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Seamless Driver Handover:
Stowage Solutions for Level 3 Autonomous Vehicles

Graduation project

Daantje Vogels

STUDENT

D.E.E. Vogels (Daantje)
MSc Intergrated Product Design
4663527

UNIVERSITY

Delft University of Technology
Faculty Industrial Design Engineering

SUPERVISORY TEAM

Chair - Prof. dr. ir. C.N. van Nes (Nicole)
Mentor - E.D. van Grondelle (Elmer)
Company Supervisor - A. Cuming (Andrew)

CLIENT

Jaguar Land Rover Limited (JLR)
Research Department

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Executive Summary

Problem

The issue of insufficient stowage space around the front seats has become increasingly problematic over time, with only minor improvements over the years. With the rise of autonomous driving, there's an increasing desire for entertainment and convenience during non-driving periods. This results in a greater need to bring more items that are within reach into the car, that need to be stored easily in case of a handover situation from car to driver.

Goal

This project focuses on developing innovative stowage solutions for level 3 autonomous vehicles, specifically designed for Jaguar Land Rover (JLR). The primary goal is to address the growing need for accessible and functional stowage in autonomous vehicles. The project's emphasis is on level 3 autonomy, where the vehicle manages most driving tasks but requires the driver to be ready to take control in complex situations. By concentrating on this level, the project aims to create solutions that can eventually scale to higher levels of autonomy.

The project's scope involves creating stowage solutions that accommodate a range of objects and support various user activities, particularly during the critical handover period from vehicle to driver. JLR has expressed a desire for bold, innovative designs that challenge conventional approaches while maintaining the vehicle's aesthetic integrity.

By addressing these challenges, the project aims to set a new standard for stowage solutions in autonomous vehicles, aligning with JLR's commitment to be the proud creators of modern luxury.

Analysis

The analysis involves a comprehensive review of the current landscape both within and outside JLR. It begins with an examination of the brand, followed by competitor research. To ensure that the design meets user needs, a storyboard is created to illustrate key conflicts the design needs to resolve. Additionally, literature research is conducted to determine the activities users prefer during non-driving periods.

Design

The concept is designed to support users during autonomous driving periods while allowing them to take control of the vehicle when needed. It ensures that all essential elements are easily accessible, whether for vehicle operation or for engaging in various digital and non-digital activities. The design carefully balances aesthetics, comfort, and safety to provide a seamless and enjoyable user experience.

Evaluation

A full-scale prototype has been created to gather insights that can't be obtained from drawings alone. This prototype is tested to generate insights for further development of the stowage solution concept.

Abbreviations

AV
Autonomous Vehicle

DRA
Driving Related Activities

EV
Electric Vehicle

Frunk
Front Trunk

ICE
Internal Combustion Engine

JLR
Jaguar-Land Rover

NDRA
Non-Driving Related Activity

OEM
Original Equipment Manufacturer

SAE
Society of Automotive Engineers

TOrt
Takeover Reaction Time

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PROJECT OUTLINE

Motivation

This chapter outlines the motivations behind undertaking this project, detailing the initial guidelines and approach. It explores the growing need for innovative stowage solutions in level 3 and 4 autonomous vehicles, driven by user needs for accessible stowage during non-driving periods. Additionally, it establishes the project's objectives and the methodology employed to meet these goals, ensuring the design aligns with user preferences and requirements.

Key Requirement Insights

For each subsequent chapter, all key requirements derived from the findings are listed here. These requirements are then used in the next steps to eventually develop the final concept.

Context

Levels of automation

When talking about automated driving, the conversation often involves different levels, specifically referring to the SAE levels of driving automation. In this particular project, the initial scope is focused on SAE levels 3 and 4. Starting from level 3, the emphasis shifts towards the vehicle's ability to drive itself. Unlike SAE level 5, levels 3 and 4 dictate that the vehicle will only engage in autonomous driving when all necessary conditions are satisfied. The key distinction between level 3 and level 4 lies in the requirement for the primary driver to always be ready to take control in level 3, whereas in level 4, the car may achieve complete autonomy but is limited to specific situations and areas of operation (SAE International, 2021).

