulates creativity by letting the participants see each other's sketched ideas. The execution is simple. It starts by introducing the topic of interest the researchers want to explore and defining what will be ideated around, preferably by framing a question. Each one of the participants receives a piece of paper and sketch ideas for a few minutes. When the time passed, all the participants sent their papers to the participants sitting next to them. The participants could then decide whether to continue with the sketch they received or begin a new one, but still on the same paper. When one more round of sketching has passed, it is time to send over the papers again, and when all participants have sketched on all papers once, the session ends (Wikberg-Nilsson et al., 2015).

For this project, the cluster was ideated using the Braindrawing method (see Figure 3.9), with the same participants as in the ideation of the centre stack since it was considered just a continuance of the workshop. Braindrawing was chosen as an ideation method for the cluster for various reasons. Firstly, it gave the workshop variation, keeping the participants sharp, creative, and engaged throughout the workshop. Secondly, since the cluster is a minor focus area compared to the centre stack in terms of the required features, it was reasonable that the participants ideated this area one by one, not having a discussion 2 by 2 to come up with sensible ideas. Thirdly, since the cluster only consists of visual features, choosing a method exclusively using a visual representation tool like sketching was reasonable.

Figure 3.9: Part two of the workshop, ideation by Braindrawing

The task the participants received for the braindrawing session was to develop concepts for the cluster as a whole and investigate how required features could be visualised to make the information easily accessible and understandable for the user while driving. The required features were:

- Speedometer
- Fuel gauge (electricity)

As for the centre stack, some of the required features previously placed in the cluster, such as the indicator lights, were left out in the workshop. The indicator lights, in particular, are regulated according to laws; therefore, they can not be changed. However, other features were also left out of the workshop since they were considered to have low potential in generating new creative ideas for the visualisation.

The participants were shown inspirational pictures of futuristic cluster concepts to stimulate their creativity regarding the topic. The pictures represented various types of cluster shapes and different visualisations of the included features— and the selection of pictures aimed to generate as broad variation as possible. The participants were also advised to add features in the cluster if they believed it could have contributed to a better driving experience. Since it was seen from the analysis that a good driving experience in the city context was closely related to the features directly related to the actual driving, it felt reasonable to ideate around additional potential features that may enhance that experience. However, compared to the centre stack, the cluster is more closely related to the actual driving situation, and therefore, this aspect was exclusively investigated for the cluster. The time limit for the session was set to 6x2 minutes, followed by a group discussion in which everybody presented their concepts and got a chance to comment on each other sketches. The participants were also given written instructions for the session, which they could read as many times as they wanted to recap their memory of the task during the session (see Appendix 2, Part 2).

As a final summarising task of the workshop, the participants were told to choose which concepts from the workshop were their favourites. Each participant received eight stickers; four of them were supposed to be placed next to their favourite concepts from the ideation of the centre stack and the rest next to their favourite ideas from the ideation of the cluster. That gave a brief indication of which concepts the participants saw the most potential in and helped prioritise concepts when further taking them into the brainstorming session.

3.5.2 Brainstorming

After the workshop, brainstorming within the project team was executed to develop the ideas already created from the workshop. It was also used as an ideation method for the display and steering wheel, which have yet to be investigated.

Brainstorming is equal to braindrawing since it stimulates creativity by letting the participants see and hear each other's ideas. Like Braindrawing, the session begins by introducing the topic of interest the researchers want to explore and defining what will be ideated around, preferably by framing a question. The participants then either write or sketch their ideas during a predefined time for the session (Wikberg-Nilsson et al., 2015).

For the cluster and centre stack, the ideas that emerged from the workshop ideation were compiled and used as inspiration for the brainstorming session within the project team. For the brainstorming of the centre stack, the benchmark also worked as a source of inspiration, notably since it concluded which type of controls the various brands had picked for particular features, for example, a button, wheel or lever, to mention a few types of witnessed controls from the benchmark. However, based on the ideas and concepts from the workshop and the benchmark, new ideas were created, and already existing ideas from the workshop were developed during the brainstorming sessions of the centre stack and the cluster.

Since the steering wheel was not a part of the workshop, the brainstorming of this area had to start from scratch. However, inspiration was found from the benchmark of *how* features on the steering wheel have been physically represented in various car brands, for example, with buttons or other types of controls. It was also seen from the benchmark *where* particular features were usually placed on the steering wheel and *what* symbols were generally selected to represent the various features.

Inspired by this, a brainstorming session was executed where ideas regarding the steering wheel were created.

For the Display, an adapted version of brainstorming was used to generate ideas. Since the display is relatively standardised in the design of its required features, with the GPS, Apple Carplay, and Android Auto, the focus for the ideation of the display was not single features; instead, the focus was on the layout and structure of the required features within the home page of the display. Since the display has a digitalised interface with many interactions and connections, the brainstorming was executed in Figma, a software that can easily be used to visualise ideas and concepts of this type. The brainstorming of the display was executed individually by the project team members, not to get influenced by each other. Usually, brainstorming sessions aim to get the participants influenced and inspired by each other by watching each other's ideas, but in this case, getting a variation of ideas was considered more likely without influencing each other, and therefore, the ideation of the display was done individually.

3.6 Prototype development

The ideas generated from the workshop and brainstorming sessions created prototypes for each of the four focus areas. The prototypes were created based on set requirements from the requirement list. Still, the focus was on fulfilling the set design guidelines, which were considered the most important factors for making the prototypes specifically applicable to the urban context.

3.6.1 Prototyping

When the ideas had been decided and created, they were visualised using prototypes, a method used to make untouchable ideas visible to others, either the project team members or users. Prototyping can be used for several reasons: to understand a problem, to communicate ideas, to test and improve ideas or products, and to advocate a result, which means prototyping can be useful in several parts of a design process (McElroy, 2016).

For this project, prototypes were made to evaluate the ideas created. Communicating the ideas clearly to the users through prototypes was considered vital for generating a credible evaluation. Due to the four focus areas' various characteristics, both digital and physical prototypes were created to visualise the ideas.

Since the centre stack and the steering wheel exclusively consisted of physical features, physical prototyping was suitable for these ideas. The prototypes were done like mock-ups, a full-scale model often used to test interiors such as cars or aeroplanes when space is limited and needs to be considered in the design (Wikberg-Nilsson et al., 2015). The material used for the physical prototypes was Capa-boards.

Since the display and cluster, on the other hand, exclusively consisted of digital features, digital prototyping was the most suitable for these two focus areas. The software used for the digital prototypes was Figma, which enabled visual representation and interactions with the interface, which were considered useful for the evaluation of these ideas.

3.7 Evaluation with users

When prototypes had been created for all areas (a total of eight prototypes: two for the cluster, one for the steering wheel, two for the display and three for the centre stack), an empirical evaluation took place where users gave their input and preferences on the prototypes. Empirical evaluation methods can be utilised either in a formative or summative manner, depending on where in the design process it is utilised. The evaluation is based on the user input on the actual product, which can then be evaluated against set guidelines or requirements. Empirical evaluation methods can generate subjective or objective data depending on the selected method (Verschuren & Hartog, 2005).

For this project, empirical evaluation was done for formative purposes to gain insight into which prototype was best performing based on set requirements and design guidelines, mainly to gain insights into how that prototype could be further improved. For evaluation purposes, the interview method enables a discussion between the user and the researcher, which can create a broader understanding of the prototypes and help when deciding which prototypes to bring further (Jordan et al., 1996).

For this project, the interview was considered the best evaluation method due to the complexity, with many features to consider, and was therefore used as an evaluation method for all four focus areas. The interviews focused on generating insights about the design guidelines, which were the main focus even when creating the prototypes. Furthermore, the interviews also enabled discussions about both single features as well as the overall prototype, generating a broad understanding of the prototypes, detailing what was good and what could be further improved based on set guidelines and requirements. The prototypes also enabled the users to interact with the ideas, generating valuable insight into the perceived user experience of interacting with the prototypes, which was helpful information when selecting the final prototype.

The interviews were conducted semi-structured to ensure that specific questions regarding design guidelines and requirements were answered. However, the parts that concerned the overall impression of the prototypes were more open for discussion, enabling the user to share information of their choice and highlight specifically important aspects to them.

The evaluation was divided into two sessions: one for the physical focus areas and one for the digital. In other words, the centre stack and steering wheel were evaluated in the same session, and the cluster and display were evaluated in the other. The evaluation was split like this to make it manageable and allow a more detailed evaluation of single features. Evaluating the whole interface, consisting of all four focus areas jointly, may have been overwhelming for the users due to the significant scope of the project, which could have negatively impacted the result of the evaluation.

3.7.1 Evaluation of Steering wheel and Centre stack

The session involving the physical areas was executed with five participants, with the gender division 60% female and 40% male. All with a background in either industrial design engineering or interaction design engineering. The age span of the participants was 23-28 years.

The physical evaluation started by introducing the centre stack's three prototypes, each with a description of its main idea. Then, the users had the opportunity to interact with the prototypes themselves while answering interview questions regarding distraction, overstimulation, and usability (the main topics of the design guidelines) for all three prototypes.

When the three prototypes for the centre stack had been evaluated, the focus went to the steering wheel, where the interview was structured similarly. However, more focus was on evaluating usability since distraction and overstimulation were not considered equally distinctive problems for the steering wheel compared to the other three focus areas.

3.7.2 Evaluation of Cluster and Display

The session involving the digital areas was executed with five participants, with the gender division of 80% female and 20% male. All with a background in industrial design engineering. The age span of the participants was 23-38 years.

The digital evaluation started with the display, which had a different structure compared to the other three areas. In addition to the interview, the display was also evaluated by a practical usability test since it was the only focus area where tasks involved multiple interactions in being completed.

The users' satisfaction with executing the tasks was considered the most essential part of the usability test. Therefore, the subjective input the users gave afterwards about their experience interacting with the prototypes was of more interest than the objective measures, such as time for completing a specific task or number of errors. The subjective input about the satisfaction of the usage gave a more holistic picture of the usability and the experience of using the prototypes, which was helpful when selecting a final prototype.

The tasks the user was supposed to execute were selected based on the factors affecting the user experience identified from the user studies, like the accessibility of media, the number of interactions, and the possibility of phone calls; a more detailed list is presented with the findings later on; therefore, tasks related to those factors were constructed. The tasks were as follows:

- Turn on the radio channel called Mix Megapol (media system)
- Set the navigation to "home" (navigation system)
- Call "mother" (spoken communication)
- Control the tyre pressure (car status)
- Turn on Apple CarPlay (connection of phone)
- Turn off the display to not get distracted (overstimulation)

The usability test was followed by an interview with the same structure as for the evaluation of the steering wheel and the centre stack. During the interview, the users had the opportunity to interact with the prototypes themselves while answering questions regarding distraction, overstimulation, and usability for all three prototypes.

When the two display prototypes had been evaluated, the focus switched to the cluster. The evaluation of the cluster's prototypes was executed similarly to the steering wheel and the centre stack, with a brief description of the two prototypes before the users had the opportunity to interact with them while answering interview questions regarding distraction, overstimulation, and usability for all three prototypes.

3.7.3 Analysis

The evaluation was analysed in four separate parts corresponding with the four focus areas (cluster, steering wheel, display and centre stack). Since the evaluation sessions were video recorded, transcribing them was the first step before the analysis could start. After that, all answers to one specific question were clustered to understand better the users' common opinions on a particular question. Input from more open discussions about, for example, how the prototypes prevented distraction and overstimulation, was also clustered to get a more comprehensive understanding of the input from the users.

The analysis mainly focused on how well the prototypes performed in preventing distraction and overstimulation and whether the prototypes provided good usability, which were the main topics from the design guidelines and also the main focus when designing the prototypes of the four focus areas. In addition to the design guidelines were the analysis also based on the specific requirements from the requirement list. However, all requirements were not relevant for evaluating all four components (see Table 3.4); for example, the requirements corresponding to physical pleasures were considered more appropriate for evaluating the centre stack and the steering wheel due to their physical character.

Table 3.4: An illustration of evaluated requirements for each area

ID	Constraint: The product should...	Relevant for evaluation of...
1.1	Enable adjustability of climate	Centre stack
1.2	Provide good reachability	Centre stack, steering wheel, display
1.3	Provide a good sound environment	Centre stack, steering wheel, display, cluster
1.4	Enable adjustability of sound	Steering wheel, display
1.5	Enable physical identifications of buttons	Steering wheel, centre stack
1.6	Facilitate minimal user interactions for completing tasks	Centre stack, steering wheel, display
1.7	Provide driving assistance	Steering wheel, cluster
1.8	Provide good sight	Cluster
1.9	Support priorisation of functionality and information	Centre stack, steering wheel, display, cluster
2.1	Enable easy accessiblility of sound media	Steering wheel, display
2.2	Enable information about sound media	Display
2.3	Allow custumisation of sound media	Steering wheel, display
2.4	Prevent overstimulation	Centre stack, steering wheel, display, cluster
2.5	Prevent distraction	Centre stack, steering wheel, display, cluster
2.6	Be compatible with phones	Display
2.7	Allow charging opportunities for electronic devices using 12V	Centre stack
2.8	Ensure understandable features	Centre stack, steering wheel, display, cluster
2.9	Provide clear safety reminders	Cluster
3.1	Enable presence of passengers	Centre stack
3.2	Allow passengers to interact with non-driving tasks	Centre stack, display
3.3	Enable communication through phone calls	Steering wheel, display
3.4	Enable written communication	Steering wheel, display
4.1	Enable information about the environmental effects while driving	Cluster
4.2	Enable environemntal friendly choices	Centre stack
4.3	Support safe driving	Centre stack, steering wheel, display, cluster

Four prototypes, one for each of the four focus areas, were selected from the evaluation based on how well they performed against set design guidelines and requirements. However, all four selected prototypes were given input on potential improvement areas. The improvement areas for all four prototypes were compiled and formed the basis for further development.

3.8 Development of Final Concept

The four selected prototypes for the four focus areas could be redesigned and further developed based on the compiled lists of improvement areas. Some improvement areas were minor and easily fixed, while others, especially for the centre stack, required more effort to find the best way forward. The redesigns were made digitally in Figma for the cluster and the display and detailed sketches for the centre stack and steering wheel.

Until this process stage, the four focus areas (cluster, steering wheel, display and centre stack) had been developed separately; however, with a common aim - to prevent distraction and overstimulation and provide good usability. When the four redesigned prototypes for the four focus areas for the first time were going to be assembled, it was done by 3D modelling. The redesigned prototypes were built up digitally and created a holistic concept.

The 3D modelling also came with some finalising visualisation work. Colouring and form-giving work were made in order to create a coherent, holistic final concept. The visualisation work of the holistic concept was considered to contribute a lot to the perceived experience of the final concept. Therefore, the last visualisation work was one of the most essential parts in the development of the final concept.

3.9 Final Evaluation

A theoretical evaluation was conducted to evaluate whether the holistic final concept should contribute to a good user experience. The theoretical evaluation focused mainly on the usability aspect of the final concept since it was considered to have a risk of being affected by assembling the four components. The other two aspects from the design guidelines - preventing distraction and overstimulation, were not considered to have the same risk of being affected when assembling the four focus areas into one holistic concept since usability was considered to be the more extensive factor, covering both overstimulation and distraction. Thus, an interface with fewer distractions and less overstimulation was supposed to result from improved usability. For example, suppose the evaluation indicates that tasks can be solved with good usability, efficiently and without confusion. In that case, the user is most likely not either overstimulated or distracted while executing the task since that had also affected the usability.

The theoretical evaluation of the final concept was based on two methods: CW (cognitive walkthrough) (Lewis et al., 1997) and PHEA (predictive human error analysis) (Embrey, 2004), which approach usability from various perspectives. However, executing the two methods required preparation in terms of selecting which tasks to evaluate, tasks that one should imagine the user should execute, and identifying interface flaws regarding usability aspects.

3.9.1 Selecting Tasks

Evaluating all tasks the user could execute in interaction with the interface would for sure be the best alternative to identify all possible usability problems. In this case, an enormous number of tasks could be executed with an interface consisting of a significant number of features. Therefore, tasks needed to be carefully selected to narrow the scope of the evaluation. However, choosing the “right” tasks to evaluate could be considered to cover those tasks left out of the evaluation. For example, if two tasks are executed similarly, but one is considered slightly more difficult to execute for some reason, only the somewhat more difficult task was evaluated since it would cover all possible usability flaws for both tasks. This approach was applied when selecting which tasks to include for the evaluation of the final concept.

The following list consists of seven categories, covering all possible tasks for the interface. Under each category are the selected tasks presented, and next to some of them follows a comment on which other task has been excluded due to its similarity or its simplicity compared to the already selected task.

- Basic Driving
  - Select drive mode (select all other gears was excluded)
  - Start engine (Stop engine and turn on hazard warning light were excluded)
  - Use the Car Horn
- Climate
  - Change air temperature (change airspeed was excluded)
  - Turn on seat heat (turn on steering wheel heat was excluded)
  - Use Auto (Use A/C was excluded)
  - Turn on the defrost on the front windshield (turn on the defrost on the back windshield was excluded)
- Media
  - Change song
  - Change media
  - Adjust the volume
  - Check media information
- Navigation
  - Set any destination on navigation (set the home destination on navigation was excluded)
  - Follow navigation directions

- Phone
  - Connect phone with Apple CarPlay (connect phone with Android Auto was excluded)
  - Call a contact
  - Activate reading assistance of messages
- Driving Assistance
  - Activate adaptive cruise control (activate lane control was excluded)
- Driving Information
  - Check speed
  - Check electricity gauge
  - Solve safety messages
  - Note electricity consumption
  - Check tyre pressure
- Storing
  - Use the phone storage (use the car key storage was excluded)
  - Use the cup holder (use drawer storage was excluded)

Some of the tasks in the list, mainly those under *Driving Information*, were more related to understanding specific information than physically executing a particular task. However, they were still included in the list of tasks since understanding the presented information can also depend on usability aspects, which was what the CW and PHEA were evaluating in the next stage. A combined template of CW (Lewis et al., 1997) and PHEA (Embrey, 2004) was used for the evaluation of the tasks. In those cases where the understanding of presented information was evaluated, a revised version of the template was used to fit those particular tasks better.

3.9.2 CW

CW constituted the first part of the theoretical evaluation and aimed to evaluate users' mental processes required to solve a specific task. The analysis was built upon four questions (Lewis et al., 1997, pp. 722-723):

1. *Will the user be trying to achieve the right effect?*
2. *Will the user notice the correct action is available?*
3. *Will the user associate the correct action with the desired effect?*
4. *If the correct action is performed, will the user see that progress is being made?*

These four questions were answered for all tasks from the list. If the answer was "No" to some of the questions, the identified problem causing that "No" answer needed to be stated in the template.

3.9.3 PHEA

PHEA constituted the second part of the theoretical evaluation and aimed to predict errors when executing a task and identify how these errors can be recovered. This evaluation was executed in five steps: first, describe the error and then explain what caused it. After that, describe the consequences of the error and then how the error could be discovered and finally recovered (Embrey, 2004).

Some of the information-related tasks were not applicable to the PHEA since it focuses more on practical errors. In these cases, the CW formed the basis for the evaluation. However, the PHEA was a valuable tool for evaluating the other, more physically executed tasks.

3.9.4 Analysis

The final analysis of the holistic evaluation aimed to identify patterns from the CW and PHEA and create an understanding of how the final concept performed from a usability perspective.

The analysis was divided into two parts: the first part analysed the more practical tasks (see Appendix 3, Part A), such as "Adjust air temperature," and the second part analysed the more informative tasks (see Appendix 3, Part B), such as " Check the speed." However, the procedure for analysing the two parts was the same.

The procedure started by clustering answers from all practical tasks on question one from the CW. By clustering the answers for the same question, it was easy to get an overview of all tasks and identify whether any commonalities had been applied to the interface of the final concept, which in turn could have affected the usability.

The same clustering was made for the other three questions from the CW to possibly identify new patterns among the tasks and other interface flaws from a usability perspective.

The PHEA analysis was performed almost in the same way as for the CW. All answers were clustered based on the five categories in the PHEA to identify patterns regarding physical errors made when executing the tasks. However, the PHEA analysis was not made for the informative tasks since they did not apply to the PHEA, which focuses on physical errors.

The final part of the analysis was a compilation of the patterns identified from the practical and informative tasks to see whether there were commonalities between those two classifications as well. This compilation was important to consider since it could be used to identify usability flaws that could show up all over the final concept's interface. If that were the case, it might have significantly affected the holistic user experience of interacting with the interface.

3.9.5 Scenario - Evaluation of future user experience

A scenario was created to evaluate the user experience of the final concept. A scenario is a method that tells a story about the user and the usage of a product or system in a particular context. Scenarios are mainly used for two reasons: to understand the usage situation in order to create needs and requirements for the product, or to evaluate and communicate already developed concepts in order to understand better how the product is supposed to work in real life (Wikberg-Nilsson et al., 2015).