The decision has ultimately been to concentrate solely on level 3 autonomy. This choice is driven by the challenges presented by level 3 vehicles, which can manage most driving tasks but still need the driver to intervene in complex situations. Designing effectively for level 3 autonomy offers a clearer pathway for scaling up to level 4, as opposed to scaling down a level 4 design to meet level 3's more demanding requirements within this scope.

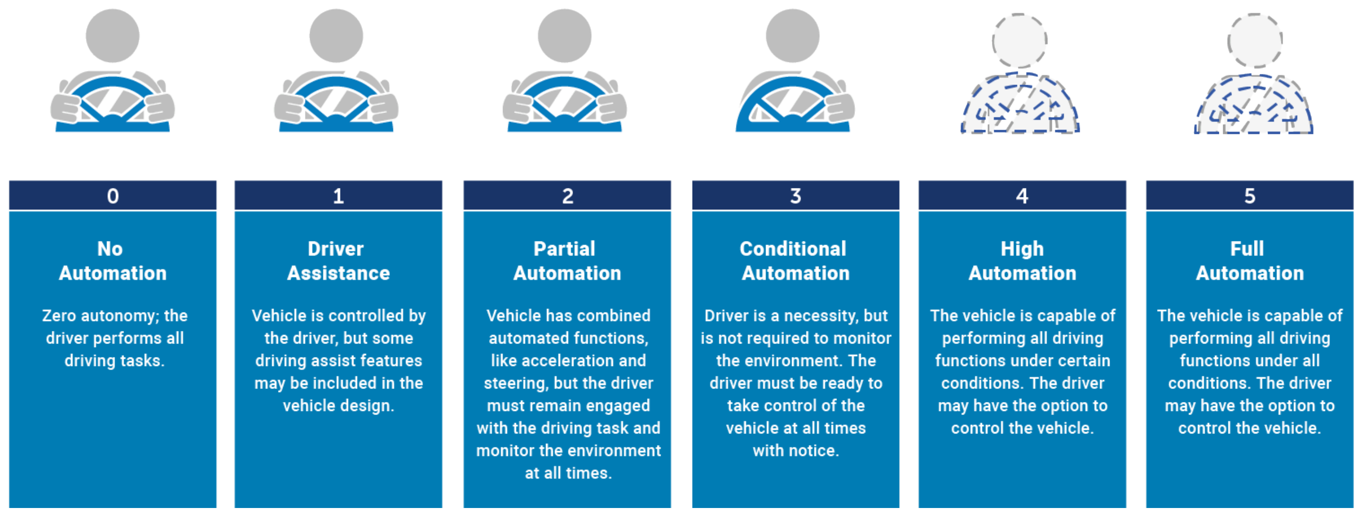

Figure 1: SAE levels of driving automation (Başargan, 2019)

Design context

Many mobility concepts aim for level 5 full autonomy, where vehicles operate without human intervention. If these technologies succeed and become available to the mass market, autonomous vehicles (AVs) could profoundly transform transportation networks. As described by Fagnant & Kockelman (2015), they hold the potential to revolutionize transportation systems by preventing fatal crashes, thus ensuring safer journeys. Moreover, they could greatly enhance mobility for the elderly and physically impaired (Nastjuk et al., 2020). Additionally, AVs contribute to environmental sustainability by reducing emissions and fuel consumption (Brown et al., 2014). Level 5 autonomous vehicle concepts often envision vehicle interiors redesigned as living spaces, devoid of traditional driving controls such as steering wheels and pedals, as demonstrated by various concept cars from different manufacturers.

However, the transition towards AVs is slowly progressing in stages, with OEMs acknowledging the importance of creating and implementing vehicles with partial autonomy (Levels 3 and 4). These intermediate levels of autonomy are crucial for several reasons. Firstly, they address significant barriers to the achievement of full autonomy, which include not only technological and safety challenges but also individual and societal hurdles (Nastjuk et al., 2020). Current technology, despite its advancements, still falls short of replicating the human capacity for instant instinctual decision-making, required in dynamic driving scenarios (Garsten, 2024).