However, this project used a scenario to evaluate the user experience of the final concept in an urban context. The scenario was a helpful tool for imagining future user experiences of interacting with the final concept. It worked as an evaluation method to determine whether the final concept could possibly result in a good user experience and highlight the contributing factors leading to that experience.

4
Findings

This chapter presents the project's findings. The first two subchapters aim to answer the first two research questions, showing results regarding essential features and factors affecting the user experience. The following three subchapters address the last research question, answering how a rich user experience can be created while reducing the number of features by presenting a final concept exemplifying how it can be made based on set requirements.

4.1 Currently available features in cars

For the 40 cars studied during the benchmark, all of which had manufacturing years between 2017 and 2024, similarities were shown among the different brands regarding the number of physical features, with some exceptions. Below are two tables representing the number of physical features for the tested cars, one with features placed in the centre stack and one with features placed on the steering wheel. Both tables are divided into three areas represented by green, yellow, and red colour. The green category contains cars with few physical features; yellow includes cars with an intermediate number of features, and red includes cars with many physical features. The data for the table was gathered by counting the number of physical features for the tested cars, which was then compiled into these tables.

Table 4.1: Range of features for the centre stack

Centre Stack		
Number of features	Number of cars	Category
0-9	8	Few
10-29	23	Intermediate
30+	9	Many

Table 4.2: Range of features for the steering wheel

Steering Wheel		
Number of features	Number of cars	Category
0-9	5	Few
10-14	28	Intermediate
15-20	7	Many

As the intermediate range of features represents the majority of modern cars (see tables 4.1 and 4.2), the project's focus was decided to be on this category and investigate whether the number of features in this category could be reduced while still contributing to a rich experience for the driver.

Based on the analysis of the number of features in the intermediate category, a baseline car representing the intermediate range of features was selected for the project. The car Lynk & Co 01 has 14 physical features both within the centre stack and steering wheel, aligning with the intermediate range. Thus, it was considered a suitable baseline car for the project.

The benchmark analysis revealed many similarities but also many differences in the arrangement of features among the studied cars in the area of the centre stack and steering wheel.

Centre stack

Common features within the centre stack were features such as parking brakes, hazard warning lights, drive modes, auto hold, and a shifter in the shape of a lever. The exact placement of those features varied a bit, but they were usually placed within the space between the driver and passenger. The shifter was also usually placed within this area, but sometimes, it was placed behind the steering wheel.

Two significant distinctions in the centre stack were the presence of physical controls for managing media and/or climate features. Media controls encompassed audio features like Spotify operation, radio tuning, track selection, play/pause, and volume adjustment, while climate controls regulated the car's environmental conditions, including temperature adjustment, air conditioning (A/C), fan speed control, automatic climate control (auto), and front and rear defrost functions.

Out of the total sample, 12 cars (30%) featured extensive media control interfaces, 10 cars (25%) were equipped solely with media shortcut buttons, and the remaining 18 cars (45%) lacked any physical media controls.

25 cars (62,5%) featured extensive climate control through physical interaction, and the remaining 15 (37,5%) lacked physical climate controls.

Given the prominence of media and climate control in cars, it is reasonable to assume that cars lacking physical controls for either or both areas likely integrate them into the display interface instead.

Steering wheel

The analysis of the steering wheels showed that most had 10-14 features built in. Where the majority consisted of features regarding driving on one side of the steering wheel, such as adaptive cruise control or a line keep assist, and other features not directly related to the driving task on the other side of the steering wheel, such as adjustment of volume, arrows to control display and call features. Which side the features regarding driving and the non-driving features were placed on, differed between the cars. Below are the buttons belonging to the baseline car, where features related to driving are placed on the left side of the steering wheel (see Figure 4.1a) and features not directly connected to driving are placed on the right side (see Figure 4.1b), the majority of the tested cars had similar/same features but with varying symbols and side placement.

(a) Left side (b) Right side

Figure 4.1: Buttons on the steering wheel

4.2 Needs and requirements for a future user experience

The in-depth interviews from user study 1 generated a lot of interesting insights regarding driving in an urban context, in particular. For example, from the question *What do you think could enhance your driving experience?*, the focus was not on adding new, impressive features but on reducing existing ones. One user emphasised, "The focus should be on the experience of driving, not on numerous extraneous features unrelated to driving," another stated, "Get rid of the clutter; today's cars have too many features." and a third user stated, “You barely need a speedometer; you just follow the flow of the traffic”, which indicates that the users saw a potential in reducing the number of features.

Additionally, there was a strong emphasis on simplifying functions and interactions to enhance awareness of one's surroundings, aiming for a balance between the driving task and the environment. One user stated, “It is an experience just driving in the city; everything does not need to be in the car. Capture the experience outside the car rather than inside the car.”, another emphasised “The driving shall be in focus, so enhance that experience rather than extra features in the screens that are cool.”, and a third said, “Features not related to driving and safety should not be there”. All this emphasises the surroundings and highlights that driving and related activities significantly contribute to a positive driving experience.

Another interesting finding was that the users expressed a need to minimise the distraction caused by the interface in the car to increase situation awareness and alertness to critical situations in the traffic. One user stated, “Safety is the most important thing, and distractions (caused by the interface) are a major contributing factor to lowered safety.” Another said, “You are missing a lot of the surroundings when it is happening this much inside the car," which indicated that the interface was a contributing factor to distraction, thus a factor to consider for a good user experience.

It was also found that users did not appreciate redundancy of features. Redundancy was considered confusing and overstimulating because it gave the users more than one option for doing the same task, which increased the workload of interacting with the interface. One user strongly emphasised, "It is too much double information. Simplify it!" The users expressed that their cognitive capacity needed to be put on the actual driving task rather than struggling with decision-making in the interface.

However, there were different opinions about the preferred representation of features. One user stated, "There are a lot of features that do not need a button, in my opinion; you can find most of their functions in settings, which is enough." while another stated, "I don't think it is necessary to have features both on the screen and as physical buttons. I prefer physical buttons since it gives better feedback if it is activated or not.", which indicated that there are different opinions regarding the preferred representation of features, either physical or digital.

Users also raised overstimulation in terms of the urban context per se. One user stated, "I feel overstimulated, but that is not due to the car; it is because of the surroundings." and another said, "I often feel overstimulated due to the constantly shifting circumstances in the traffic". They both felt the overstimulation affected them negatively since it lowered their cognitive capacity. Therefore, it is likely to believe that preventing overstimulation from the interface is also an important factor in creating a good user experience.

Another general finding about driving in urban contexts was about usability. It was found that users often had difficulties understanding particular features and how to interact with them, which in turn required unnecessary time and attention from the driver. One user stated, "I am, in general, strongly disliking struggling with tasks in the interface while driving", and another emphasised, "It is always difficult to try to understand how to use the interface while driving. You seldom take time for doing that that before you start driving.". This highlights the importance of good usability of the interface, making the interaction with it efficient so that users can focus on the actual driving. Therefore, usability was also considered to be an important factor in creating a good user experience.

UX curves

Other findings about the user experience were identified after compiling and analysing the collected UX curves (see Figure 4.2), resulting in findings regarding patterns and trends among the various trips, concerning *when* particular factors affected the users during the trips, and *how* it affected them, positively or negatively.

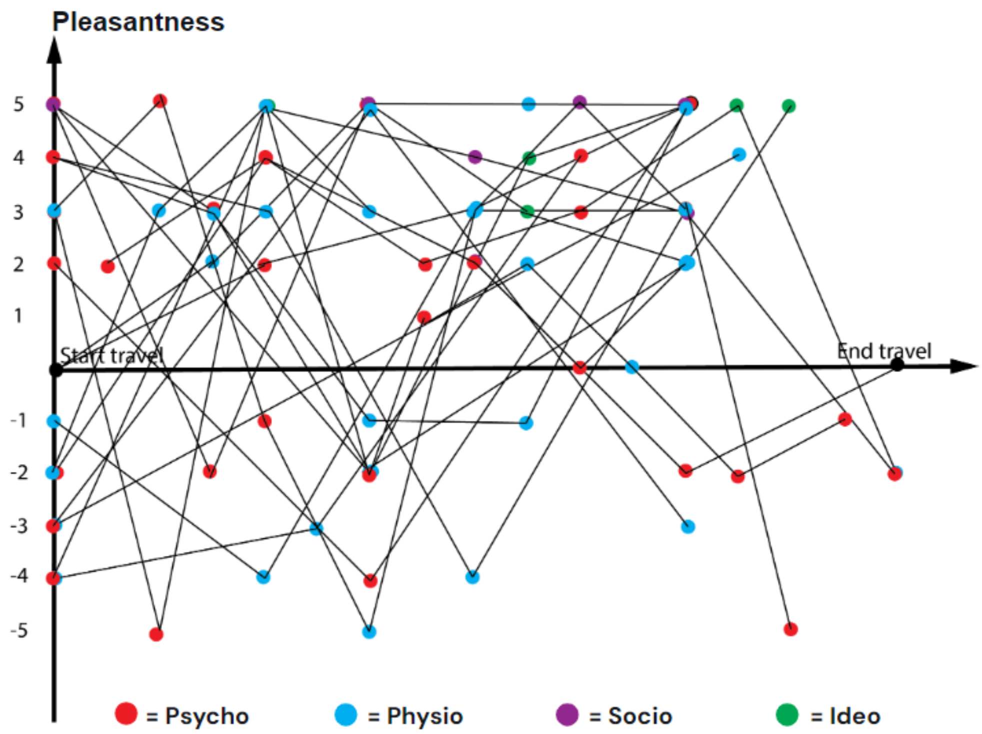


Figure 4.2: Compilation of UX curves

From the analysis, it was found that all negative experiences belonged to either Physio or Psycho-related factors. Furthermore, it was also found that these negative experiences were mainly about visibility and climate; when those areas did not work as the user anticipated, they negatively affected the user, while the users felt more neutral when they worked well. With this information, climate and visibility can be counted as basic requirements. Experiences regarding climate affected the users mainly at the beginning of the trip, which was also the case for information about car status. The illustration indicates that psycho and physio factors have the most significant deficiencies.

Factors associated with Socio and Ideo pleasures only positively impacted the users, suggesting that these factors are essential to the experience but do not necessarily need to be improved to provide a positive experience.

4.2.1 Factors Affecting User Experience

Several factors affecting the user experience derived from both user study 1 and 2. These factors were compiled in a table (see Table 4.3) and narrowed down due to overlapping factors, ending up in a list of factors (highlighted in grey in the table) that can be considered to address the first research question: *"What factors affect user experience in human-machine interactions while driving?"*.

Table 4.3: Compilation of factors affecting user experience

Physio		Psycho	
U1 (Interview)	**U2 (Reflective photographs)**	**U1 (Interview)**	**U2 (Reflective photographs)**
Air climate (heat/cold)	Heat	Context (overstmulation in city)	Information about car status
Heat steering wheel	Compartment for storing things	Accessible media	Safety infromation
Comfortable body position	Driving assistance	Navigation (GPS)	Connect phone
Division between different features	Good sound quality	Safety information	Accessible media
Different structure of buttons	Reversing camera	Control media	Clear buttons
Storage for phone	Few interaction	Speedometer	Navigation(GPS)
↓	↓	↓	↓
Climate		Clear buttons	
Good sound quality		Navigation (GPS)	
Storage (phone, key)		Safety information	
Identification of buttons (texture/placement)		Accessible media	
Few interactions (Few steps to solved task)		Context (overstimulation in city)	
Driving assistance		Connect phone	
Comfortable body position		Information about car status	
Socio		**Ideo**	
U1 (Interview)	**U2 (Reflective photographs)**	**Values**	**Number of respondents**
Good sound environment	Conversation with passengers	Environment	8
Hands-free system	Conversation through phone	Economy	8
Features passengers can control		Safety	6
↓	↓	Style and Design	3
Enable presence of passengers		Trust	2
Enable phone calls		Comfort	2
Enable interactions by passengers		Quality	1

Below follows descriptions of the meaning of the identified factors from the compiled list.

Physio

According to the user study, one factor contributing to physio-pleasure included a comfortable body position that enabled good reachability to features. Users also appreciated a distinct division between features for easy recognition and varied textures on controls/buttons, allowing tactile recognition and minimised visual distraction. A pleasant and efficient climate system that could handle heating and cooling depending on outer climate and user preferences was also an essential factor for physical-pleasure.

A contributing factor to physio-pleasure was efficient storage solutions to avoid a messy impression of the car, which could cause distraction when driving. Dedicated areas for storing every day belongings such as phones and keys were appreciated since it was considered to minimise the risk of losing them in a mess of other stuff in the car. The users appreciated media in general, and good sound quality, in particular, since it enhanced the physical well-being of the hearing senses while listening to media. Lastly, driving assistance, such as adaptive cruise control or parking assistance, lowered the users' needed physical effort while driving, which the users thought facilitated their driving and contributed to a better experience.

Psycho

Most participants (four out of six) often felt overstimulated while driving in urban environments, attributing this sensation to the high level of activity—such as traffic, pedestrians, cyclists, red lights, and roundabouts—that requires drivers to monitor numerous elements constantly. The remaining two participants felt neutral about driving in such settings. Effective navigation was crucial to mitigate overstimulation, enabling users to hear and see the information. Minimising other inputs, such as reducing or turning off media, was also valued as a helpful strategy, and therefore, accessibility to media was considered a contributing factor. Having access to media in general, such as music, radio, and podcasts, along with conversations with others, either passengers or via phone, was appreciated by the users, and thereby was the ability to connect the phone to the car an essential factor since it could enhance the driver's emotional well-being talking to someone while driving.

Driving assistance was valuable in preventing overstimulation, including features such as parking assistance and adaptive cruise control. Clear and understandable buttons were considered a significant factor contributing to better usability and in turn, preventing distraction caused by the interface. Especially two types of information provided by the car were considered to enhance the psycho-pleasures among the users: information about car statuses, such as tire pressure or oil level, and safety reminders, such as a reminder of putting on the seat belt or closing a not fully closed door. These types of information both contribute to safer driving, which was considered to contribute a lot to psycho-pleasure when driving. However, safety also relates to identified factors under ido-pleasure, which will be described later.

Socio

Regarding the social aspects, answers varied on whether participants usually drove with passengers. The majority indicated a roughly 50/50 split between driving alone and with others. Almost all participants appreciated having passengers for company, except for one who found it stressful and demanding, primarily because the participant considered herself an inexperienced driver uncomfortable with passengers. Nevertheless, all participants noted that they tended to drive more cautiously when accompanied, recognising the added responsibility of another person's safety.

The helpfulness of passengers during the drive also differed: some found it irritating when passengers pointed things out, while others valued having an extra pair of eyes to catch anything they might have missed. Communicating with others was often shown to affect the driver positively, both with passengers and through phone calls.

Ideo

In terms of values, the environment, economy, and safety emerged as the most important ones based on the findings. Additionally, trust, comfort, style/design, and quality were also values highlighted by participants. Many linked economy with environmental concerns, noting that more environmentally friendly cars often consume less fuel, reducing operating costs. The high valuation of environmental considerations was primarily driven by ethical motives, with participants expressing a desire to protect the environment. However, this concern did not necessarily outweigh considerations related to the cost of buying a more environmentally friendly car.

Many users also valued the safety of the car and the driving very highly. One user talked about the car's safety in relation to the car's price. A more expensive car, often bigger and heavier according to the user, was considered safer than a cheaper one. However, users also expressed that old cars were perceived as quality cars, while modern cars break more frequently and, based on that, do not have the same quality.

4.2.2 Classification of Features

The scenario part of study 1 aimed to generate information about which features the participants considered basic and which features they considered indifferent.

Given that the primary focus of that part was to identify basic and indifferent features, most of the collected data were classified within these categories. However, some feature participants deemed essential were placed under different headings, typically performance-enhancing. This classification stemmed from transcript analysis, which sometimes showed that although participants valued these features and wanted them in the car, they were not strictly necessary. This assumption was based on the participants' expressions of their preferences. For example, one of the participants expressed, *" It would be nice to have a feature that helps you track the car's position, both to the car in front and the road; I think this is something extra that is nice as well."*. In this statement, it appears that the feature mentioned, in this case, a combination of lane keep assistance and adaptive cruise control, is something that enhances the user's experience of driving a car and was therefore classified as performance-enhancing instead of a basic feature.

The classification of features (see Table 4.4) refers to basic features as requirements (R) and performance-enhancing as needs (N). The division of features into requirements and needs displays the respondents' perspectives and opinions regarding their perceived importance, necessary features as required and desirable features as needs.

Table 4.4: Classification of features

Basic features	R/N	Indifferent features	Performance enhancing features	R/N	Excitment features
Steering wheel	R	Private locking	Connect phone	N	Auto park
Hazard warning light	R	Inbox	Change song	N	Automatic payment when parking
Cluster	R	Dark/bright mode	Heat steering wheel	N	
Speedometer	R	Drive modes	Parking assistance	N	
Fuel gauge	R	Car guide	Reversing camera (360 degrees)	N	
Car horn	R	Parking brake (External button)	Hands-free system	N	
Gear shifter	R	Auto hold	Voice dictation	N	
Parking brake	R	Car status	In-car digital speed signs	N	
Watch	R	RPM (revolutions per minute)	Written communication	N	
Indicator lights	R		Sound adjusters	N	
Start/Stop enging	R		Adaptive cruise control	N	
Climate system	R		Media information	N	
Navigation system	R				
Media system	R				
Storing possibilities	R				

In response to the second research question, *"What features are essential for a positive user experience while driving?"* the essential features belong to basic requirements and performance enhancers. Features classified as indifferent and excitement generators are not included, indifferent as they are not considered to impact the user experience and excitement generators as they are not classified as essential.

Conflicts occasionally arose due to differing opinions among the users; for example, one participant might consider a specific feature a basic requirement, while another might view the same feature as indifferent and unnecessary. The analysis showed that many conflicts, where users had differing opinions, typically revolved around whether a feature was considered basic or indifferent, or performance-enhancing or indifferent (see Table 4.5). Often, a feature was categorised as indifferent primarily because the user was unfamiliar with it and lacked knowledge of its operation, leading to its classification as such. Users might have classified differently if they had been more accustomed to these features. For example, adaptive cruise control illustrates this point well; the majority (four out of six) who understood and frequently used this feature appreciated its benefits in facilitating driving. In contrast, the remaining two participants, unfamiliar with how it worked, did not use it and deemed it unnecessary.

The final categorisation of the features was primarily based on frequency. If the majority of users identified a feature as a basic requirement, while only one considered it indifferent, the final decision aligned with the majority view. When the different categories were even, the project team decided through discussion.

Table 4.5: Compilation of factors affecting user experience

Feature	Conflicting categories	Final classification
Speedometer	Basic feature - Indifferent feature	Basic feature
RPM (revolutions per minute)	Basic feature - Indifferent feature	Indifferent feature
Radio	Basic feature - Indifferent feature	Basic feature
Adaptive cruise control	Indifferent feature - Performance enhancing feature	Performance enhancing feature
Meeting	Indifferent feature - Performance enhancing feature	Indifferent feature
Inbox	Indifferent feature - Performance enhancing feature	Indifferent feature
Media information	Indifferent feature - Performance enhancing feature	Performance enhancing feature
Android Auto	Indifferent feature - Performance enhancing feature	Performance enhancing feature

Some of the features mentioned by the users in user Study 1, named Co-lab, Camera (selfie/outdoor), Connective, Car Guide, Car Sharing, Private Locking, and Meeting, could all have been classified as performance-enhancing features. However, they were left out from the final classification of features since they were considered car-specific features for Lynk & Co, and not including those was supposed to generate a more general result.

To see whether the identified features from the Kano model matched the factors affecting the user experience, they were compiled and illustrated in one picture (see Figure 4.3). The factors from user study 2 are displayed within the table, while the features derived from the Kano model in user study 1 are presented outside the table. Next to the feature is a letter representing which Kano category it belongs to: (B)= Basic requirements, (P)=Performance enhancing, (I)=Indifferent and (E)=Exitement generators.

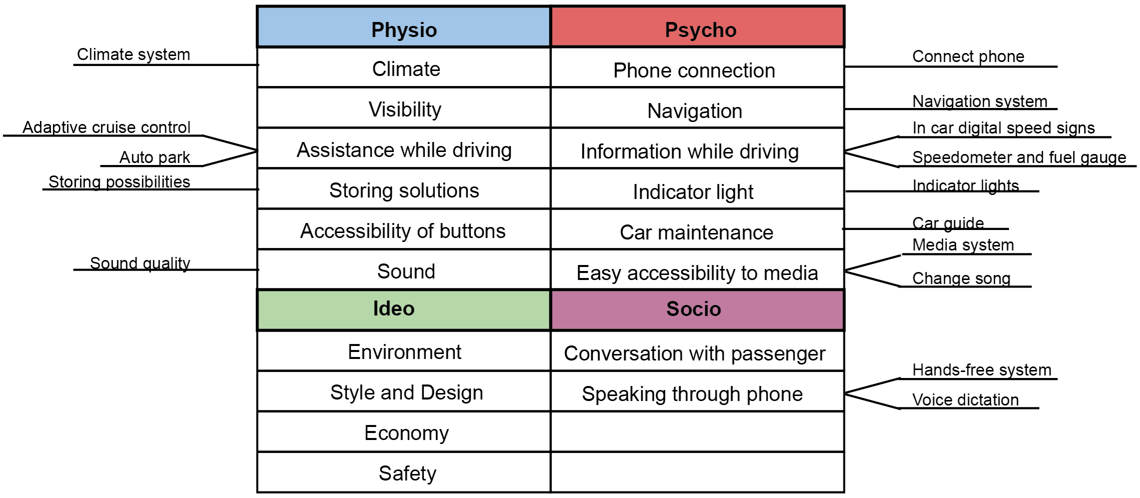


Figure 4.3: Compilation of features from the Kano model and UX factors

The comparison shows that features mentioned and placed in the Kano model largely respond to the results from areas that affect the experience from the second study. This shows that user study 1 and user study 2 largely support each other, where features from user study 1 can be considered to solve the needs for several factors mentioned in user study 2. However, the results showed two areas of influencing factors from user study 2 that affected the experience, not covered by features from user study 1, which belonged to design choices and values.

Features from user study 1 do not address the factors “clear buttons” and “accessibility of buttons” associated with design choices. This lack is generally attributed to the idea that such factors pertain more to the overall design and usability of the interface, influencing user experience indirectly rather than being attributable to specific, responsive features. Consequently, it is deemed reasonable that these factors are not linked to any specific features from user study 1.

As listed in the table, none of the factors associated with Ideo pleasure are directly addressed by any feature from user study 1. Given that Ideo pleasure predominantly relates to values and principles, it is understandable that there are no specific features corresponding to these values. This gap highlights the challenge of integrating values directly into tangible design elements.

Information about car status was mentioned as important to the participants’ experience from user study 2. This area has a connection to two features, where “car status” is one of them. However, car status was mentioned as an indifferent feature from user study 1 (participants considered that car status was redundant in the car used for the study and, therefore, unnecessary). Via user study 2, information about car status, including, for example, information about tire pressure, was considered to affect the driver’s experience positively and thus was a significant factor. Therefore, to support the factor affecting the user experience, the feature “car status” was, after the compilation, considered a performance-enhancing feature.

4.2.3 Requirement list & Design guidelines

A requirement list was finally assembled based on the findings (see Table 4.6). The requirement list was based on factors affecting the user experience but left out the required (basic) and needed (performance-enhancing) features previously presented since a particular feature does not directly correspond to a pleasure, which this requirement list refers to. However, both single features belonging to basic requirements and performance enhancers previously identified, as well as the requirements and needs in this requirement list affecting the user experience, were considered within the upcoming concept development.

Table 4.6: Requirement list

ID	Constraint: The product should…	Comments	Pleasure	R/N
1.1	Enable adjustability of climate	Temperature and fan	Physio	N
1.2	Provide good reachability		Physio	R
1.3	Provide a good sound environment		Physio	R
1.4	Enable adjustability of sound		Physio	N
1.5	Enable physical identification of buttons/controls		Physio	R
1.6	Facilitate minimal user interactions for compleating tasks		Physio/Psycho	R
1.7	Provide driving assistance		Physio/Psycho	R
1.8	Provide good sight		Physio	R
1.9	Support priorisation of functionality and information		Physio	R
2.1	Enable easy accessability of sound media	Music, radio, podcast, audiobook	Psycho/Socio	R
2.2	Enable information about sound media		Psycho	N
2.3	Allow customisation of sound media	Change song or media type	Psycho	R
2.4	Prevent overstimulation		Psycho	R
2.5	Prevent distraction		Psycho	R
2.6	Be compatible with phones	Android and Apple	Psycho	R
2.7	Allow charging opportunities for electronic devices	Phones/headphones (12 V)	Psycho	R
2.8	Provide opportunity for customisation of the interface		Psycho	N
2.9	Ensure understandable features	Clear symbols/information	Psycho	R
2.10	Provide clear safety reminders		Psycho	R
3.1	Enable precense of passengers		Socio	R
3.2	Allow passengers to interact with non-driving tasks	Climate, volume, media	Socio	N
3.3	Enable communication of through phone calls		Socio	R
3.4	Enable written communication	With help of voice dictation and automatically read messages	Socio	N
4.1	Enable information about the environmental effects of the driving		Ideo	N
4.2	Enable environmental-friendly driving choices		Ideo	R
4.3	Support safe driving		Ideo	R

In addition to the requirement list were three design guidelines created:

- Prevent distraction
- Prevent overstimulation
- Provide good usabilty
- Avoid redundancy

The design guidelines derived from the user studies highlight the essential factors affecting the user experience of driving, especially in urban contexts. Therefore, they were crucial in further conceptualisation to ensure the final concept's applicability to the urban context in which the project worked.

4.3 Allocation of features in the four focus areas

Below is the allocation of the features presented (see Figure 4.4). The features are placed within the different focus areas of the project cluster, steering wheel, centre stack and display.

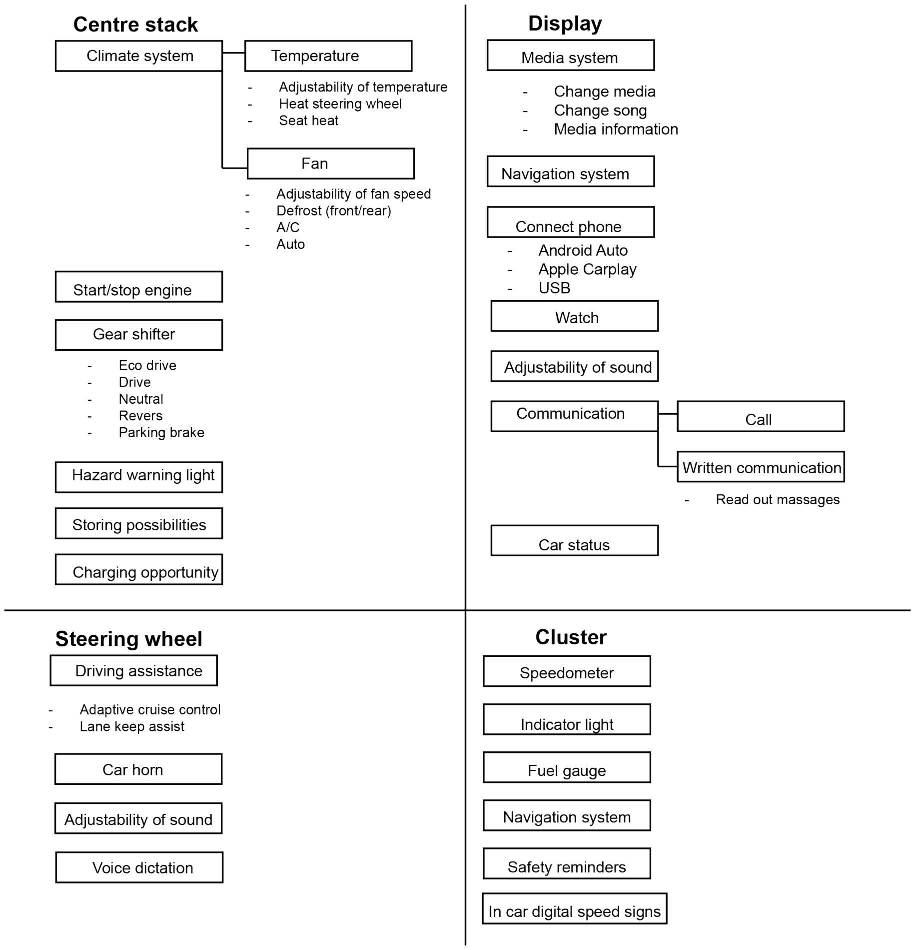


Figure 4.4: Allocation of features within the four focus areas

The allocation was made based on the prioritisation of features. Features with a higher prioritisation, in other words, features closer related to the actual driving, were placed on the steering wheel or in the cluster. Users' mental models, identified from the user studies, were also considered when features were allocated. Going too far from their mental model when placing the features would have created unnecessary confusion. Lastly, user preferences identified from the user studies were also considered when allocating the features.

4.4 Prototypes and evaluation of each of the four focus areas

This part displays the developed prototypes for the associated cluster, steering wheel, centre stack, and display (in this order). It begins with a brief description of the general idea of the prototypes developed for the particular focus area and then provides more detailed descriptions of each prototype. Finally, it provides insights from the evaluation of the prototypes of the specific focus area and suggestions for future improvements.

4.4.1 Cluster

For the cluster, the usability aspect, specifically the understanding of the features, was considered the major contributing factor to distraction and overstimulation. Therefore, two prototypes developed for the cluster focused on various representations of features to investigate the users' understanding of the features. Furthermore, the concepts also investigated if the amount of features had any impact on distraction and overstimulation or if it just adds value to the driving experience. The user studies found that investigating features closely related to the actual driving contributed more to a better experience than investigating in other features unrelated to the actual driving. Therefore, the added features in the cluster were experimented with within the prototypes of the cluster as well.

Prototype 1

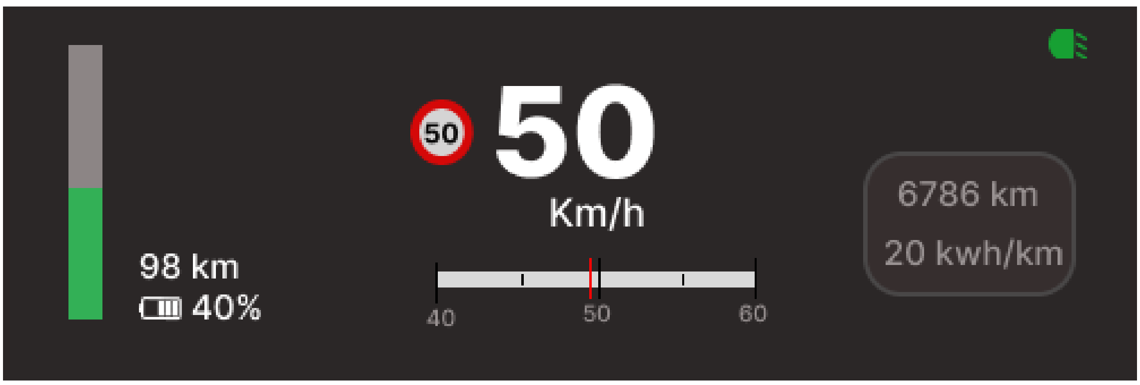


Figure 4.5: Prototype 1, cluster.

Prototype 1 (see Figure 4.5) is clean and simple in its design, consisting of only the required features. This prototype focuses on minimalism and prioritisation of features to prevent overstimulation and distraction. Furthermore, it also has a new type of speedometer that aims to counteract distraction caused by movement.

Speedometer: The speedometer in this prototype was developed to prevent distraction caused by the numbers switching when the speed changes. Therefore, the speedometer in this prototype only switches numbers every 5:th km/h, but in addition, a small bar with an interval of 20 km/h indicates more precisely the current speed driven in, and depending on the current speed, the interval will change. For example, if the user drives at 90 km/h, the interval on the bar will go from 80km/h to 100 km/h. The idea of this speedometer is to eliminate the frequently changed numbers, which can disturb and distract the user while driving, and instead add a speed bar that will move more smoothly when the car's speed changes. However, the number enables the user to glance and quickly get an idea of the current speed, which was the reason for keeping the speedometer with numbers.

Traffic sign: A sign of the road's current speed limit can be found to the left of the speedometer, which is helpful for the user when the traffic is busy and there is a risk of missing a sign. It can also help the user lower the workload while driving.

Odometer: This number tells the distance the car has been driven during its lifetime, from production until now. It can be used to tell when it's time for service or as a valid source for a car buyer to know how much the car has been driven. The odometer has constantly low opacity in the cluster compared to other features since it is information with low priority for the user.

Navigation assistance: When the navigation system is activated on display, additional clarifying illustrations of the upcoming action and the distance at which the action needs to be performed become visible in the cluster. These notifications can be a right turn in 300 metres or a slip road in 2 km. The user will also see the following action in advance to plan the route better. These clarifying notifications assist the user while driving and may provide a sufficient amount of information to navigate, which means glancing at the map in the display can be prevented, which is more of a distraction than glancing at the cluster.

Consumption of electricity: This number indicates the amount of electricity consumed by the car, as described by the unit kWh/100 km. It can also indicate the user's driving behaviour, which can help the user drive more sustainably. Like the odometer, this information also constantly has low opacity due to its low priority in the cluster.

Safety messages: These messages appear as a banner from the upper part of the cluster to attract the user's attention to the safety message (see Figure 4.6). The safety message can either disappear by itself after a while or stay until the user has fixed the issue, depending on the character of the message.

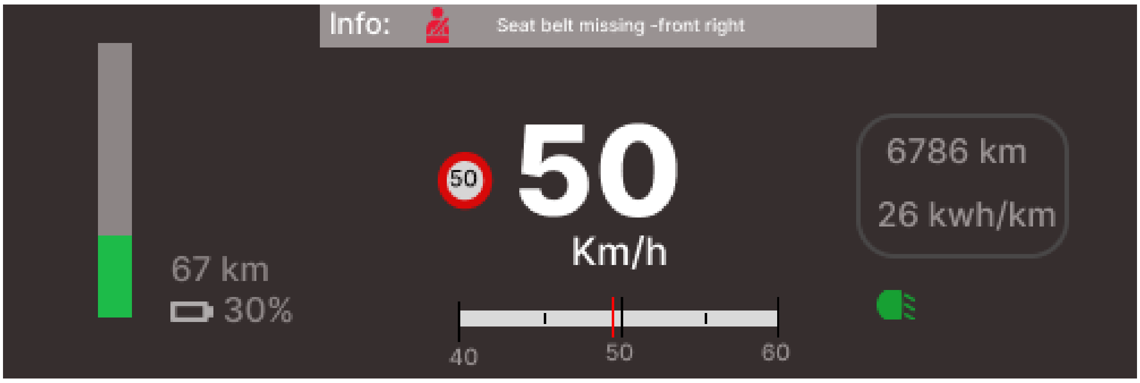


Figure 4.6: Prototype 1 with safety message

Battery status: The remaining electricity in the car's battery is indicated with green in the standing bar. Besides, the bar shows the remaining battery in per cent and the corresponding distance. The battery bar has a low opacity while the battery is sufficiently high to avoid attracting unnecessary attention. However, when the battery level drops to 30%, the priority of this feature increases since it is now important to charge the car. Therefore, the opacity of the battery bar rises to get the user to pay attention to the information.

Prototype 2

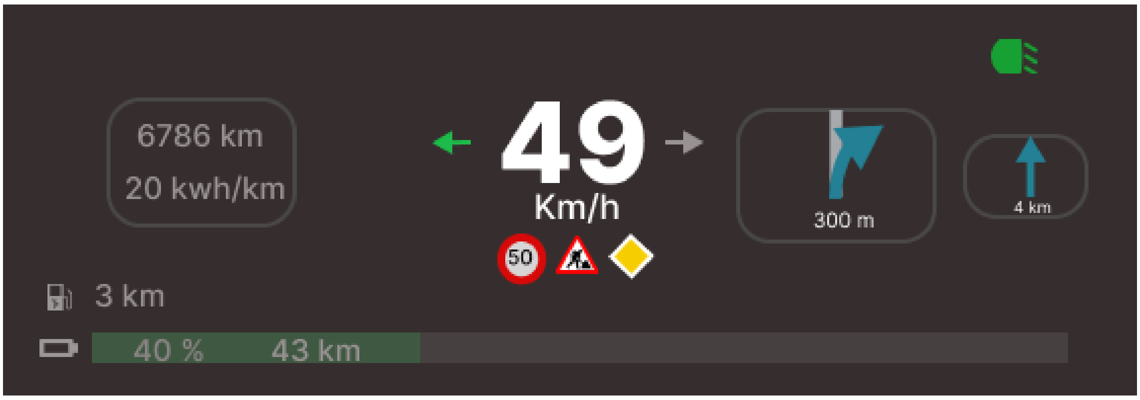


Figure 4.7: Prototype 2, cluster.

Prototype 2 (see Figure 4.7) introduces additional features designed to enrich the driving experience and provide added value for the user. While these enhancements may risk overstimulation, the prototype's clear structure and prioritisation are intended to mitigate this effect.

Speedometer: The speedometer in this prototype is like the ones on the market today. It shows the car's current speed using numbers.

Traffic signs: This prototype provides the user with additional traffic signs compared to prototype 1, such as the sign indicating the main road or the warning sign for the road under construction, in addition to the sign marking the speed limit for the road.

Turning lights: On each side of the speedometer, an arrow corresponds to the lights on the outside of the car, indicating in which direction the next turn will go. This light is activated using a lever on the steering wheel.

Navigation assistance: When the navigation system is activated on display, additional clarifying illustrations of the upcoming action and the distance at which the action needs to be performed become visible in the cluster. These notifications can be a right turn in 300 metres or a slip road in 2 km. The user will also see the following action in advance to plan the route better. These clarifying notifications assist the user while driving and may provide a sufficient amount of information to navigate, which means glancing at the map in the display can be prevented, which is more of a distraction than glancing at the cluster.

Safety messages: In this prototype, the safety messages appear as an info box containing both an illustration of the issue and a description, which may be more understandable for the user than the banner (see Figure 4.8).

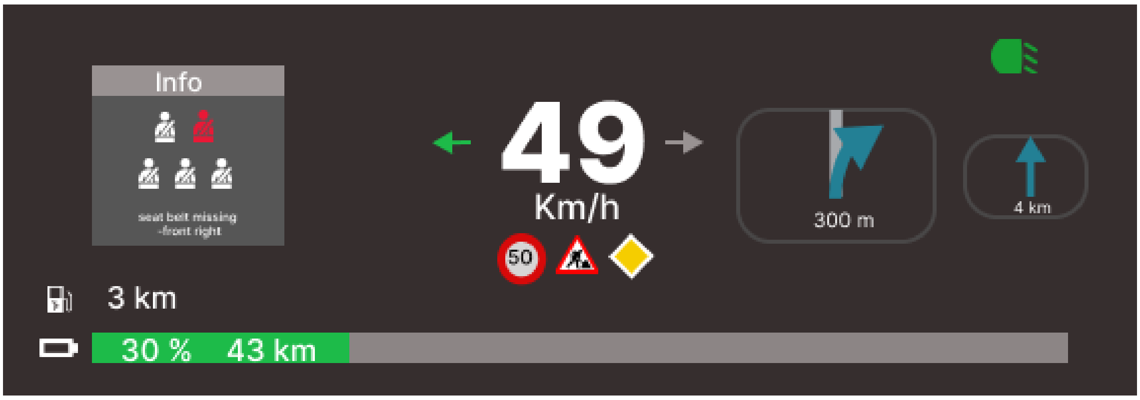


Figure 4.8: Prototype 2 with safety message

Battery status: The bar indicating the remaining electricity in the battery has the same appearance as the one in prototype 1, except for its horizontal position.

Closest charging station: An additional feature to the required ones is a symbol indicating the distance to the closest charging station, which can help the user decide when to charge the car.

Evaluation

After evaluating the cluster, it was found that prototype 1, the more minimalistic concept, was the best-performing prototype according to the users based on set design guidelines and requirements. However, adding some influences from prototype 2 would make it even better.

The users expressed that the simplicity of the layout in prototype 1 enabled a good overview of the features, which was appreciated. Regarding the traffic signs and information messages, which provided different amounts of information in the various prototypes, the evaluation showed that prototype 1, with less information presented, was the most appreciated. Most users did not experience added value from adding extra traffic signs or added information in safety messages.

The users liked the lower opacity on the battery status bar when the battery was high, which both prototypes provided, since the information about a fully charged car was not considered highly prioritised information for the driver. However, the users preferred a standing bar for the battery status like in prototype 1, since the horizontally positioned bar in prototype 2 was perceived more as a progress bar.

Feedback from the evaluation indicated that both prototypes had easy-to-understand features due to the use of carefully chosen symbols.

However, prototype 1 also raised concerns in the evaluation; for example, the banner showing the safety messages needed to be more alarming to attract attention. Another input about prototype 1 was about the battery status bar, specifically when the battery has been running low, and the opacity goes from low to high. At this stage, the participants also wanted the colour to change to yellow and, later on, even to red to attract attention from the driver and prioritise the information even more on the cluster. Today's idea, where increasing opacity on the bar was the only indicator for when the battery status was becoming more critical (since the colour is constantly green), was not considered enough.

The users appreciated minor features, like the distance to the closest charging station and turning lights, provided by prototype 2, which added value without invoking unnecessary attention and distraction. Therefore, adding these features to prototype 1 would improve the overall experience of the cluster. However, the symbol illustrating a charging station used in prototype 2 could have been more explicit since not all users understood the meaning of it.

The odometer and the number indicating the electricity consumption per 100 km were given too much space in the cluster according to the users, which is not in line with its low prioritised information compared to other information in the cluster. Therefore, another place and size for that information would be beneficial.