Furthermore, Levels 3 and 4 AVs play a pivotal role in the broader adoption of autonomous driving by facilitating environmental learning and communication with other vehicles and infrastructure (Khan et al., 2022). Such capabilities are crucial to enhancing perception, decision-making, and overall intelligence of the vehicle. Additionally, the psychological aspect of adopting AV technology is significant. Shariff et al. (2017) argue that the principal obstacle to the widespread acceptance of autonomous driving is psychological rather than technical. They argue that by offering users familiarity and confidence through Levels 3 and 4 autonomy, the path to accepting full autonomy becomes more navigable.

Opportunities JLR

According to Guan et al. (2022), the market segment that JLR operates in is expected to face increasing competition in the coming years due to the importance of new attackers. Additionally, over 70 percent of current owners of premium and luxury internal-combustion-engine (ICE) vehicles are open to switching to EVs for their next purchase. This shift to EVs is leading to more similar features across different brands, which can make it hard for companies like JLR to stand out based on their vehicle's performance and engineering. As a result, it is important for JLR to identify innovative ways to differentiate itself in this dynamic market.

Luxury car buyers demand personalisation (Guan et al., 2022), and a great way to do this is by customizing the interior. This customization can go beyond just choosing different materials or colors. It can include tailoring the car's interior to fit how customers use their cars. Especially for the scope of this project, it is important to understand what customers like to do during autonomous driving—whether they prefer to work, relax, or be entertained—the interior can be designed to accommodate these activities. This approach not only improves the driving experience but also makes JLR's cars unique.

Challenge

Problem definition

The issue of stowage space surrounding the front seats has grown increasingly problematic over time, with minimal development and small improvements over the years (see figure 2). When browsing for car accessories on platforms such as Amazon, at least half of the recommendations typically consist of third-party stowage solutions (Amazon.com : Car Accessories, n.d.). This suggests that solutions provided by OEMs often fall short in meeting consumer needs.

With the upcoming of autonomy, users desire entertainment and convenience during periods of non-driving. Consequently, there's a growing need to bring more items into the car, with the need for easy accessibility from the seat. However, during level 3 autonomy, occupants must still be prepared to take over control within 10 seconds (JLR, personal communication, 2024). This will present challenges for current stowage solutions which are already often insufficient, and will increasingly become worse as time constraints become a factor.