Another concern was the speedometer, and more precisely, the speed indicator that should change every 5:th km and not change every time a new speed is reached. The user expressed that this feature would be more suited for driving at higher speeds, where the accuracy of the speed is not that essential. It was found the the speed accuracy was more important to the user at lower speeds, where more stringent traffic rules about the speed limits exists. Having a speedometer indicating the speed of every new 5:th km/h was therefore considered to be too seldom. Thus, some adjustments on how frequently the speed switch would be necessary to develop the speedometer further. However, users still see the potential in switching numbers less frequently than it is done today to prevent distraction caused by flicking numbers.

Navigation assistance, provided in prototype 2 was considered to add value for the user. Since driving in a city context implies more frequent decision-making, it was believed that it should facilitate navigation by having the upcoming action presented in the cluster to minimise the number of times needed for checking the map on the display, requiring longer periods with eyes off the road.

Based on this user input, the list below summarises possible improvements for further concept development of prototype 1.

- Make the banner more alarming
- Add additional colours to the battery status bar.
- Add distance to the closest charging station and clarify the symbol.
- Add turning lights.
- Add navigation assistance.
- Adjust the speedometer to fit the city context.
- Adjust the prioritisation of the odometer and the electricity consumption.

4.4.2 Steering wheel

For the steering wheel, usability was considered the significant contributing factor to distraction and overstimulation. However, only one prototype was developed for the steering wheel (see Figure 4.9) due to today's steering wheels' relatively standardised symbols and layout. However, the symbols and layout still needed to be evaluated.

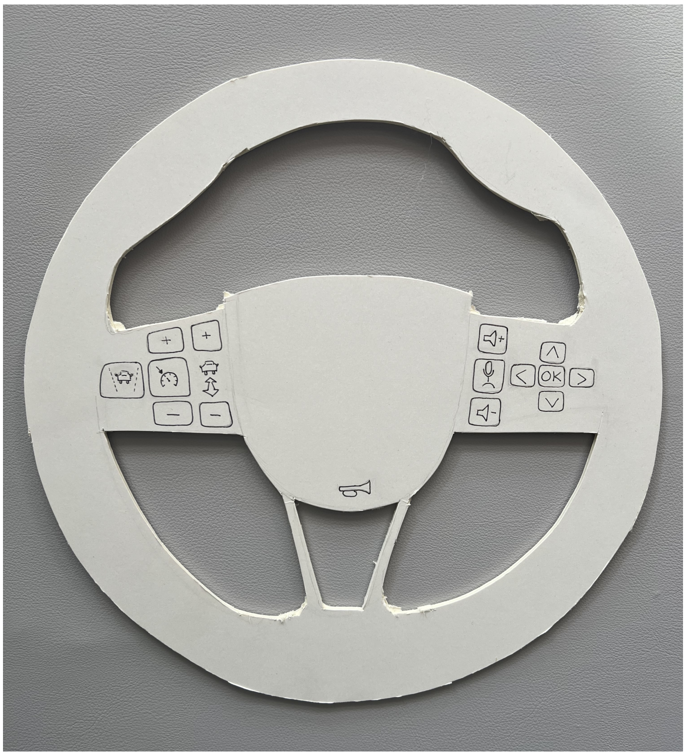


Figure 4.9: Prototype, steering wheel.

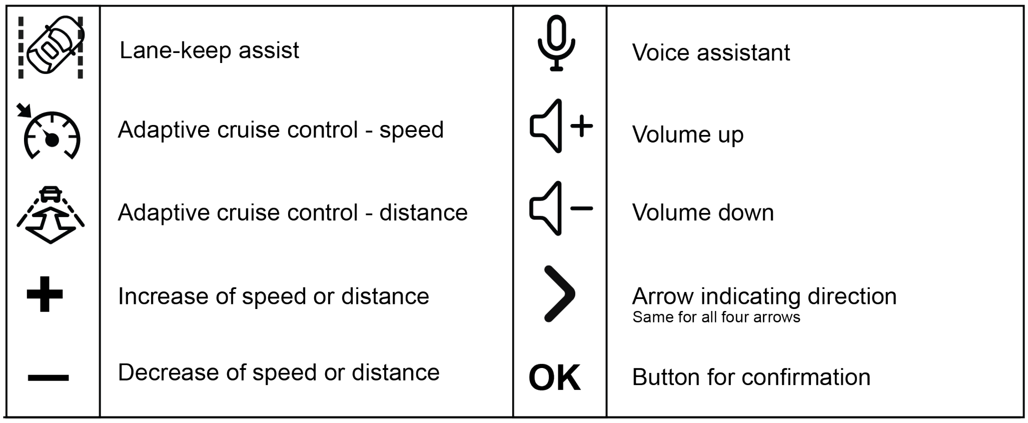


Figure 4.10: Symbols for buttons

1. *Lane control:* A safety feature, that provides driving assistance by helping the user keep in the lane. It is more useful on bigger roads like highways, which are prevalent in urban areas.

2. *Adaptive cruise control:* This feature consists of two components. The first component is a button in the middle of the steering wheel's left side, which sets the car's current speed by pressing it. Even if the driver removes the foot from the gas pedal, the speed will be kept. The + or - buttons can also adjust the set speed up or down. The second component of the adaptive cruise control adjusts the distance to the car in front and is located to the right of the speed adjuster. The distance can only be adjusted when the cruise control is active, i.e. when the button that sets the speed has been pressed.

3. *Voice assistance:* This feature has a mic symbol, and by pressing this button, the user can speak to the car by asking for help navigating to a specific place, playing a particular song, or calling a specific person, etc., just by telling the voice assistant to do so.

4. *Adjusting volume:* The two buttons with the symbols of a speaker with a + or a - on the right side of the steering wheel adjust the volume of the media playing in the car, either increasing it with the + button or decreasing it with the - button.

5. *Navigation control:* This feature consists of five buttons, four arrows pointing up, down, right, and left, and a button in the middle with the text OK. It enables navigation in the display without removing hands from the steering wheel, which otherwise requires physical contact to work. With the four arrow buttons, the user can navigate the display's interface and press the OK button to choose an option/feature.

6. *Car horn:* This feature is activated by pressing anywhere on the middle part of the steering wheel, enabling the driver to attract attention from other motorists on the road.

Evaluation
Since only one prototype was developed for the steering wheel, there was no need to choose between prototypes. Instead, feedback from the steering wheel's evaluation was used to discern which features were understandable and which could be refined to enhance usability.

The evaluation found that the users appreciated the categorisation of the features, with driving-related features on the left side and features controlling the display and media on the right side of the steering wheel. The understanding of the symbols selected for the various features was also high among the users, apart from the symbol for lane control and voice assistance. Based on that, the only areas of improvement found for the steering wheel were the following:
- Clarify the symbol for lane-keep assistance.
- Clarify the symbol for voice assistance.

4.4.3 Centre stack

For the centre stack, the accessibility to features was considered the major contributing factor to distraction and overstimulation. Therefore, the three prototypes developed for the centre stack represented three different levels of accessibility, aiming to investigate the ultimate level of accessibility to features to prevent distraction and overstimulation.

Prototype 1
Prototype 1 is open in its design, with easy access to all features (see Figure 4.11). It is considered the most similar prototype to modern centre stacks. The prototype follows the space between the driver and the passenger.

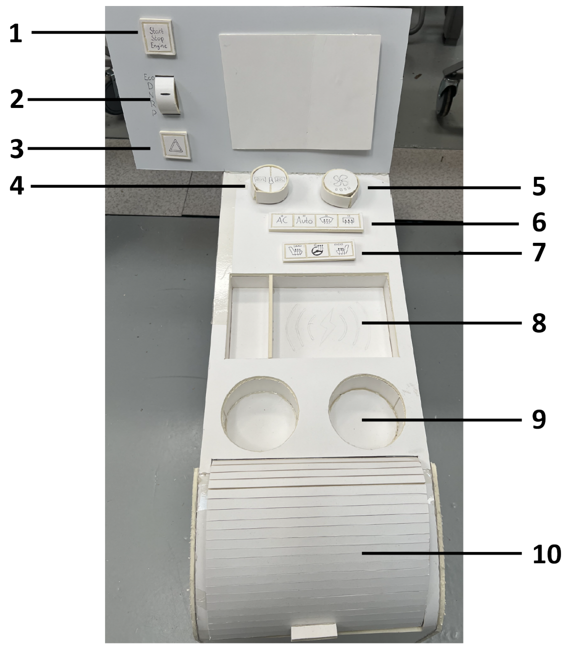


Figure 4.11: Prototype 1, centre stack.

1. *Start/Stop of engine:* A prominent button with the text Start/Stop Engine is placed on the panel.

2. *Gear shifter:* A scroll button which can be rotated to change gear. The included gears on the shifter are, from the bottom to the top: P (Parking), R (Reverse), N (Neutral), D (Drive), and Eco (Eco driving mode). The line on the wheel should align with the desired gear when choosing a gear. To make it even more apparent which gear is chosen, the gear letter (P, R, N, D or Eco) beside the wheel will also light up when a gear is active. The wheel also has built-in physical resistance, so it cannot accidentally stop between two gears. The resistance also makes it easier for the user to stop the rotation at the desired gear.

3. *Hazard lights:* A prominent button with the standardised symbol of a red triangle is placed close at hand on the panel between the steering wheel and the display in case of emergency.

4. *Air temperature:* This can be changed using a wheel as a control. The control consists of a rotatable outer part and two buttons on top of it. The two buttons have small displays that show the set temperature on the respective side of the car. For example, the left display on the left button shows the set temperature for the driver, and the right display on the right button shows the set temperature for the front passenger. To set a new temperature for one particular side, the user presses one of the buttons and then rotates the outer part of the control to set the right temperature. If the user wants to set the same temperature for both sides, it's enough to rotate the control without pressing any button; it will then change both sides. A thermometer symbol in the centre of the rotary control indicates that the temperature can be set using that control.

5. *Fan speed:* A wheel control with almost the same appearance as the air temperature except for the two buttons on top of the control. Regarding the fan speed, it's only possible to change it for both sides of the car simultaneously; therefore, the buttons are unnecessary for the fan speed control. When rotating the outer part of the control, the speed will change to one of the four levels. The indicator lights on top of the control show the speed status. A fan symbol in the centre of the rotary control indicates that the fan can be set using that control.

6. *Air bar:* A bar consisting of four buttons (features), all connected to the airflow in various ways in the car. From left to right, the features are AC, Auto, Defrost windshield, and Defrost rear window. Each button has an indicator light that shows whether the feature is activated or not.

7. *Heat bar:* A bar consisting of three buttons (features), all connected to the heating of various places in the car. From left to right, the features are Heat in

the left seat, Heat in the steering wheel, and Heat in the right seat. The two buttons controlling the heat in the seats have three indicator lights, meaning that there are three heating levels, while the button controlling the heat in the steering wheel only has one indicator light, meaning that it could either be activated or not.

8. *Phone storage:* An open box suitable for quickly dropping the phone from your hands. When placed in the box, the phone can be charged by QI-charging. The box also has a minor part where smaller belongings like AirPods and keys can be stored.

9. *Cup holder:* Two substantial cup- and can holders are positioned in the Center stack. They are easily accessible since they do not have any cover.

10. *General storage:* A box that can store significant belongings, such as handbags or other gadgets, and things always stored in the car, such as cords or cleaning wipes. A jalousie can be used to cover the contents of the box if desired.

Prototype 2

Prototype 2's design is more compact and closed than Prototype 1's, which makes it less accessible but might also make it less distracting (see Figure 4.12).

Figure 4.12: Prototype 2, centre stack

Start/stop engine, Hazard light, air temperature, fan speed, air bar, and heat bar are the same as in prototype 1.

1. *Gear bar:* A bar with five buttons, one for each gear, where pressing a button changes the gear. The gears on the bar are, from the bottom to the top, P

(Parking), R (Reverse), N (Neutral), D (Drive), and Eco (Eco driving mode). To make it apparent which gear is active, the gear letter (P, R, N, D or Eco) on the button will light up when a gear is chosen.

2. *Storage of car key:* A small box dedicated to the car key, keeping it in place while driving.

3. *Phone storage:* A box dedicated to mobile phones with a lid that needs to be pushed forward to access the box's space. When releasing the hand from the lid, it automatically returns to its closed position, which prevents the driver from being distracted by the phone. The bottom of the box is a QI charger, which means the phone will be charged when placed in the box.

4. *General storage:* An intermediate-sized box with general storage possibilities. Pressing lightly at the top of the front opens it.

5. *Cup holder:* Two cup holders hidden in the Center Stack when not used. Pressing lightly on the outside will open the door, and the cupholder can be used.

Prototype 3

Prototype 3 is an adjustable prototype in which users can customise the accessible features to prevent distraction and overstimulation (see Figure 4.13).

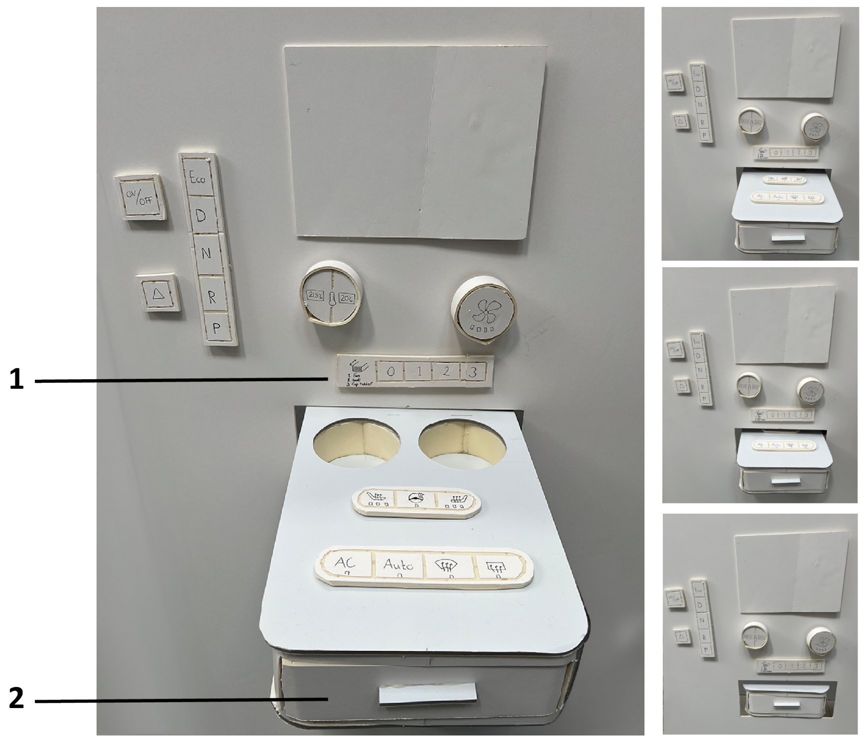


Figure 4.13: Prototype 3, centre stack, and its 4 different positions

Start/Stop engine, Hazard lights, Air temperature, Fan speed, Air bar, Heat bar, and Cup holder are the same as in prototype 1. The gear bar is the same as in prototype 2.

1. *Position bar:* A bar consisting of four buttons numbered 0-3, from left to right. Each number indicates the position of the tray. Number three means the tray's utmost position, where all its features are accessible to the user. Pressing number two instead means the tray is automatically pulled into the panel, covering the cup holders in case the users find the feature unnecessary. Pressing number one means the tray is pulled even more into the panel, covering the heat bar, in case the user considers that feature unnecessary, for example, during summer. Finally, pressing the number zero means the tray is wholly pulled back into the panel, only showing the front with the cabinet. The bar also has a descriptive picture of its function and the four positions.

2. *General storage:* A versatile, intermediate-sized cabinet with general storage possibilities.

Evaluation

For the centre stack, prototype 2 was the best-performing prototype, according to the users, who evaluated it based on set design guidelines and requirements.

The evaluation feedback for Prototype 2 highlighted that its compact design allowed the driver and passenger to easily access all features. The users valued the high guessability of most features in all prototypes, a benefit that inexperienced drivers especially valued. However, some features demonstrated learnability and were deemed acceptable for users who would operate the car regularly.

The categorisation of features, which was the case in all three prototypes, was appreciated for simplifying the understanding and identification of each feature. The storage size was also adequate for smaller items like AirPods or wallets. It was found that larger items, such as handbags, were typically placed on the passenger or back seat. For prototype 1 this became a huge problem, since the dedicated space for handbags within the centre stack in that prototype then became unused.

The specific storage for car keys in prototype 2, perceived positive feedback, filling a gap noted in current car designs, and also served as a useful reminder to take the keys when exiting the car. The phone storage solution, which includes a lid covering the screen, was appreciated for minimising distractions. While the users liked the immediate access to their phones in prototype 1, they recognised the advantages of the screen cover in reducing distractions like in prototype 2. However, the idea of placing the phone in a fully enclosed compartment, as proposed in prototype 3, was less favoured due to concerns about forgetting the phone or feeling compelled to check it, potentially increasing distraction.

The less accessible design of the cup holders in concept 2 was also favoured, as the users indicated that this feature was infrequently used and thus should be deprioritised.

Prototype 2 generally received positive feedback but involved some concerns by the users that would benefit from further refinements. For instance, the cup holders were seen as too concealed, making them hard to identify. Additionally, the functionality of the QI charging was not clear to some users.

Despite the use of standardised symbols and titles in all prototypes, confusion existed regarding their functionality. As a solution, the users suggested that more descriptive labelling should enhance the understanding of these features.

A concern related to the storage box in prototype 2 was that some users found it challenging to use due to the difficulty of seeing and retrieving content effectively.

The evaluation revealed a split between users preferences for the gear shifter wheel from prototype 1 and buttons from prototypes 2 and 3. There was a little advantage to the buttons as three out of five (60%) preferred that shape. However, uncertainty was expressed about which shifter the users preferred and that the users valued them almost equally on several occasions. Both shifters were considered to provide a clear overview and easy interactions, while the wheel shifter was considered to be less space-consuming. As the distribution of preferences was relatively even, the slimmer appearance of the wheel resulted in the wheel being the chosen shifter for further development.

Based on this feedback, the following list summarises potential improvements for further development:

- Make the cup holders more visible.
- Provide clearer instructions or indicators for the QI charging feature.
- Enhance clarity of the AC and Auto features.
- Improve the labelling on the temperature control wheel.
- Enhance accessibility to items stored in the storage box.
- Adopt the gear wheel shifter from Prototype 1 for better efficiency and space utilisation.

4.4.4 Display

In the same manner as for the centre stack, accessibility to features was considered the major contributing factor to distraction and overstimulation for the display. Thereby, the two prototypes developed for the display represented different levels of accessibility to features, aiming to investigate the ultimate level to prevent distraction and overstimulation.

Prototype 1

Prototype 1 emphasises accessible features. It offers more features and options directly on the homepage, reducing the interactions required to access information to complete a desired task (see Figure 4.14). This design approach may help minimise distraction and overstimulation.

Figure 4.14: Prototype 1, display.

Media: In the upper part of the group named "Media", the status of the songs playing is shown by type of media and title of the song playing. Underneath, the song can be adjusted by pressing the middle button indicating play/pause or pressing the forward/backward arrow, which changes to the next/previous song on the list. If the radio is playing, the arrows will instead indicate changing to the next/previously found radio channel.

Under the box containing the status and adjustment of the media playing, there is a button named "Spotify". When a phone is connected to the car, this button can be pressed, taking the user to its Spotify page. The button named "Radio" takes the user to a page where a radio channel can be chosen. Pressing the connect button will take the user to a page where the phone can be connected through the USB port and, in that way, control the media from the phone.

Navigation: The navigation group consists of three features. The picture illustrating a map is a button, and by pressing it, the user is taken to the main navigation page where several options exist. The user can either enter any address themselves, choose one of the recent tips driven, choose one of the trips added to the favourite list, or go Home, a preset address for that particular destination.

Returning to the home page, where the group named Navigation was, there are also two other buttons, one illustrated like a magnifying glass and one like a house. These buttons are shortcuts and take the user to either the position where an address is entered or directly to the map where the destination is set to go home.

Settings: The feature named settings is a button that takes the user to a page that handles everything related to the car, including its settings, information, and status.

Phone: The group named Phone consists of four features, three buttons, and one information box. "Apple CarPlay" and "Android Auto" can be used if the user wants to replace the display's original interface with the phone's interface. The user chooses which of the two features to interact with, depending on whether it is an Apple or Android phone to be connected. The feature named "Call" takes the user to a page where four categories can be chosen: favourites, contacts, recent calls, and missed calls. The last feature in the group, the phone, is an information box showing the phone's battery status when connected to the car.

Volume bar: The volume bar can adjust the volume for the media, calls, or voice assistance. The indicator can be slid to the right for increased volume or to the left for decreased volume.

Voice assistance: The same functionality as on the steering wheel.

Distraction mode: If the user presses this button, the display gets dark except for the bar at the bottom, which still shows its features. This feature can be used if the display is not used for the moment or if the user feels distracted by having access to all features while driving.

Home: By pressing this button, the user returns to the start, which is the home page.

Prototype 2

Prototype 2 prioritises a cleaner aesthetic by placing features under distinct headings, giving the home page a slimmer appearance that prevents features from attracting attention (see Figure 4.15). This prototype could potentially decrease distractions and overstimulation from the interface. However, it is important to note that this approach increases the interactions required to complete tasks, potentially leading to increased cognitive load.

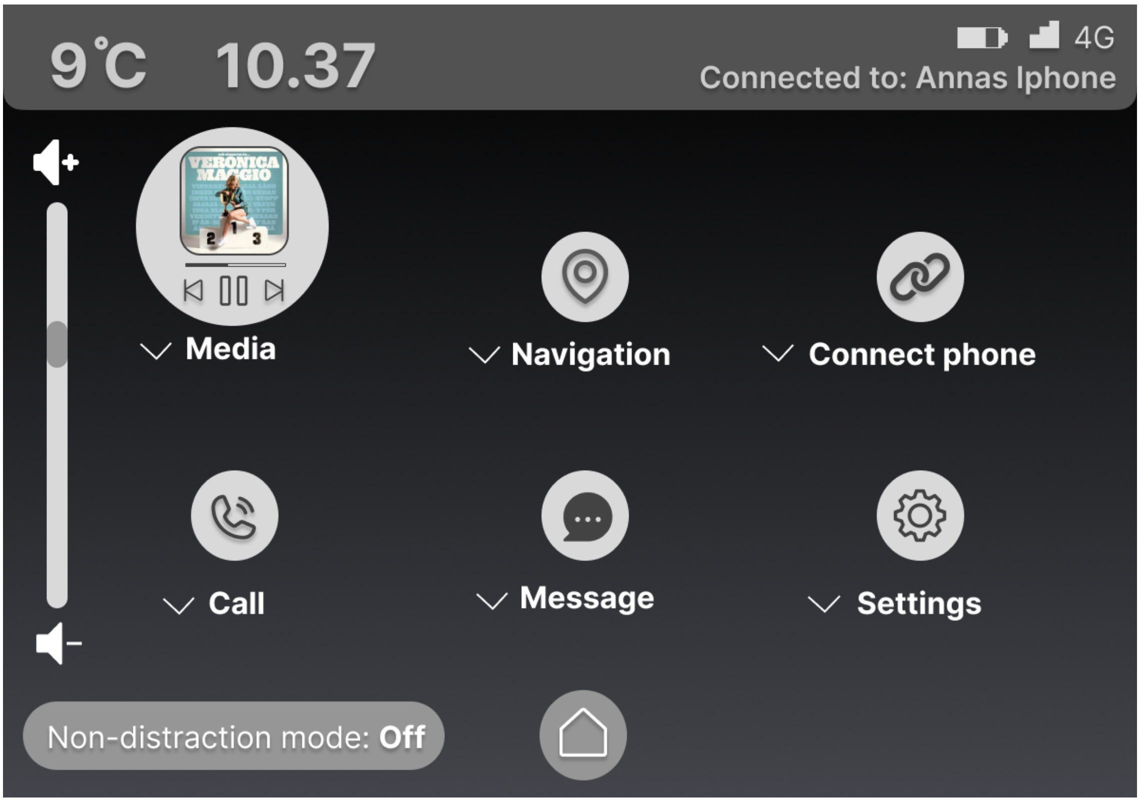


Figure 4.15: Prototype 2, display.

Media: The Media category comprises four subcategories: Spotify, Radio, Podcast, and Audiobook (See Figure 4.16). Spotify and Radio work similarly to prototype 1, but podcasts and audiobooks are two added features that can be used when a phone is connected to the car. If the user has an active audiobook or podcast on the phone, it can be found here. The user can also find saved audiobooks or podcasts from the phone under each subcategory.

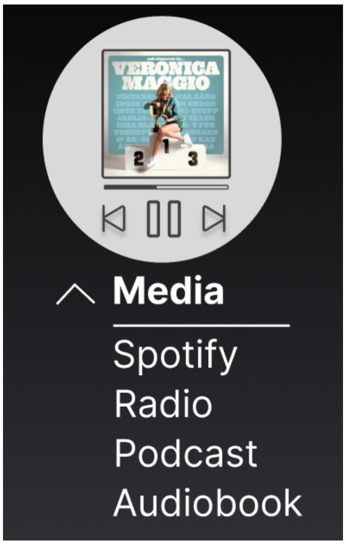


Figure 4.16: Subcategories

Navigation: The navigation category consists of three subcategories: “Where to go?”, Recent trips and Favourites. All three features work similarly to the corresponding features in prototype 1.

Connect phone: Connect phone comprises three subcategories: Apple CarPlay, Android Auto, and Connect with USB, which all work similarly to the corresponding features in prototype 1.

Call: The category Call comprises three subcategories: Enter number, Recent calls, and Contacts (including favourites). The Enter number feature is new to this prototype, enabling the user to call any number by pressing the numbers physically, compared to prototype 1, where voice assistance is the only way to call any number otherwise, the user has to call a number from the contacts.

Message: This category consists of two subcategories: Read with voice assistance and Send with voice dictation. These features can also be found in prototype 1, but they are less highlighted than in this prototype since they aren’t in a designated position on the home page.

Settings: This category is divided into five subcategories, including the same car settings, information, and status as in Prototype 1.

Volume bar: The feature is the same as in prototype 1, except for its vertical position.

Non-distraction mode: This feature is the same as the “Distraction mode” from prototype 1 but is named differently in this prototype.

Home: Same as in prototype 1.

Evaluation

For the display, prototype 1 was the best-performing prototype according to the participants, who evaluated it based on set design guidelines and requirements.

The evaluation identified several positive aspects of prototype 1, for example the layout, which was considered the most intuitive due to the categorisation of features. Despite presenting more features on the homepage than prototype 2, the categorisation gave the interface a simple and user-friendly appearance. The participants particularly appreciated the prototype´s prominent symbols, making it easier to detect features while driving compared to the textual descriptions in prototype 2. The participants also valued the inclusion of small descriptive texts alongside the symbols for further clarification.

Prototype 1 was favoured for its large buttons, which facilitated easier interaction with the interface while driving, a significant advantage over prototype 2. Additionally, prototype 1 demonstrated effective prioritisation of features, with media and navigation options larger than other categories. In contrast, prototype 2 treated all categories equally, making it harder for the participant to separate features due to their uniform shape and size.

Visually, the participants liked the dark background common in both prototypes, as it helped minimise distractions.

Furthermore, the usability test revealed that prototype 1 involved shorter interaction sequences to complete tasks, which were beneficial and appreciated. In comparison, prototype 2 involved extended interaction sequences, which led to frustration due to the increased time and effort needed to complete tasks, causing more distraction.

It was also found that most participants needed clarification regarding the setting category in both prototype 1 and 2. The title “Settings” confused the user since it was not apparent that information regarding the car’s status was also included. However, some users said that one by exclusion knew that it should be placed under settings since it did not fit into any of the other categories. Anyway, it can still be clarified. The phone category was another category that could possibly be developed in prototype 1. In prototype 2 where the features for connecting the phone to the car, calls, and messages are placed in separate categories, was appreciated by the users. Therefore, the users also believed it would be beneficial for prototype 1 to categorise its phone category in another way to increase the understanding of the features since “phone” was not accurate enough for including both connecting phone, calls and messages, according to them.

Another confusion was that some users thought that the button directing the user to the home page and the navigation button for the home address did the same task since the same house symbol appeared in both places.

The distraction mode leaded to concerns. All users understood what the feature was supposed to do, but whether it would be used in an actual usage situation was questionable. A majority meant that the display interface prevented overstimulation and distraction by itself, by its layout and design and did not feel the need to remove the accessibility to the features to prevent distraction.

User also expressed that the watch could be placed closer to the driver instead of the passenger, like in prototype 2, to enable glancing at the watch more efficiently. However, the watch’s size was appreciated by many users since the large size made it easy to identify (same for both concepts). Regarding the visual aspect of prototype 1, it felt too plain and flat in its appearance to some users; adding more contrasts was believed to make the features and symbols pop more on display, generating visual clarity for the interface.

Based on this user input, the list below summarises possible improvements for further concept development of prototype 1.

- Clarify the setting category.
- Clarify the phone category.
- Change the home button in the navigation category or the entire screen.
- Remove the distraction button.
- Place the time closer to the driver.
- Add more contrasts to the interface.

4.4.5 Summary of the evaluation

By compiling the insights from all four evaluations, three common categories were found throughout the focus areas, which can be considered the main takeaways for the entire interface from the evaluations.

The first common category found from the evaluations was about applying symbols in general. The evaluation showed that users might appreciate clear and large symbols on features above written titles. Having symbols describing the features made the recognition of the sought feature much easier and, in that way, made the time identifying the feature shorter compared to features with written texts, which is beneficial in a driving context where the eyes need to be on the road.

The second category identified concerns the size of buttons. The size of buttons was identified as an essential factor for the simplicity of interacting with the interface, regardless of whether the button was digital or physical. Since the car constantly moves while driving, a big button was considered much more manageable to press, facilitating the interaction with the interface and lowering the risk of missing or pressing the wrong button.

The third common category identified from the evaluations was that clear grouping and categorisation of features simplified the identification of features a lot. Grouping features made it easier to get an overview of the features and an impression of fewer features, facilitating the identification of features. The grouping of features made it a lot easier to learn the tactile location of the features, enabling the user to press buttons without watching and continue having the sight on the road.

4.5 Final concept

This chapter presents the final concept, developed from the evaluation outlined in the preceding chapter. The chapter begins with an overview of the overall concept and then proceeds to dissect each focus area—cluster, steering wheel, centre stack and display—separately. Its overarching objective is to furnish the reader with a comprehensive understanding of the finalised concept. The chapter also presents a theoretical evaluation of the final concept and a scenario illustrating how the final concept contributes to a good user experience.

4.5.1 The overall concept

Figure 4.17: Rendering of Final Concept

The figure above depicts the culmination of iterative evaluations, resulting in the final concept (see Figure 4.17). Primarily built upon prototype 2 from the previously mentioned centre stack, display of prototype 1, the steering wheel, and a blend of the two cluster prototypes, where each area receives detailed examination in subsequent chapters.

A consistent colour palette is maintained throughout digital and physical interfaces to ensure a cohesive design across the entire concept. Physical buttons are dark grey, matching the grey of the digital screens' borders and various display widgets. Most text and symbols are rendered in white to provide contrast against the dark background, enhancing visibility.

Exceptions were made for the home button on display, which features a black symbol on a light background and the symbol for the warning triangle, which is red, concerning the standard symbol having the colour red. Most features are represented by standard symbols, as the utilising of familiar cues as symbols are considered to enhance the overall usability of the system (Dekker & Woods, 2002), while some of the standardised symbols needed added clarifying symbols to enhance the understandability of its functionality.

Non-functional elements of the design are coloured black to maintain a discreet appearance that minimises distraction, which also applies to the two drawers and compartments for the car key and mobile phone. However, careful attention is still given to contrast to aid visibility for the driver. The cluster displays slightly more colour than other parts due to its critical role in providing information directly related to driving, necessitating heightened visibility and attention.

The theory indicates that a balanced level of mental workload is essential, as both excessive and insufficient workloads involve risks (Biondi & Jajo, 2024). To achieve a balanced workload level, the concept integrates a selected number of automated assistance systems, including adaptive cruise control and lane-keeping assist. These systems are designed to support the user effectively, reducing workload without overextending automation to prevent the driver from getting distracted by other features. Consequently, the number of features has been deliberately limited to prevent overwhelming the user with unnecessary input.

4.5.2 Cluster

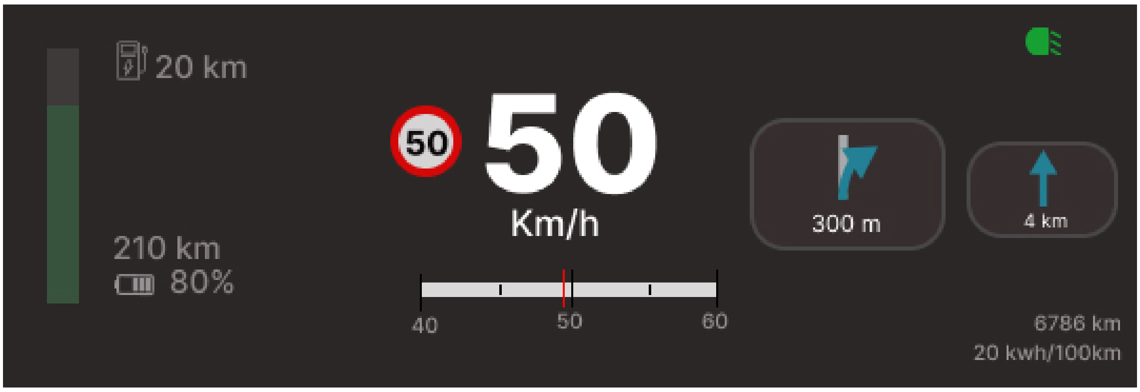


Figure 4.18: Final cluster

The final cluster combines the two evaluated prototypes (see figure 4.18). It will be described in three parts: speed, amount of electricity, and navigation.

Speed: In the evaluation of Concept 1, the speed display operates similarly, with the number changing in intervals of either two km/h or five km/h, depending on the car's speed. Additionally, a meter provides an exact reading of the current speed.

The prevailing speed limit on the travelled road is displayed in the cluster adjacent to the speedometer. This feature assists drivers in maintaining awareness of the speed limit, especially if a speed sign is missed.

Navigation: When navigation is set on the display, simplified directives will be displayed in the cluster. The navigation feature is organised into two popups: the larger popup details the upcoming manoeuvre, while the smaller popup previews the subsequent one, enabling users to plan their journey better. Upon completion of a manoeuvre, the display updates automatically—the smaller popup transitions to the larger size, and a new smaller popup appears to provide forward-looking navigation information continuously.

Electricity: The cluster includes a vertical electricity gauge that displays the remaining battery charge in percentage and the estimated driving range in kilometres. When the battery level is high, the opacity of the meter is reduced, reflecting its lower immediate importance. As the battery depletes, the display's opacity increases to draw more attention.

The gauge changes colour to yellow at 30% battery life to signal a medium level of remaining charge and shifts to red at 20% to alert the user that the electricity level is critically low (see Figure 4.19). Additionally, the display provides information about the distance to the nearest charging station, allowing drivers to plan their charging stops efficiently.

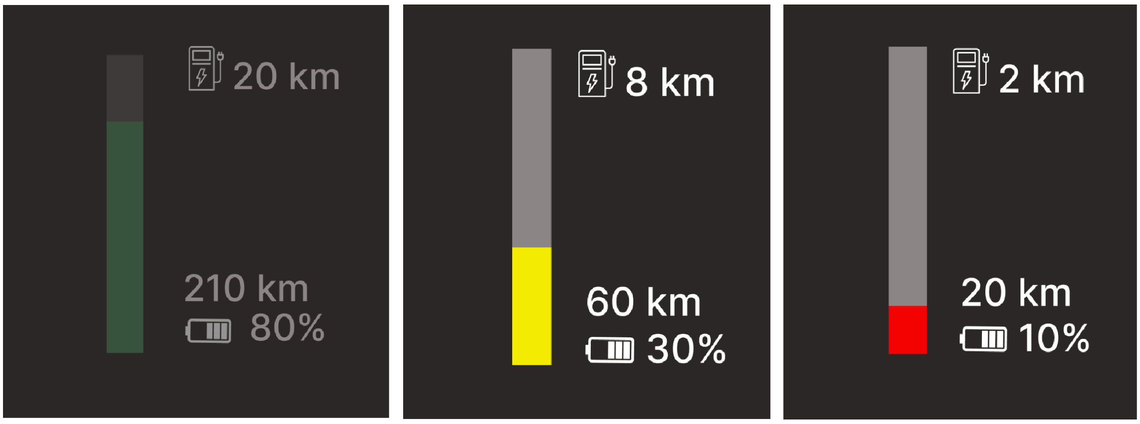


Figure 4.19: Representations of different battery levels

In addition to the previously mentioned features, indicator lights will illuminate in the upper right corner of the cluster. The lower right corner will display the total kilometres driven by the car and the electricity consumption per 100 kilometres.

Security messages will appear when needed as a banner descending from the top edge (see Figure 4.20). Once the security issues are resolved, the banner will retract and disappear.

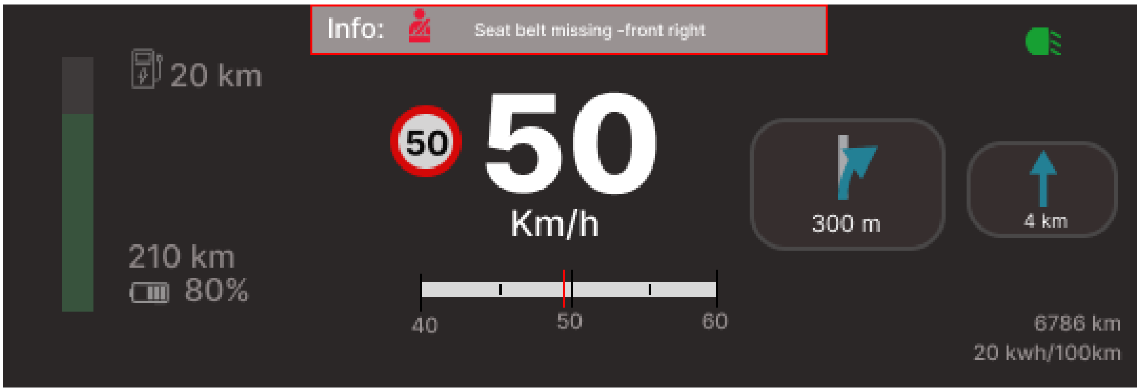


Figure 4.20: Final cluster with safety message

4.5.3 Steering wheel

The new steering wheel's design closely mirrors that of the baseline model and aligns with other steering wheels currently on the market (see Figure 4.21). The primary focus of the redesign has been refining the layout and design of the buttons to enhance user comprehension rather than altering the steering wheel's shape itself.

Figure 4.21: Rendering of steering wheel

(a) Buttons left side (b) Buttons right side

Figure 4.22: Buttons of the respective side on the steering wheel

The list below describes the various symbols that exist on the new steering wheel (see Figure 4.23).

	Lane-keep assist		Voice assistant
	Adaptive cruise control - speed		Volume up
	Adaptive cruise control - distance		Volume down
+	Increase of speed or distance	>	Arrow indicating direction Same for all four arrows
—	Decrease of speed or distance	OK	Button for confirmation

Figure 4.23: Symbols for buttons

The steering wheel's left side buttons are dedicated to driving-related functions (see Figure 4.22a), with the corresponding information displayed on the cluster. Conversely, the buttons on the right side pertain to features not directly associated with driving (see Figure 4.22b). Among these, the arrow buttons are designed to control the display settings on the steering wheel's right side.

The evaluation of the steering wheel indicated that its design was generally clear and straightforward. However, some users perceived the voice assistance function as ambiguous. In the prototype assessed, the symbol for voice control was a microphone. In the final design, this was altered to depict a person's profile with sound waves, deemed less confusing. Lane-keep assistance was also considered a bit difficult to understand, but since the symbol is a standard symbol, it remains the same as in the evaluation.

4.5.4 Centre stack

The centre stack is a protruding section that seamlessly integrates with the panel (see Figure 4.24). Its rounded sides harmonise with the panel's curved geometries. By extending no more than 20 centimetres outward, this centre stack creates substantial space beneath it and enhances the spatial arrangement between the driver and passenger.

Figure 4.24: Rendering of centre stack

The centre stack area also includes the section housing buttons between the display and the cluster (Start/stop engine, warning triangle and shifter) and the wheels for temperature and fan settings.

The controls available to the user (buttons and wheels) are organised into three categories to facilitate the user. These categories include:

1. *Driving Controls:* This area features the start/stop engine button, shifter, and warning triangle. Located between cluster and display.

2. *Temperature Controls:* This section includes seat heating, steering wheel heating, and a wheel for adjusting the temperature. (Buttons placed within the bar

of three buttons, and temperature wheel between the display and the centre stack, to the left side)

3. *Fan Controls:* This encompasses defrost for front and rear windows, air conditioning (A/C), an automatic climate setting (Auto), and a wheel to adjust fan speed. (Buttons placed within the bar closest to the panel with four buttons, and the fan speed wheel between the display and the centre stack, to the right side).

Symbols have been added to the A/C and Auto functions to enhance comprehension, as evaluations indicated these features were initially challenging to understand (see Figure 4.25). Positioned within the fan control grouping on the fan bar, the A/C and Auto buttons are strategically placed on the far left side, adjacent to the temperature wheel, reflecting their dual role in both fan and temperature adjustments. The symbols for the temperature and fan wheel are large for fast detection.

Figure 4.25: Close-up on the buttons and wheels on the centre stack

Buttons and controls provide immediate feedback to the user when any changes are made. Each button within the two bars features a light that indicates when the function is activated. The seat heater includes three light settings depending on the heat level. The gear selector illuminates to show the selected gear. The start/stop engine button lights up when the car is operational, in the same way as the warning triangle when activated. The temperature control adjusts its display numbers based on the set temperature for each right and left side. Additionally, the fan control varies the number of illuminated lights according to the fan speed.