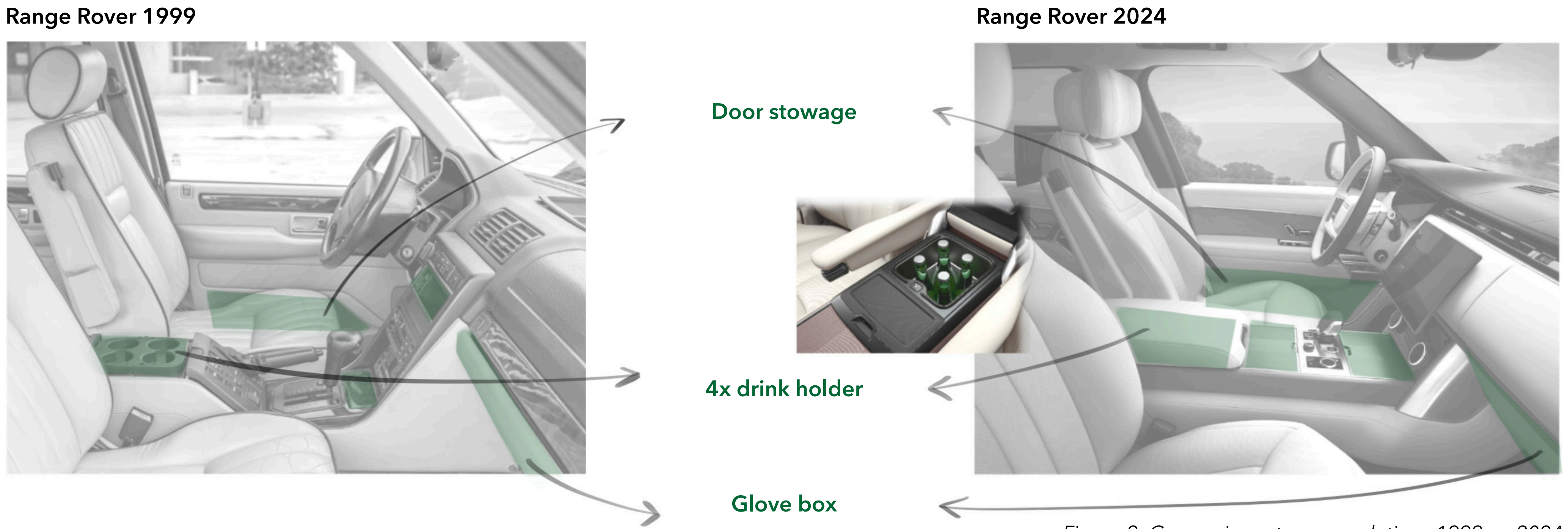

Figure 2: Comparison stowage solutions 1999 vs. 2024

Approach

Project Scope

"To create potential stowage solutions for the primary user, that enable a range of objects, which enable at least 3 clusters of non driving related activities, in level 3 and 4 autonomous vehicles, during a handover situation from vehicle to driver."

Since the focus is on the handover situation from vehicle to driver, the decision has been made to ultimately solely focus on level 3 autonomy.

Expectations JLR

This project has been undertaken for JLR's engineering research team. They encourage a bold approach, seeking fresh perspectives that can spark valuable discussions. Typically, stowage solutions in vehicles see minimal changes from one model year to the next, such as adjusting the orientation of cup holders or resizing door stowage compartments. Significant changes are uncommon.

However, as new technologies emerge and user needs evolve, the challenge of designing effective stowage solutions becomes more complex. Yet, this presents an opportunity for OEMs to distinguish themselves by offering original yet minimally invasive solutions that intelligently cater to customer demands, setting them apart from competitors.

In the design decision-making process, it is crucial to consider the design team's influence. A solution that enhances functionality but disrupts the vehicle's aesthetics may face resistance and ultimately not be approved.

Methods

This project aims to explore JLR's user preferences and find ways to align them with the current product environment. It is crucial to continually focus on user needs and avoid being overly influenced by existing products. To do so, research on various use cases is conducted to understand the activities users plan to engage in. Based on these activities, specific items are identified.

A storyboard is developed to visualize potential challenges of integrating current stowage solutions into level 3 and level 4 autonomous vehicles. This storyboard helps identify any conflicts, which are used to generate requirements for developing new stowage solutions.

Preliminary design concepts undergo evaluation using a weighted objective method. This involves assessing each concept against various criteria, each with different levels of importance, to determine the most promising option.

Finally, an initial prototype is tested to assess its added value and identify areas for potential improvement, helping to refine the concept further.

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CURRENT LANDSCAPE

2

Motivation

To understand the current market landscape and identify opportunities for JLR to differentiate itself, a company and competitor analysis is conducted. This analysis includes not only recent findings but also those presented over the years, providing insight into the evolution of these solutions and the user needs they address. To capture current user needs, a storyboard is created, illustrating a scenario with existing solutions in a level 3 autonomous vehicle. This storyboard highlights specific conflicts, which are then elaborated upon and translated into design requirements.

Key Requirement Insights

Designated stowage utility: Ensure every NDRA related item has a designated stowage space

Unhindered driving: Ensure that the stowage solutions do not compromise the vehicle's driving capabilities or driver accessibility.