Phone compartment:

(a) Opened lid (b) Closed lid

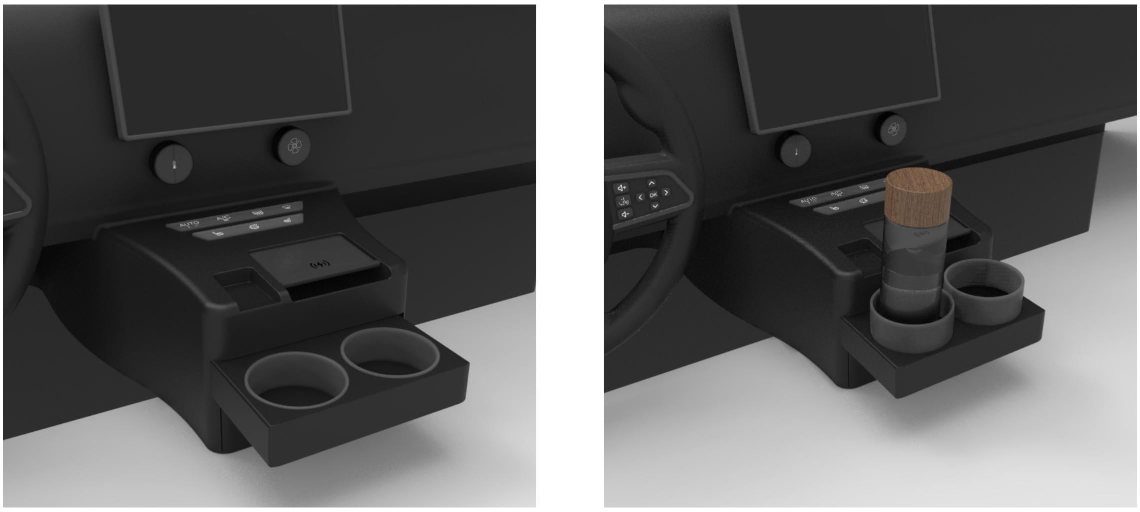
Figure 4.26: Illustrations of the phone compartment

The theoretical study identified phone usage as a source of distraction, as phone usage has been shown to affect driver performance negatively, increasing the risk of accidents (Kashevnik et al., 2021). Distraction from the use of phones was also underscored by participants in the user study as a significant factor adversely affecting drivers. To reduce distraction from phone usage, the final concept involves a solution hiding the greater part of the phone to prevent the user from looking at it. The evaluation revealed a preference for the mobile phone compartment from prototype 2 due to its balance in accessibility and distraction. The design effectively mitigates phone-related distractions while ensuring ease of access.

The compartment's flap operates with minimal user effort and retracts upon release (see Figure 4.26), thereby hiding a substantial part of the phone. Although the phone remains partially visible beneath the lid, this design choice was guided by the observation that participants valued the ability to visually verify the presence of their phone, thus helping them recollect the phone after travel. The compartment is outfitted with a QI charger, facilitating convenient charging during drives. Charging options are further delineated by symbols on the compartment's base and the lid, augmenting user understanding of the charging features. Additionally, a raised edge at the front of the compartment prevents the phone from sliding out unintentionally during travel, especially in sudden deceleration.

Adjacent to the mobile phone compartment is a designated area for car keys, featuring a forward tilt to prevent the key from sliding during travel, particularly under conditions of pronounced deceleration.

Cupholder:



(a) Drawer for cup holder

(b) Extended cup holder with bottle

Figure 4.27: Illustrations of the cup holders

In the prototype, the cupholder was positioned on the side of the centre stack body. However, in the final design, the cup holders have been relocated to the front edge of the section. This modification was prompted by the observation that side-mounted cup holders could disturb the steering wheel space, especially when accommodating larger water bottles, potentially obstructing or annoying the driver. The cup holders have been integrated into a retractable drawer feature (see Figure 4.27a).

To reduce the overall height of the protruding section, the drawer is designed to be lower than conventional cup holders. An inner section can be extended upward from within the cup holders to compensate for this reduced height, effectively doubling their height (see Figure 4.27b). When the drawer is closed, this additional cylinder is depressed, allowing the cup holder to retract to a neutral position. The drawer, when closed, is securely locked in this neutral position and requires user interaction to unlock by pressing inward on the drawer. To clarify the location of the cup holder, a cup symbol is placed on the front edge of the drawer.

Storage:
Below the cup holders is an additional compartment for storing smaller items while driving. This compartment opens and closes like the upper one, where the drawer is extended and retracted by clicking it out and pushing it back into a neutral position when closed (see Figure 4.28).

Figure 4.28: Drawer for storage

4.5.5 Display

Figure 4.29: Final Display

The final display comprises five categories: Media, Navigation, Info and Settings, Connect Phone, and Communication (see Figure 4.29), each containing specific features. Media offers features like Spotify, Radio, and phone connection via USB, while Navigation includes shortcuts for home and search functions. Connect Phone supports Apple CarPlay and Android Auto, and Communication enables calling and message reading. Below these categories is a bar that allows the user and the passenger to adjust the sound level.

Differences from the display in the initial prototypes involve renaming the Settings category to Info and Settings, as it was previously unclear that functions such as tire pressure were included under settings. The original Phone category has evolved into two separate categories: Connect Phone and Communication.

According to the evaluation, some users were unfamiliar with the symbols for Apple CarPlay and Android Auto; however, these icons are standardised and align with those used globally for the respective functions, thus remaining unchanged. Within the Communication category, the option to read messages has been added, allowing drivers to choose whether phone messages should be read aloud. This feature is toggled with a slide function displayed within the button's framework.

The voice assistance button has been removed from the display, assuming that passengers can manually input information if needed and that a driver is present whenever a passenger is in the car during the drive. Moreover, the steering wheel retains a voice assistance button. Modern cars increasingly incorporate built-in voice assistants, activated by speech, similar to the iPhone's Siri. Given this trend, it is anticipated that by 2030, cars will also feature such technology, reducing the necessity for physical buttons to activate voice control.

4.5.6 Reduction of Features

In this part, the number of remaining features and a compilation of reduced features for the entire concept are presented. The data is based on comparing the baseline car (Lynk & Co 01) and the developed final concept.

Centre stack

The newly designed centre stack integrates thirteen tangible control elements, including various buttons and mechanisms that users can operate without drawers and compartments. Compared to the baseline model (Lynk & Co 01), this revised centre stack demonstrates a 13% decrease in features, down from the baseline of fifteen features. In the baseline, the seat heating control was located in the display, but it has been moved to the centre stack in the new design. Suggesting that the actual feature reduction is more than 13%, considering that two features have been added. Thus, from the baseline set of features in the centre stack, the reduction exceeds 13%.

Steering wheel

The new steering wheel contains 14 features, a decrease from the baseline by 12,5% (Baseline 16 features).

Display

The newly designed display comprises five fixed widgets that cannot be customised. Within these categories, there are four applications. Additionally, users can adjust the volume, bringing the total number of features in the new car to ten. In contrast, the baseline model offers more options: 13 selectable widgets, 12 features accessible via a dropdown menu, 16 pre-installed applications, dual seat heating, dual temperature controls, and voice assistance, totalling 47 features. Consequently, the new display represents a 78.8% reduction in features. However, the number of features may vary as additional apps can be downloaded and customised by the user, so an increase and decrease are possible.

Cluster

The baseline car's cluster provides five different information types while driving: an electricity gauge, a fuel gauge, an indicator showing whether the car is using electricity or fuel, adaptive cruise control information, and speed. Additionally, a list function allows the user to interact with five categories: Media, My Lynk & Co, Phone, Navigation, and Energy Flow. Each category offers further interactions, such as switching between Radio and Spotify.

In the new cluster, information is limited to electricity remaining, speed, navigation, miles driven, consumption per 100 km and adaptive cruise control information. The list function was removed to simplify the cluster and reduce user input, consolidating those features into the display rather than duplicating them across both areas. As a result, the features have been reduced from 10 (excluding subcategories) to 6, representing an approximate 40% reduction.

Total reduction

Baseline: 15 + 16 + 47 + 10 = 88 features

Final concept: 13 + 14 + 10 + 6 = 43 features

Total difference: 1- (43/88)= 0,51

The final concept achieves a total feature reduction of 51%, halving the number of features compared to the baseline. The most significant reductions were made in the digital components, including the display and cluster.

4.5.7 Theoretical evaluation of the final concept

This part presents the result from the theoretical evaluation, where the first section presents the results from the practical tasks and the second section presents the results from the informative tasks, which were more focused on understanding presented information than executing a physical task. The theoretical evaluation was made on the final concept where all four focus areas had been assembled.

Practical tasks

From the first question of the CW, which was: *Will the user be trying to achieve the right effect?*, it was found that the user was going to execute every single task sometime when driving, but maybe not execute all tasks during the same trip, since it depends a lot on the circumstances, both personal and contextual, whether a specific task was executed or not. For example, the task “use the car horn” will only be executed when needed due to contextual circumstances. That finding motivates keeping all features in the final concept, since all were considered valuable during various circumstances. However, one task, “Activate read assistance of messages” was considered not to depend much on circumstances, but more on preferences, whether the user wants the messages read or not. A task that may be executed once and after that is not touched anymore. However, it was still considered an important feature to keep since it was found from the users studies that preferences regarding the read messages varied a lot, and having the opportunity to turn it on and off was considered beneficial, which motivates keeping the feature in the final concept.

From the second question of the CW, which was: *Will the user notice the correct action is available?*, it was found that redundancy could create confusion for the users when trying to notice the right action. The “Switch song” task, for example, can be executed in two places in the interface, both on the steering wheel and on the display, to enable the passenger to interact with non-driving tasks such as this one. But, having the feature appear in two places in the interface may confuse the user in deciding which one to select for completing the task. It might be a problem that the feature is more intuitive on the display, which might convince the user to interact on the display instead of the steering wheel, which had been the better choice for the driver.

It was also found from the analysis that using standardised symbols such as the ones for defrost of front/back windshield, could be confusing. Due to their similar appearance, it might be confusing for the users to identify their differences. So, the user will for sure notice that the correct action is available but not in detail, such as which one of the features focuses on the front windshield and which focuses on the back. “Auto” is also one of the standardised titles of features that do not, prominently connect to “automatic climate”. However, the added symbols of a thermometer and fan contribute somewhat to a better understanding of the feature, which will clarify that the action is available.

From the third question of the CW, which was: *Will the user associate the correct action with the desired effect?*, it was found that most of the actions were easily associated with the desired effect, which in turn means that the guessability of those features is high. However, some of the tasks, such as “Adjusting air temperature” was built on features considered to provide high learnability, which does not necessarily need to be worse, according to empirical evaluation of that particular feature.

From the last question of the CW, which was: *If the correct action is performed, will the user see that progress is being made?*, no concerns or problems were identified from any of the tasks. That means the feedback on executed tasks is sufficient for the final concept, and adjustments are unneeded.

When analysing the results from the PHEA, most of the errors identified were made by accident, usually due to small buttons that led to wrong-pressing. Pressing smaller buttons requires good fine motor skills, which also get worse when driving due to the movement in the car. Therefore, increasing the size of the smaller buttons would be a possible area of improvement for the final concept.

It was also found from the PHEA that users had no problem discovering errors made when executing a task and neither to recover the error, which is a good result for the final concept.

From both the CW and PHEA it was found that the tasks “Activate read assistance for messages” and “Adjust air temperature” were the two tasks with the highest risk of creating confusion for the user when executing them. Regarding the message assistance, it was the symbol that could be misleading and may get the user to think of voice dictation instead of messages read aloud to them. The text underneath the symbol “read messages” does not make the understanding clearer, thus more confusing since the user may wonder if it is the car that should read incomming messeges, or themselves that are suppesed to messages seak to the car aloud telling the car what to send in a message without typing the text manually. However, the feature needs further development in the final concept in order to clarify the task.

The other task “Adjust air temperature” could also cause confusion for the user, according to the evaluation. The main problem was the buttons on the wheel, which might not be found by some users, due to the buttons smooth integration to the wheel. Pressing one of the buttons before rotating the wheel enables the user to set the temperature for either the left or right side of the car solely depending on button pressed, either left or right button. However, there are also small integrated screens on each button showing a temperature, which can work as a cue for the user, telling them that the temperature can be different on the left and right side of the car.

Informative tasks

Looking into the informative tasks instead, where understanding the information presented in the final concept distinguished these tasks. From question one from the CW, which was: *Will the user be trying to achieve the right effect?*, it was not found any concerns or problems from any of the tasks evaluated, which most likely means that the user will try to execute the type of tasks analysed for the evaluation and find them necessary for their driving.

From question two on the CW, which was: *Will the user notice the correct information is available?*, it was found that the low opacity on the electricity gauge could make it difficlut for the user to notice that the correct information is available. However, the lower opacity on the electricity gauge was a conscious decision made for the final concept since it was considered to be low-prioritised information when the battery has a power status of 30% or higher. When the battery level goes under 30%, the information is considered to be higher-prioritised, and the opacity of the electricity gauge will increase, making it easier for the user to notice the information. However, it was seen as a good result that the user might have difficulties noticing the information when the opacity is low because when it increases, it will then create a more significant contrast and attract more attention from the users, which was the purpose of the feature.

From question three from the CW, which was: *Will the user associate the information with the desired effect?*, it was found that some of the features, such as the electricity gauge, provided high guessability, while others, such as the direction notifications and the speedometer instead, provided high learnability. However, that was not considered a problem since the users from the empirical evaluation expressed that they were okay with features providing high learnability instead of guessability because you learn your own car quite fast.

The 4:th question from the CW, which was: *If the correct action is performed, will the user see that progress is being made?*, was only applicable to evaluate some of the tasks since progress is not usually made when the task is just understanding the information presented. However, for those tasks where progress could be made, which were: “solve safety messages” and “check tire pressure” it was considered clear to the users when progress was made.

Since the PHEA focuses on physical errors, it was not used as an evaluation method for the informative tasks.

To summarise the theoretical evaluation of the selected tasks, it was found that all features were considered relevant for the interface and useful for the user. It was also found the features provided sufficient feedback when interacting with the interface, helping the user to understand when progress of an action has been made. However, the redundancy of features provided could be considered a problem with the interface of the final concept. Providing two alternatives for executing the same task was useful when the passenger wanted to interact with non-driving tasks. However, the confusion it causes for the driver, having two options for executing the same task, might be more critical to consider in this case. The redundancy of features in the interface is an aspect that needs to be investigated further to be able to take a clear standpoint on the question of whether redundancy is good or not. The evaluation also found that the two most confusing tasks were “Adjust air temperature” and “Activate read assistance for messages”, where features related to those tasks may have to be further improved to prevent this confusion and, in turn, enhance the usability of the final concept. However, the usability can generally be considered good based on the results of the theoretical evaluation.

4.5.8 Scenario - Illustrating future user experience of the final concept

Emil, 27, and Emilia, 29, are travelling by car from the outer city where they live to the city centre, where Sofia, a friend of Emilia’s, is having her birthday party today. The city they will navigate in is a middle-sized city located in Europe, and on their way, they pass various types of roads, residential areas, highways and low-speed areas in the very city centre are some of them.

Emilia drives the car, and the first thing she does before leaving is to press the navigation category on the display and type the destination to the correct location for the party. Emilia finds it easy to do the task since the navigation category is highly prioritised on the home screen, with its large button and clear map symbol. Before leaving, she also places her phone in the dedicated phones compartment, which charges while driving, which Emilia thinks is nice since she will arrive at the party with a fully charged phone. Placing the phone in the compartment also helps Emilia shift her focus to driving and enjoy the conversation with Emil, which she really appreciates.

Emilia starts driving using eco-driving mode on the gear shifter wheel. Emilia likes that the eco-mode is a possible driving choice since it aligns with her values and environmentally friendly lifestyle. Of course, she knows that just having a car is not the best choice from an environmental point of view, but since Emil needed a car for his job, it was important for Emilia that the car they bought was as sustainable as possible. Therefore, they bought an electric car, which they both were very pleased with. Emilia also highly values the eco drive mode, which she uses every time she drives the car, and appreciates that it is the easiest choice of gear, located above all other gears, which makes it easy to see and shift to, which has also made Emil to change his behaviour and now use the eco mode.

When Emilia starts driving, she notices that the battery is running low since the colour on the electricity gauge is yellow and the staple is low. Emilia takes a look at the number beside the electricity gauge, indicating the distance to the empty battery, and compares it with the distance to the closest charging station, which is also shown in the cluster. She can ascertain that there is no risk of running out of battery, which calms her.

After a while driving, Emilia presses the voice assistance button on the steering wheel and says, “Call Sofia,” and the assistant answers, " Calling Sofia.” Emilia really appreciates the voice assistance since it facilitates her driving and enables her to focus on the road with minimal distraction. She also likes that the button for voice assistance is located on the steering wheel, which makes it easy to reach while driving.

When Sofia answers, Emilia tells her that they will arrive at the party in approximately 20 minutes, which she can easily find out from the navigation on the display, which estimates the arrival time. Emilia also asks Sofia if she knows of any good charging station close to where she lives. Sofia mentioned a road close to her that had charging stations, and Emilia could easily find the corresponding place on the map, which also pinpointed all available charging stations. Emilia appreciated the easy and quick communication with Sofia since she could easily focus on the road while still having an informative call with Sofia.

Today's weather is sunny, and it is getting warmer and warmer in the car. Emilia glances at the centre stack and quickly identifies the group of features controlling the climate. She identified it quickly since it is just one out of a total of two major groups of features. In the climate group, she identified a button with the text AC and a snowflake and could easily understand that this button would lower the car's temperature. The quick glance at the features gave Emilia enough information to set out her left hand and press the right button, just by using her tactile sense. The few features in the centre stack, combined with their well-organised categorisation, made it easy for Emilia to identify the right feature. When pressing the AC button, Emilia also felt that the good reachability to the button enabled her to continue having a good body posture, ensuring a good and safe driving position. Emil and Emilia appreciate how fast the conditioning kicks in, making the temperature comfortable in the car.

After driving for 5 more minutes, they arrive at the highway, where the traffic is stable for the moment with a constant flow of cars. Emilia glances at the cluster and sees that the upcoming action will be in 20 km, when she will exit the highway. Therefore, she decides to put on the adaptive cruise control, which Emilia thinks is a helpful and comfortable tool in these driving situations, which often occur on highways in middle-sized cities like this one.

Even though the adaptive cruise control is activated, it is still important for Emilia to focus completely on the road and traffic. She knows that crucial situations can quickly occur and then it is important to be able to be alert and take action. However, everything is running smoothly on the highway for the moment, and Emilia asks Emil to play some music to get them in the right mood for the party. Emil quickly finds out how to connect his phone to the car since it is one of the main categories on the display, and after just a minute, Coldplay is playing in the speakers. Both Emilia and Emil appreciate that Emil could handle the music, Emilia since she could then focus exclusively on the road, and Emil since he feels he could support Emilia when she is driving by managing non-driving tasks like this one.

When Emilia finally exits the highway and gets onto smaller roads as they proceed into the city centre and progress towards the party location, the traffic situation becomes more intense. Emilia feels that she needs to focus on navigation and her surroundings to reach the destination on time. Therefore, she decided to lower the sound of the music by pressing, without taking her eyes on the road, the volume button on the steering wheel, which she had identified before when she set the cruise control, which was also located on the steering wheel. Having the possibility to lower the sound of the music quickly was appreciated by Emilia since she felt less distracted and overstimulated and could fully focus on the navigation and the surroundings when the sound was not there.

The last minutes of the trip went well, and Emil and Emilia arrived at the charging station close to the party location right in time. Both of them enjoyed the trip through the city and felt that the car supported them, or mainly Emilia, in her driving through the city. Overall, Emilia and Emil experienced a smooth, distraction-free drive, where the focus was on the road, the traffic and the surroundings throughout the entire trip.

End of scenario.

Based on this scenario, the user experience of interacting with the final concept in an urban context can be considered good. Emilia felt that the concept actively supported her driving and made her focus on the actual driving, which she really appreciated. In situations when she needed to execute tasks in the interface, she did it without any difficulties and very quickly, sometimes without even watching, just using her memory and tactile senses. It was especially appreciated when driving in the city centre, as the navigation was getting more intense and required her full attention. In general, Emilia felt grateful for how the design supported her in her driving, which made her a better and safer driver in the city context, which was the major contributing factor to her positive user experience.

5

Discussion

This discussion chapter provides a comprehensive overview of the thesis and its contributions, addressing the research questions. Discussing weaknesses, implications of the findings, and suggestions for future work.

5.1 Overview and contributions

This research aimed to explore the interplay between feature reduction and user experience in urban driving contexts, evaluating the feasibility of reducing the number of features while creating a rich experience. The study reveals that excess features can diminish usability and safety, while features aligning with the users' needs can create a pleasant driving experience.

The findings demonstrate that a rich experience can be created even with a reduction in the number of features. The final concept reflects a reduction of features by roughly 50 per cent, whereas the final evaluation reveals that the level of usability is high for the new concept. Theoretical insights from Yang et al. (2021) support this finding, highlighting a direct correlation between usability and overall experience. Specifically, the ease of use, ready access, and clear comprehension of essential information enhance user satisfaction. It is deemed highly likely that the final concept delivers a rich user experience, as the retained features have been meticulously chosen to fulfil user needs.

The project aim has been achieved by addressing the stated research questions from the introduction.

Q1: What factors affect user experience in a human-machine interaction whilst driving?

The first research question was addressed by compilation of the factors affecting user experience from User Study 1 and User Study 2 (See table 5.1). The table illustrates several factors that can affect the driving experience; those factors are considered important when designing as, when designed in the right manner, they can positively affect the user experience and enrich the overall user experience.

Table 5.1: Factors affecting user experience

Physio	Psycho	Socio	Ideo
Driving assistance	Information about car status	Presence of passengers	Safety
Body position	Safety information	Communication with others	Economy
Identification of features	Navigation help	Interaction by passengers	Environment
Number of interactions	Clear buttons		
Storage	Context		
Climate	Accesibility of media		
Sound quality	Connect phone		

The observed effects on user experience showed that physio and psycho factors had more impact than socio and ideo factors. The UX curves further demonstrated that the experiences negatively affecting the driver were predominantly associated with physio and psycho pleasures. Previous research provided additional insights that aligned with these categories, frequently discussing the negative consequences of feature overload. These discussions highlighted the links between an excessive number of features and increased workload, as well as reduced situational awareness due to distractions ((Grahn & Kujala, 2020), (Sajan & Ray, 2012) & (Dekker & Woods, 2002)). These issues primarily impact psycho pleasure, but also, to some extent, physio pleasure.

Conversely, literature on socio and ideo pleasures as influences during driving was less abundant. This scarcity was reflected in both user studies and literature reviews that predominantly highlighted physio and psycho pleasures. Consequently, the abundance of information on these pleasures naturally steered the project's focus more toward these areas.

Although socio and ideo factors were considered in the project, the predominance of data regarding physio and psycho factors may have shaped the project's outcomes, resulting in a final concept more targeted towards physio and psycho. It would be intriguing to explore further how the outcomes might have differed if there had been a more balanced focus across all four pleasures or if the emphasis had been shifted towards enhancing socio and ideo factors.

Q2: What features are essential for a positive user experience whilst driving?

The second question was addressed by collecting data about features and their relevance and placing them into the Kano model. The second research question includes the features placed within basic and performance-enhancing features from the Kano model (see table 5.2).

Table 5.2: Essential features for a positive experience

Basic	Performance-enhancing
Steering wheel	Connect phone
Hazard warning light	Change song
Speedometer	Heat steering wheel
Fuel gauge	Parking assist
Car horn	Reversing camera
Gear shifter	Hands-free system
Parking brake	Voice dictation
Watch	In-car speed signs
Indicator light	Written communication
Start/stop engine	Sound quality
Climate system	Adaptive cruise control
Navigation system	Media information
Media system	
Storing possibilities	

The basic requirements were deemed essential as the lack of them would negatively affect the experience. Since the project evaluated the user experience of driving a car and how to create a rich experience, the performance-enhancing features were also deemed essential for the driving experience as their presence could enrich the experience.

An unexpected insight from the user study regarding essential features for a rich user experience was that entertainment-related features did not positively impact the users as much as anticipated. And thus the number of essential features belonging to performance-enhancing were lower than predicted. Instead, trends suggested that the absence of such features actually enhanced the experience. Participants indicated that modern cars often include too many extra features that distract from the act of driving itself. For instance, one participant noted, *"The focus should be on the experience of driving, not on numerous extraneous features unrelated to driving."* This feedback revealed that users today may not value all the additional features typically added to cars to maximise the experience. This finding not only supports our project's direction but also provides further justification for reducing the number of features, aligning both with safety considerations and better meeting users' preferences.

The information for both research questions 1 and 2 was collected through user studies to understand drivers' needs and preferences. Adopting a user-centric design approach is essential in identifying which features to retain and which to eliminate. Features that consistently ranked high in terms of utility and user engagement from these studies were prioritised, while those that added no or little value from the users' perspective were phased out.

Q3: How can a rich user experience be created while reducing the amount of features?

The answers to the two preceding questions establish the basis for addressing Research Question 3. A final concept was created to evaluate the project's aim.

The findings of this study underscore that reducing the number of features in urban driving contexts does not necessarily compromise the user experience. Instead, a rich user experience can be created through strategic feature selection and focusing on the integration of essential features that directly enhance usability and driver satisfaction.

The study revealed that user satisfaction depends not solely on the number of features but also on their relevance. By prioritising essential features that support core driving tasks and safety, the design can enhance the driving experience without overwhelming the user with unnecessary complexity. In the context of driving in urban settings, mental overload was found to be a common challenge when driving. To make it easier during urban driving, cars should be designed to reduce their workload, where a reduced complexity and number of features is a good step in the right direction. This is supported by earlier research mentioning a balance in workload as important, as high or low mental workload increases the risks of accidents and can overwhelm the drivers, making them less satisfied (Biondi & Jajo, 2024).

However, evaluating the workload further would have been beneficial, as the study indicated that the context impacted the workload level. It was high in urban settings, and there were indications towards low workload and boredom in suburban settings. Due to this, one interesting area for future work would be to examine how the context influences the level of workload and how to design for a good balance.

Certain market trends are moving toward minimalism, which eliminates physical features and results in a car interface with fewer apparent features. However, the insights from this project reveal that minimalism does not necessarily equate to fewer features. In fact, cars that adopt a minimalist aesthetic may incorporate more features that are integrated into digital interfaces like screens rather than physical controls. The screens are then considered to be more complex and harder for the user to understand, and consequences in the form of distraction or overstimulation seem common.

5.2 Weaknesses

User Study 1 was conducted in a Lynk & Co 01 parked outside the Lynk & Co Design Office due to regulatory restrictions prohibiting moving the car. This limitation constrained participant recruitment to the office's location, resulting in four out of six participants being company employees. Although efforts were made to include employees from diverse disciplines, the participant group could still be considered relatively homogeneous, representing a potential area for improvement in the study. For user study 1, it would have been beneficial to include a more diverse and numerous group of participants. Since many participants were already familiar with the car being studied due to their employment at the company and because several had a background in design, it is likely that these factors influenced the results. Ideally, Study 1 would have been conducted with a broader array of participants to gather more varied insights and avoid biased responses. It would have been particularly valuable to involve more individuals aged 30-60 who are not affiliated with the car industry, as people in this demographic often own cars and possess substantial driving experience, providing a more representative perspective on the car's impact. A more diverse participant demographic might have provided insights that are more representative of the general user experience across different user groups.

In addition to the factors identified in User Study 1, User Study 2 also yielded valuable insights into factors affecting the driving experience. Since the first study was conducted in a parked car and thus might have missed insights only obtainable during actual driving, User Study 2 was deemed essential. This second study was conducted while driving, using the participants' own cars, which made them feel more comfortable and secure and provided a more realistic reflection of everyday driving conditions. However, because User Study 2 was conducted in the participants' home environments, it lacked the controlled conditions and direct observation possible in a more structured setting as the first study. For user study 2, the study probably would benefit from a larger sample size. With more participants the data would likely be more covered, allowing a better generalisation of the results. In User Study 2, only physio and psycho factors were identified as contributing to negative experiences; a larger sample might have revealed additional insights into the negative experiences associated with socio and ideo factors that were underrepresented in the current data set.

The studies noted that some participants might have provided responses they thought were desirable rather than their genuine opinions. This desirability bias might skewed the results. It would have been advantageous to simplify the tasks assigned to participants and include a larger number of participants, thereby minimising the time demand on each individual while still gathering a more extensive dataset.

The evaluation of the prototypes was executed in parts, where the steering wheel and centre stack were evaluated as one part and cluster and display as another evaluation part. Dividing the evaluation into two parts instead of making a large evaluation that covers all parts may have affected the evaluation as the holistic view is missing.

Evaluating all together would probably also have increased the understanding of the different parts and the connection between them.

Furthermore, the evaluation was executed only with participants from industrial and interaction design engineering, which probably influenced the project outcomes as the participants were used to design and had knowledge within the field of design and product development. Ideally, the evaluation would have been executed with a wider range of users. The total number of participants for the evaluation part was ten. A greater number of participants would also benefit the outcomes by collecting more data, as the answers from every single participant influenced the outcomes a lot, and thus potentially steered the answers more than desirable.

The final concept was evaluated theoretically using cognitive walkthrough (CW) and predictive hierarchical error analysis (PHEA); it would have been beneficial to carry out a more in-depth evaluation in which the concept was also evaluated with the users in order to evaluate how the final concept is responsive to the users' needs and to evaluate the experience more in-depth with the intention to examine how rich the experience for the final concept is.

It would be rewarding to evaluate the final concept in relation to the baseline car. For this comparison, the final concept and baseline car need to be on equivalent levels. This involves enhancing the final concept to match the actual car by creating a model of the included components at this higher standard. If the baseline car does not align with the developed concept, it may need adjustments to bring it to a similar level. Comparison can also be made by lowering the level of the baseline car; in this project, the final concept is visualised using 3D modelling in Catia to represent the same level the baseline car can be represented in the same way to provide fair and accurate results. This approach ensures that discrepancies do not influence participants' perceptions of the conceptualisation level of the designs. By evaluating the concept of the baseline car, insight can be gathered into how well the new concept performs in relation to the baseline car.

The project has involved driving in urban contexts in Europe. Since the project was executed in Gothenburg, Sweden, its focus has been on this context. In general, cities in Sweden are quite small in relation to many other cities around Europe; therefore, looking into other cities as well, mainly bigger cities would have been valuable. Since traffic situations can vary among different cities, the project would benefit from involving more cities around Europe. In larger cities, the assumption can be made that the trends encountered during city driving in the project were overstimulation; the assumption can be even greater challenges in larger cities and thus becomes an even more important factor.

5.3 Implications

The implications of the findings for this project can help car designers design products that focus on the essential features and factors to ensure a good user experience without adding unnecessary features that can negatively affect the users and, thereby, the company. By fulfilling the requirements in the requirements list, future car designs can be developed for users with their actual needs in focus.

The findings from this study underscore several implications for car companies aiming to enhance user experience while considering feature reduction in car design.

Automotive companies should concentrate on identifying and enhancing core features that significantly impact the driving experience. This means prioritising features that improve safety, ease of use, and comfort. For example, companies should focus on features related to the driving task, which are valued over less essential features like advanced entertainment systems.

We believe that companies would benefit from adopting and strengthening user-centred design practices. This involves integrating users more into the design process, from initial data collection to evaluation of final concepts. Engaging with a diverse group of users early and often will help ensure that the features developed are genuinely reflective of user needs and preferences, which are also deemed relevant from a marketing perspective, as happy users are more willing to stay with one brand.

Given the negative impact of feature overload on usability and situational awareness, companies should streamline interaction interfaces to reduce cognitive load and help the users. This could involve designing more intuitive displays, reducing the number of steps required to perform common tasks, and employing more universal icons and symbols.

Car designers need to create a fully developed concept to enable the implementation of a car based on our findings. The final concept presented in this project should not be considered a finished concept proposal but rather an example of how it can be achieved. The final concept needs to undergo further evaluation and development for implementation.

Finally, companies need to evaluate the project in terms of long-term applicability. As cars become increasingly automated, the applicability of the project needs to undergo discussion. With more automated cars, there is a concern that users may struggle to assume control due to a lack of understanding, leading to an increased risk of distracted drivers, which has been an essential aspect of this project. Our project is deemed relevant for cars where the driver needs to be able to take over the control, but less applicable to fully autonomous cars, as distractions do not pose direct safety risks.

6
Conclusion

The automotive industry is currently highly competitive, with companies trying to attract buyers by providing the best possible experience. This competition has led to cars being equipped with an excess number of features. However, this distribution of features has been linked to several negative consequences, including imbalances in workload and reduced situational awareness. Due to this, the study aimed to explore the impact of feature reduction on user experience within urban driving settings.

The findings reveal that a streamlined approach to car design, focusing on essential features, can create a rich experience and efficiently address safety and usability concerns. The implications of the findings suggest that car manufacturers should prioritise features directly linked to the driving task and usability over feature abundance. The findings from this project indicate that this shift from feature abundance could lead to new designs that better meet users' needs.

Our project demonstrated that reducing non-essential features from the investigated areas could lead to a more focused and safer driving experience. Participants participating in the user study expressed higher satisfaction levels when interacting with cars offering fewer features, as it, in turn, reduced the cognitive load and allowed drivers to focus more on the driving task itself, which was an essential aspect of driving in cities, as the traffic situation in urban settings were deemed challenging.

These findings can contribute to the ongoing debate regarding user experience in the automotive industry. By highlighting feature reduction, this research supports a shift towards more simple and user-centred designs in car manufacturing. We encourage companies to reconsider the current trend of "more is better" and instead evaluate the actual impact of added features on driver experience and safety.

The project addressed a noticeable gap in the existing literature in automotive research, which currently focuses more on the consequences of an abundance of features rather than how to tackle the consequences by reducing them. We believe the implementation of this project extends beyond the automotive industry, suggesting a broader consideration of how features within product design are aligned with user needs.

We encourage future studies to explore the long-term effects of reducing the number of features and examine how the experience is affected over extended periods. It would also be beneficial to evaluate how the context influences the users' needs, in terms of urban or suburban environments as well as cultural contexts, to examine how cultural differences might affect preferences for car features.

In conclusion, the findings from this project underscore the need for more thoughtful integration of features in car designs, prioritising essential features focusing on the driving task and overall experience over the mere number of features. This project suggests a shift towards simplicity that could redefine user expectations and industry standards in the years to come. A balance between innovation and user-centric design should lay the ground for a new approach valuing simplicity and functionality, leading the transformation for safer and more enjoyable driving experiences.

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A

Appendix 1

Contextual inquiry template

This research is dedicated to exploring user experience in cars and assessing whether a reduction in features can maintain or enhance the level of positive user experience compared to the current models with abundant features.

The objective of today's study is to gather data about current user experiences and feature interactions directly from actual users within a vehicular context.

The study will concentrate on the driver's experience. We ask that you envision yourself as the driver throughout the entirety of this study, focusing on in-car experiences and factors affecting them while disregarding external elements such as weather. Please keep an open mind; remember, there are no right or wrong answers, only your personal insights.

The study consists of two parts: the first is a scenario walkthrough, and the second is an interview.

Part A

You wake up at 7:00 and look out the window to see that it's a misty February morning. It's 7:30 when you leave your home on Spaldingsgatan (Johanneberg) to head to work at Lync & Co Design in Lindholmen. The sun is just starting to rise as you start your car and head out onto the roads.

Part A

Figure A.1: Map over the route for the senario

What would be needed at this time?

The first part of your journey takes you through the city centre. You navigate through narrow streets, passing by beautiful buildings while keeping an eye on the traffic. Sometimes, you have to stop at red lights while waiting for your turn to continue.

Is there anything you feel you need to add to what you've previously mentioned?

After navigating through the city's congested streets, you reach the highway. You accelerate and merge into the flow of traffic. The morning rush hour becomes noticeable, and you find yourself in line among all the other drivers. Eventually, the traffic clears up, and the straight stretch of the highway gives you a chance to relax a bit while maintaining a steady speed.

Is there anything you feel you need to add to what you've previously mentioned?

But soon, you're approaching Lindholmen, and it's time to exit the highway. You follow the signs and navigation to reach your destination. The road becomes more winding as you approach Lindholmen, and you have to pay attention to road signs and other drivers as you navigate through roundabouts and narrow roads.

Is there anything you feel you need to add to what you've previously mentioned?

Finally, you reach Lync & Co Design in Lindholmen just as the clock strikes 8:00.

Despite the different road conditions and challenges along the way, you've managed to arrive on time to start your workday.

Is there anything you feel you need to add from what you've previously mentioned?

THE CAR IS COVERED UP

Is there anything you feel you want to add now that you see what's in this car?

Now, let's turn it around. What do you feel you don't need? What feels excessive and unnecessary? First, look at physical features, then go into the screen and look at the main menu.

Part B

What do you currently feel contributes the most to a good driving experience? Which features/aspects?

What do you think could enhance your driving experience if you could think completely freely? It doesn't have to be things that are currently available in cars.

Physio:

How would you describe the physical comfort level of the car you're in?

Can you mention any features or elements of the car that you feel contribute to your physical well-being?

Psycho:

Do you ever feel over or under/over-stimulated when driving in urban environments? How do you feel most often? What contributed to this feeling, and what do you do to prevent it?

Are there any specific features or elements of driving that uplift your mood or emotional well-being?

Socio:

Do you often drive alone, or do you frequently have passengers with you? How does their presence affect your driving experience?

How important is the social aspect of driving to you? Are there any features or elements that facilitate your social engagement while driving?

Ideo:

What do you value when it comes to cars? What is important to you? (Safety, reliability, comfort, affordability, environmental impact, style and design, space.)

Are there any environmental or ethical considerations that influence your choice of car or driving behaviour?

B

Appendix 2

Appendix 2 is divided into two parts: one part for ideating the centre stack and one part for fortifying the cluster.

Part A

Part 1: Center Stack 16:00-16:30 Method: Pairs will sketch concepts, followed by a discussion where all concepts are reviewed (pros/cons).

Time Spent: Concept generation 20 min, Discussion 10 min.

Task: You are to develop concepts for the centre stack that must include the following functions:

Shifters (R, D, N, P)

Climate control (seat warmer, steering wheel warmer, air heater)

Engine Start/Stop

Storage for mobile phones and drinks (mobile charging)

When developing the concepts, consider the placement and design of the function (it should have a physical form like a lever, knob, button, etc.), and how these functions provide feedback to the user about their status.

Imagine it's the year 2030, and electric cars are the standard! This means that the space in the car is not limited by the elevation between the front seats since it does not need to exist in electric cars. Here are some example images that can help you with inspiration for idea generation. You will also have access to a drawn model of a panel if you do not want to sketch the panel from scratch.

Here are some words to keep in mind when developing the

concepts:

Minimalist

Accessible

Understandable

Work in pairs and sketch at least two different overall concepts that include the aforementioned functions. You have 15 minutes. This will be followed by a group discussion where all concepts are explained to the group, and the pros and cons of each concept are collectively discussed.

Part B

Part 2: Cluster 16:30-16:55

Method: Braindrawing, followed by a discussion where all concepts are reviewed (pros/cons).

Time Spent: Braindrawing 6x2 min, Discussion 10 min.

In this task, you are to develop concepts/ideas for the cluster where the following information should be included:

Speed

Electricity meter

(The size and shape of the cluster are optional)

Consider whether these features could be presented/visualised on the screen to make the information more accessible to the user while driving, preferably towards a simpler and more minimalist approach.

The aforementioned functions must be present on the screen, but it is also open to add other features if you feel they would contribute to a better driving experience. However, it should still feel minimalist!

This task will be conducted as a Braindrawing session where each participant gets a piece of paper to sketch on for two minutes. Then the paper is passed clockwise to the next person who can choose to continue sketching on the previous person's sketch or start a new sketch (still on the same paper) if they have a new thought or idea. The session ends when all participants have had all the papers.

This will be followed by a full-group discussion where all ideas/concepts are explained, and everyone has the opportunity to share opinions and thoughts about the ideas/concepts.