Convenient cleanup facilitation: Integrate accessible and easily cleanable spaces for NDRAs, coupled with designated trash disposal areas

Minimise motion sickness: Arrange seating and item placement to offer forward-facing views and engagement within a 30-degree downward gaze limit

Efficient takeover time management: Implement automated stowage solutions for NDRA items

Airbag safety considerations: Incorporate clear zones around airbags, factoring in NDRA-supportive item placement

The Jaguar Land Rover Brand

Introduction

Before delving into a specific aspect of such a large machine with a rich history, it is important to first understand the context. The automotive industry has reached a significant turning point, emphasizing the need for car brands to distinguish themselves more than ever. This chapter outlines a timeline that focuses on the company's origins and extends to the brand as known nowadays.

Timeline

JLR is a British automotive company known for its luxury vehicles, combining the heritage and reputation of two iconic brands: Jaguar and Land Rover. Jaguar, originating as the Swallow Sidecar Company in 1922, evolved from producing motorcycle sidecars to becoming a symbol of speed and luxury with cars like the E-Type (Jaguar USA, n.d.). Land Rover was established in 1948 with a focus on rugged utility vehicles, introducing the upscale Range Rover in 1970 (Land Rover USA, n.d.). The paths of these two brands came together when they were both acquired by Ford in the late 20th century.

In 2008, Tata Motors, a leading Indian automotive company, bought both brands and merged them in 2013 into a single entity that is meant to represent true British heritage. Under Tata's ownership, JLR has focused on innovation, particularly in electric vehicles, exemplified by the launch of the Jaguar I-PACE, the brand's first all-electric SUV.

House of Brands

The JLR "House of Brands" consists of four distinct sub-brands, each with a unique identity and target audience (see figure 3). These sub-brands aim to bring to life their distinctive characters: the adventurous approach of Defender, the family-friendly focus of Discovery, the refined luxury of Range Rover, and the sporty heritage of Jaguar. Each sub-brand caters to different lifestyles and therefore target audiences, while consistently upholding the same high standard of quality.

Figure 3: (JLR Media Newsroom, 2023)

Starting point: What defines a Range Rover?

Introduction

For this project, the starting point is the 2024 Range Rover SV model, which stands for Special Vehicle (see figure 4). It is the most luxurious and personalized Range Rover currently available. As a high-end SUV, the Range Rover represents luxury travel, reflecting true modern luxury in various aspects. This is particularly shown in its interior, where the elegant design combines clean lines with advanced technology, including curved touchscreens with haptic controls, remote park assist, and active noise cancellation. The car showcases a true eye for detail, resulting in a stress-free and harmonious environment. The Range Rover SV is available in two versions: the Standard Wheelbase and the Long Wheelbase. The primary difference between the two lies in the rear seat options. The Long Wheelbase version offers enhanced rear seat features, making it ideal for those who prefer to be chauffeured. This model provides a high-end experience, even when not driving yourself.

This chapter highlights several interior design cues that can be utilized for a new stowage solution. To achieve this, the Automotive Form Hierarchy will be employed. This method, developed by Grondelle & Groot (2016), allows to assess automotive form in a structured manner. Given that the goal of this project is to create a new interior component, the emphasis will be on the styling strategy. Therefore, detailed analysis will be conducted on the lower three levels of the hierarchy, keeping the project's scope in mind (see figure 5). By thoroughly analyzing these elements, the project aims to create a design tailored for a Range Rover, adhering to the highest standards of luxury, performance, and craftsmanship that JLR is known for.

Figure 4: 2024 Range Rover SV (Land Rover, 2021)

Theme & Coherency
Platform & Segment
Volumes & Package
Surfacing
Design Detail
Colour & Trim

Figure 5: Automotive Form Hierarchy

Surfacing

The interior design of the Range Rover features many continuous lines and smooth, uninterrupted surfaces, a characteristic that extends to the vehicle's exterior as well. This design choice not only enhances the aesthetic appeal but also creates a more cohesive and uncluttered environment. By keeping functional elements out of sight, the vehicle preserves its elegant and refined appearance.