C
Appendix 3

CW			
TASK: Select drive mode	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes/No	It is a standardised task to do when driving an automated car, which can be confusing if the user is not used to them.	The appearance of the gear shifter does not look the same as the gear shifter in a car with a manual shifted gear
2. Will the user notice the correct action is available?	Yes	If the user is used to an automated car it will be obvious that the D stands for Drive, if the user is not used to automated cars it can be confusing. However, D is a logic shortening of the word Drive	.
3. Will the user associate the correct action with the desired effect?	Yes	It should be obvious that the indicator on the wheel shall be rotated to aligned with the desired gear.	
4. If the correct action is performed, will the user see that progress is being made?	Yes	The letter D will light up when it is selected	

PHEA				
Error	**Cause**	**Consequences**	**Discovered**	**Recovery**
Select the wrong gear	The user rotates the wheel too far, either up or down, due to its continuous movement	The wrong gear will be selected, either Eco drive which actually is a positive consequence, or to N (neutral) which means the car will not go anywhere.	The wrong letter will light up	Rotate the wheel to the right gear

CW			
TASK: Start engine	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes	The user usually wants to drive when sitting in a car	
2. Will the user notice the correct action is available?	Yes	The text "Start Engine" is written on the button	.
3. Will the user associate the correct action with the desired effect?	Yes	Yes, the text "Start engine" is a clear indicator of the effect when pressing the button	
4. If the correct action is performed, will the user see that progress is being made?	Yes	The text on the button will light up	

PHEA				
Error	**Cause**	**Consequences**	**Discovered**	**Recovery**
Pressing the hazard light button by accident	These two button are placed very close to each other, and the user can therefore press the wrong button by accident.	The car will not start (the hazard light will not start since the car is not yet started)	The car is not starting, the text does not light up	Press the right button

CW			
TASK: Use the car horn	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes/No	When the user feels it is necessary	
2. Will the user notice the correct action is available?	Yes	There is a symbol of a horn on the center part of the steering wheel	.
3. Will the user associate the correct action with the desired effect?	Yes	It is a standardised symbol and position of the car horn	
4. If the correct action is performed, will the user see that progress is being made?	Yes	The car horn will generate a loud sound	

CW			
TASK: Adjust air temperature	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes	The user wants to adapt to the temperature due to weather conditions and their own preferences.	
2. Will the user notice the correct action is available?	Yes/No	• A symbol of a thermometer indicates this action is available. • Small displays on the buttons illustrating the set temperature will indicate the action available due to the Celcius symbol.	• The user will notice it is possible to change temperature but may not notice that it can be changed for both sides simultaneously. • The user will notice that the temperature can be changed but may not notice that it can be changed for each side separately.
3. Will the user associate the correct action with the desired effect?	Yes/No	If the user understands that they can adjust the temperature on each side, they will associate the correct effect. If they want to change the temperature for both sides they have one right way and one way that is working both not preferable.	• Adjusting the temperature for both sides of the car can be done in two ways. One is simpler and preferable, so it could be seen as a problem doing the other, more complicated way.
4. If the correct action is performed, will the user see that progress is being made?	Yes	Small displays will change when progress is being made. ex. 20°C→21°C	

PHEA

Error	Cause	Consequences	Discovered	Recovery
Adjust to the same temperature for both sides by pressing the two buttons, when just rotating the wheel should have been enough	Unclear interface. The user does not now just rotating the wheel will change the temperature of both sides.	It takes a longer time to achieve the right action.	Rotating the wheel by accident without pressing the button first.	No need to recover to do right next time

CW			
TASK: Turn on the seat heat	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes	When it is cold outside, the user wants to get warmer fast	
2. Will the user notice the correct action is available?	Yes	A standardised symbol for seat heat is used on the button.	
3. Will the user associate the correct action with the desired effect?	Yes/No	The user will understand the function of seat heat but might have difficulty understanding different heating modes.	The three lights indicating the heating modes can be unclear to the user, resulting in too high heating.
4. If the correct action is performed, will the user see that progress is being made?	Yes	The light/s will indicate that action is performed.	

PHEA				
Error	**Cause**	**Consequences**	**Discovered**	**Recovery**
Setting too high heat on	The three lights that indicate the modes are unclear to the user.	Feeling uncomfortable using the seat heat.	When trying to turn it off, the user will notice it will lower one mode at a time when pressing it, i.e. it requires three presses to turn it off	Adjust the heat mode by pressing the button
Not understanding there are one button for each side (driver/passenger)	Unclear to the user that there is one button for each side	Turning on the heat on the wrong side	There will be no heat on the side for the one that wants heat, and if a person is on the other side, they will feel the heat instead.	Turn on the heat on the right side.

CW			
TASK: Use Auto	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes/No	If the user feels that they want to use an automated system for temperature and fan, they will try to achieve the right effect; otherwise, they will not.	
2. Will the user notice the correct action is available?	Yes/No	The symbols, in combination with the text, will get the user to know the correct action is available	If the user does not know what Auto is they maybe will not know what the button does.
3. Will the user associate the correct action with the desired effect?	Yes/No	If the user knows the button from before, they will associate the correct action with the desired effect. But if the user doesn't know it, the symbols and text may give them a clue about what will happen.	The user may not know that the set temperature on the rotary control will affect the performance of the Auto button.
4. If the correct action is performed, will the user see that progress is being made?	Yes	A light on the button will shine when the feature is activated.	

PHEA				
Error	**Cause**	**Consequences**	**Discovered**	**Recovery**
Does not understand the connection between Auto and Temperature	The user does not understand that they set the temperature for Auto themselves	When the Auto is activated, the temperature can get too high or too low, creating a discomforting climate in the car.	The temperature gets too warm or cold.	Adjust the temperature on the rotary control

CW			
TASK: Turn on Defrost Front	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes	They want to have good sight when driving	
2. Will the user notice the correct action is available?	Yes	The user will notice that they can turn on the windshield Defrost as the symbol is standardised	you will know that the correct action is available, but may not which button is for defrosting the front windshield and which one is for the rear windshield
3. Will the user associate the correct action with the desired effect?	Yes/No	If the driver is used to the Windshield defrost, they will associate the correct action; if they are not used to the different defrost buttons, it can be unclear.	The symbols for the front windshield and rear windshield are equally illustrated which can be confusing for a beginner who then can choose the wrong button
4. If the correct action is performed, will the user see that progress is being made?	Yes	A light on the button will shine when activated	

PHEA				
Error	**Cause**	**Consequences**	**Discovered**	**Recovery**
Turn on the wrong windshield defrost	The symbols are similar so can be unclear which one controls the front	The fog/frost will remain	No clear sight	Turn on the other windshield button

CW			
TASK: Change song	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes	Music is an essential part of the driving experience, and it was considered necessary for people to adapt it to their own preferences.	
2. Will the user notice the correct action is available?	Yes	On the display, there are standardised symbols for switching songs beside the play button (an even more standardised symbol) and a picture and title of the song playing. The placement may indicate the possibility of adjusting the song somehow.	Since the information about the song is on the display, the user may not consider that switching songs can also be done using the buttons on the steering wheel; instead, they may exclusively use the touch function on the display to switch songs.
3. Will the user associate the correct action with the desired effect?	Yes/No	If the user presses the button directly on the display, they may associate the correct action with the desired effect, but they may need more cues to associate that the buttons on the steering wheel can do the same action.	The distance between where the action is executed (the steering wheel) and where it can be seen (the display) can confuse.
4. If the correct action is performed, will the user see that progress is being made?	Yes	When a song is switched, it is displayed on the screen and heard from the speaker system.	

PHEA				
Error	**Cause**	**Consequences**	**Discovered**	**Recovery**
Not using the button for switching song on the steering wheel.	The interface does not clarify for the user that the arrow on the steering wheel can also be used to change the song.	The user needs to release the steering wheel for a while when pressing the button on the display instead, which will be more of a traffic hazard.	If the user tries to switch music on the steering wheel, they may find the function.	When the user finds the function on the steering wheel, it can be used as intended.

CW			
TASK: Change media	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes	Media is an essential part of the driving experience, and it was considered necessary that people could adapt it to their own preferences.	
2. Will the user notice the correct action is available?	Yes	All media features available i.e. Spotify and radio, are presented on the home page of the display.	
3. Will the user associate the correct action with the desired effect?	Yes	Pressing the media button with the right text may be an obvious action for the user to switch to the desired media.	
4. If the correct action is performed, will the user see that progress is being made?	Yes	The media status will change on the home page of the Display	

PHEA

Error	Cause	Consequences	Discovered	Recovery
Pressing the wrong media button by accident	The small shape of the buttons may cause accidental wrong-pressing when driving due to the movement in the car.	• It takes a longer time to find the desired media. • A positive consequence may be that the user finds it easier to switch media using the more precise control buttons on the steering wheel. These controls are preferable to use from a safety driving point of view.	The user enters the wrong media.	To pick the right media, the user needs to press the home button to restart from the home page.

CW			
TASK: Adjust volume	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes	Media is an essential part of the driving experience, and it was considered necessary that people could adapt it to their own preferences, where volume is a huge part of these preferences.	
2. Will the user notice the correct action is available?	Yes	The volume can be adjusted in two ways, either on the steering wheel or on the home page of the display. In both places, standardised symbols are used which may notify the user about the available action.	.
3. Will the user associate the correct action with the desired effect?	Yes/No	The position of the buttons on the steering wheel helps the user associate with the right action, since the increasing volume button is above the decreasing volume button which follows the user's mental model of highering and loweing. The horizontal volume bar on the display on the other hand may cause uncertainties in some cases.	The users mental model of volume adjusting, is not that clear in the horizontal direction compared to the vertical direction.
4. If the correct action is performed, will the user see that progress is being made?	Yes	The user will see in the volume bar on the display and hear from the speaker that the volume has been adjusted.	

PHEA

Error	Cause	Consequences	Discovered	Recovery
The user adjusts the volume in the wrong direction.	• The user adjusts the volume in the display without looking at the bar where the symbols indicate which side of the bar is for increased and which one is for decreased volume. • The mental model of the correct side of high and low on a horizontal bar is more vague than on a vertical bar.	The user will not get the desired volume.	The user will hear on the sound that the volume has been adjusted wrongly. The user can also see on the bar where the indicator is located and then see on the symbols that it has been moved in the wrong direction.	Change to the desired volume either by adjusting it on the buttons on the steering wheel or on the volume bar on the display.

CW			
TASK: Check media information	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes	Media is an essential part of the driving experience, and it was considered necessary that people could adapt it to their own preferences, as well as see information about the media playing.	
2. Will the user notice the information is available?	Yes	The information about the media is located in close relation to where the media is adjusted (i.e., the play button and the buttons for switching songs), a position that may make it logical for the user to find information about the playing media as well.	
3. Will the user associate the information with the desired effect?	Yes/No	If the user seeks information about the media, the user then also may associate the text that shows with the title of the song playing.	The user may associate the shown information text with the album playing instead of the title of the song playing.
4. If the correct action is performed, will the user see that progress is being made?			

CW			
TASK: Set any destination on navigation	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes	Users who do not know the way to a destination want directions.	
2. Will the user notice the correct action is available?	Yes	Navigation is placed in the centre of the display and is very focused. The symbol also shows a regular destination symbol the user should be familiar with.	.
3. Will the user associate the correct action with the desired effect?	Yes/No	The user can set the destination differently on the start screen, where two ways are available; the path through the magnifying glass is a shortcut. They can choose two ways to search, which can mess it up.	The user might need clarification because there are two ways to do the same task.
4. If the correct action is performed, will the user see that progress is being made?	Yes	They will be transported directly to the search page or another page of the display, where they can press the search bar at the end and write the address.	

PHEA

Error	Cause	Consequences	Discovered	Recovery
The user sets the wrong address	Too much fine motor skills are required of the user to key in the address	The directions will not be correct.	Either when the user sees the list of addresses and notices it is the wrong city or when they notice the estimated arrival time is incorrect.	Delete the written

CW			
TASK: Follow navigation directions	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes	When navigation is activated, the directions will be shown in the cluster; the user wants to find their way to their destination.	
2. Will the user notice the information is available?	Yes	The information will be shown in the cluster close to the driver's focus.	.
3. Will the user associate the information with the desired effect?	Yes/No	The user will understand that the information presented concerns navigation but might find it difficult to understand the priority.	There will be shown two different boxes, one bigger, which represents the next manoeuvre and then a smaller box with the manoeuvre after the first one; when the first one is done, the one in the second place will shift to first, etc. It might be hard for the user to understand that the more giant box is the most relevant and the other task after the bigger one.
4. If the correct action is performed, will the user see that progress is being made?	Yes	If the user does the right manoeuvre, the next manoeuvre will move into the more giant box.	

PHEA				
Error	**Cause**	**Consequences**	**Discovered**	**Recovery**
Does the wrong manoeuvre, does the manoeuvre placed in the smaller box.	The information is not presented clearly clearly.	The driver drives the wrong way.	The navigation information presented will be updated so that the boxes are updated.	Follow the new directions.

CW			
TASK: Connect phone with Apple CarPlay	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes/No	If the user has an iPhone and wants to connect the phone to enable the interface from the iPhone while in the car, they will try to achieve this; other people will not.	
2. Will the user notice the correct action is available?	Yes/No	If the user has an iPhone, they will probably know about Carpaly. The symbol is a standardised symbol and within the category of connect phone.	If they never have user car-play, it might be hard to recognise the first time, but it is something they will learn fast.
3. Will the user associate the correct action with the desired effect?	Yes	Yes, they will associate the correct action with the desired effect, as activation is one click.	
4. If the correct action is performed, will the user see that progress is being made?	Yes	When the phone is connected, the interface of the phone will take over the screen.	

PHEA				
Error	**Cause**	**Consequences**	**Discovered**	**Recovery**
Pressing Android Auto instead of car-play	Both buttons are within the same category," connect phone." If the user is not used to the symbols/names used to connect a phone on Android or iOS, they can find it difficult and need clearer information.	The iPhone interface will not connect.	Nothing will happen; the screen will remain the same as before	Press the right button

CW			
TASK: Call a contact	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes	If the user wants to call a contact, they will try to achieve it.	
2. Will the user notice the correct action is available?	Yes	The button on the display with the call function is illustrated with a standard phone symbol and the heading call. The button is placed within communication, which should be clear.	.
3. Will the user associate the correct action with the desired effect?	Yes	The steps to call someone remind the user a a lot of what it usually looks like when you call someone with few interactions	
4. If the correct action is performed, will the user see that progress is being made?	Yes	The car's speaker system will start calling the person it is meant to call	

PHEA

Error	Cause	Consequences	Discovered	Recovery
Accessing the wrong person in the list	There is a list with the contacts, and the same for favourites. The problem can be caused by not enough space between the contacts in the list, leading to the user clicking on the wrong contact.	The car will start calling the wrong person.	If the user sees on the display whom the car is calling or the wrong person answering	Stop calling the person you are calling and do it again with the correct contact

CW			
TASK: Activate read assistance of massages	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes/No	If the user wants to take in the information from messages without checking the phone, yes; if the user does not feel that they need input from messages while driving, no; or if they will check the phone anyway.	Many users are used to checking messages on the phone and might continue doing it even though it is unsafe.
2. Will the user notice the correct action is available?	Yes/No	The button's symbol illustrates a phone and a message, with the heading "read messages". The symbol and function might be new to the user and hard to understand first.	The possibility of having a button where you can activate read assistance is considered new and can, therefore, be hard for the user to understand the first time they interact.
3. Will the user associate the correct action with the desired effect?	Yes/No	if the user understands the symbol and the associated heading, then yes. If they do not understand it, they might think they can read their messages when activating.	The problem is that the symbol and heading can be considered to relate to reading your messages on your own instead of the car reading the messages. The symbols and headings of those manoeuvres are similar.
4. If the correct action is performed, will the user see that progress is being made?	Yes/No	The bar within the button will show that it is activated, but users will only understand what it does once they receive a message.	

PHEA

Error	Cause	Consequences	Discovered	Recovery
Believes it is activated when it is inactivated	The car does not illustrate on/off clear enough	Messages will not be read out loud when they are received.	When users check their phones, they will see they have received messages.	Press the bar again to activate it.

CW			
TASK: Activate adaptive cruise control	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes/No	If the driver wants help maintaining a steady speed, then the driver will achieve the effect; if not, no.	
2. Will the user notice the correct action is available?	Yes	The feature is illustrated by a standardised symbol for cruise control and placed on the steering wheel, which is common.	.
3. Will the user associate the correct action with the desired effect?	Yes/No	The plus and minus and what they contribute to (increase/decrease the speed) are considered explicit. However, the buttons for distance to rest ahead and lane keep assist can make the driver more thoughtful about the missing knowledge.	The three buttons on the left side of the steering wheel are all related to driving and are a bit similar.
4. If the correct action is performed, will the user see that progress is being made?	Yes	Information will be shown in the cluster for the cruise control, showing the activated speed.	

PHEA

Error	Cause	Consequences	Discovered	Recovery
Pressing the + or - symbols for distance to the car in front instead of the speed	Both features have + and - signs to illustrate increase or decrease and are placed side by side.	The driver will change the distance to the car in front instead.	The distance to the car in front changes.	Return to the distance set before, either by + or—depending on where the driver pressed, and then press the buttons related to speed instead.

CW			
TASK: Check the speed	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes	Users want to know their speed, ensuring they drive at a reasonable speed.	
2. Will the user notice the information is available?	Yes	The information is presented well in the cluster in front of the driver.	.
3. Will the user associate the information with the desired effect?	Yes/No	The numbers represent the speed the user will associate correctly; since the numbers are not showing precisely, there exists a complemented bar, which can be harder to understand	The new bar is a new thing for the driver; it will illustrate precisely how fast you are driving and complement the big numbers that do not shift for each km. The new bar can be hard to understand in the beginning, but it is considered understandable after some learning.

PHEA

Error	Cause	Consequences	Discovered	Recovery
The user does not understand that the big numbers representing km/h are connected with the bar	The connection between the numbers and the bar can be challenging when first using it.	The user does not know which information they should look at	After a while of use, they will probably understand the connection between the features.	Learnability

CW			
TASK: Check electricity gauge	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes	The user wants to make sure the charge does not run out.	
2. Will the user notice the information is available?	Yes/no	The information is presented in the cluster in front of the driver and uses regular symbols as a complement. When there is a lot of electricity left, the bar will have lower opacity, which can make the information harder to understand.	.Lower opacity is more challenging to see.
3. Will the user associate the information with the desired effect?	Yes/No	The meter is very similar to ordinary meters, where it is adjusted depending on the quantity. When there is less electricity left, the meter will light up first with yellow, and when there is even less red, it may be difficult for the user to understand the limits and their meaning.	The shift in colour might confuse the driver.

PHEA				
Error	**Cause**	**Consequences**	**Discovered**	**Recovery**
The user does not understand the meter	The information is not clear enough making the user unsure when they really need to charge.	The electricity in the car can run out before you have time to charge it	Dead car.	Charge the car.

CW			
TASK: Solve safety messages	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes	When a safety message is activated, the driver must solve it; otherwise, it will not disappear from the cluster, and most drivers believe safety is important.	
2. Will the user notice the information is available?	Yes	The information will pop up in front of the driver in the cluster to grab the driver's attention.	.
3. Will the user associate the information with the desired effect?	Yes	The safety messages will pop up with text and symbols illustrating what they need to do. For example, a seat belt is missing in the front right, and a symbol illustrates it.	
4. If the correct action is performed, will the user see that progress is being made?	Yes	When the safety message is solved, the popup will disappear.	

PHEA				
Error	**Cause**	**Consequences**	**Discovered**	**Recovery**
Ignores the safety messages	The driver does not care about the safety risk related to the feature the safety message relates to.	Higher risks of injury.	The safety message will remain on the cluster screen.	Solve the message.

CW			
TASK: Note electricity consumption	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes/No	Whether users will try to achieve the effect depends on whether they care about electricity consumption or not.	
2. Will the user notice the information is available?	Yes	The information is placed in the cluster screen close to the driver.	.
3. Will the user associate the information with the desired effect?	Yes	After the number, the display will show kwh/100km, which should obvious to the driver what the numbers represent.	

CW			
TASK: Check tire pressure	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes	The tire pressure needs to be checked sometimes	
2. Will the user notice the information is available?	Yes/No	One category on the display is named "Info and Settings" which the user may associate with the right action.	Not all cars provide digital tire pressure information. Therefore some users might not notice that the "Information and Settings" category on the display provides information about the tire pressure
3. Will the user associate the information with the desired effect?	Yes/No	If the user is used to modern cars, they will probably associate the information with the desired effect; if they are not, they might not associate the category "Information and Settings" with tire pressure.	Not all cars provide digital tire pressure information. Therefore some users might not associate the "Information and Settings" category on the display with finding the tire pressure
4. If the correct action is performed, will the user see that progress is being made?	Yes	When the user has pressed the first button with the category "Information and Settings" it will bring the user to another page where "Tire Pressure" can be found	

CW			
TASK: Use the phone storage	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes/No	The mobile is a common belonging which needs to be stored somewhere when driving, but the user could also store it somewhere else, such as in a bag or a pocket.	
2. Will the user notice the correct action is available?	Yes	The small gap between the box and the lid gives the user a clue that something can be stored there. The box also has a size that can be associated with a mobile phone.	.
3. Will the user associate the correct action with the desired effect?	Yes/No	The lid needs to be pushed back to access the, which some users might not understand.	Nothing indicates that the lid is pushable.
4. If the correct action is performed, will the user see that progress is being made?	Yes	The user will access the entire storage when the lid is pushed back.	

PHEA

Error	Cause	Consequences	Discovered	Recovery
The user places the phone on the lid	The symbol on the lid, which aims to help the user understand that the phone can also be charged with QI-charging when stored in the box, can be misunderstood. The user might think that the QI charger is in the lid and, therefore, place the phone on the lid.	When placed on the lid, which is not a dedicated place for storing the phone, it runs a high risk of falling and breaking when driving.	Storage may be discovered when identifying the gap between the box and the lid and seeing the potential space for storage.	Push back the lid and store the phone in the dedicated space instead.

CW			
TASK: Use the cup holder	**Yes/No**	**Why?**	**Problem**
1. Will the user be trying to achieve the right effect?	Yes/No	When the user brings a bottle or cup they will be trying to achieve the right effect, otherwise no.	
2. Will the user notice the correct action is available?	Yes/No	The user will probably identify that there are two drawers at the front of the centre stack module, however, they can not notice that the upper drawer consists of the cup holders.	There is no indicator of what the two drawers contain.
3. Will the user associate the correct action with the desired effect?	Yes/No		
4. If the correct action is performed, will the user see that progress is being made?			

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