Additionally, a distinction has been made between horizontal and vertical surfaces.
To achieve the goal of continuous lines and surfaces, all horizontal surfaces are straight, allowing a seamless reach from the front to the rear of the car. In contrast, the vertical surfaces are rounded, creating a sense of elegance and softness, especially when combined with the chosen materials. This curved surface is also incorporated into all the touchscreens within the car, enhancing overall coherence and maintaining continuous lines.

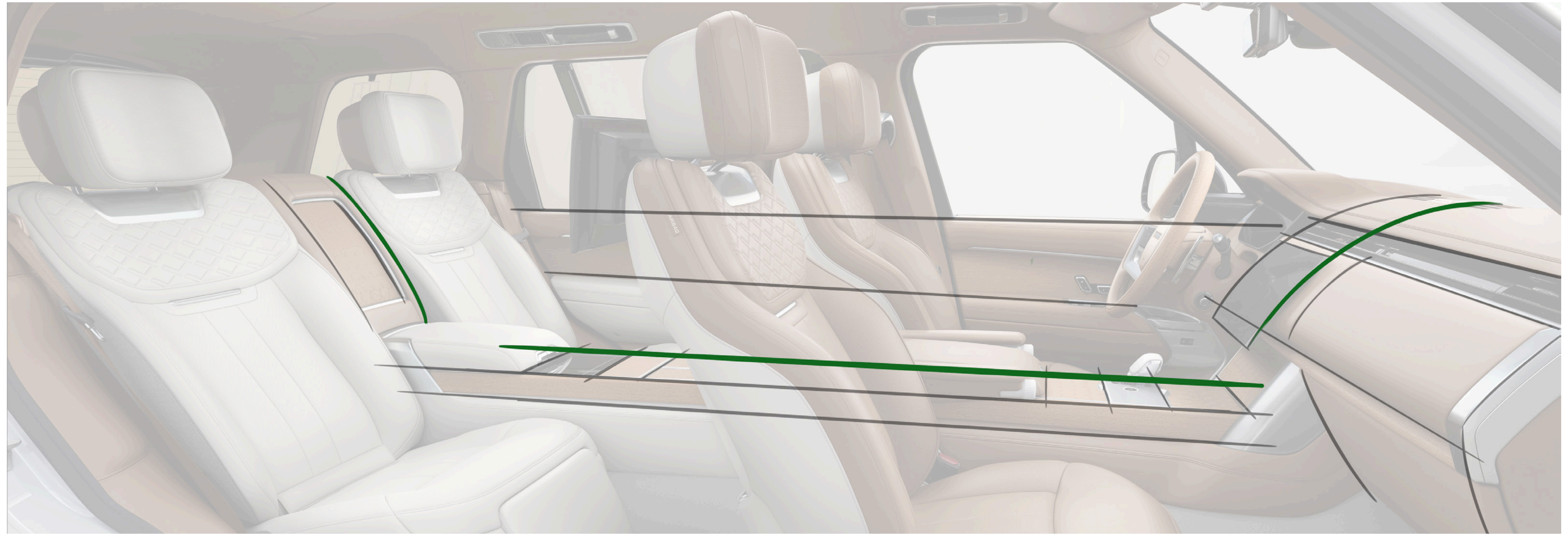


Figure 6: Surface analysis

Design detail

In both the Standard Wheelbase and Long Wheelbase Range Rover models, various methods are used to conceal elements when not in use, while still allowing them to be seamlessly presented when needed. Many of these features are operated electrically, reflecting the brand's high-end status. This design approach is applied to both the front and rear seats of the vehicle.

For instance, all compartments on the center console can be closed off, maintaining a clean and uncluttered look while locking items into place, enhancing safety during driving. In the Long Wheelbase model, there is a greater focus on the rear seats, incorporating features such as a mini fridge, table, and touchscreen control in the center console. The stowage compartments offer different solutions depending on the model, made to enhance functionality and luxury.

Figure 7: Design details (Land Rover, 2021)

Colour and trim

Materials
The interior of the SV Range Rover features a sophisticated combination of predominantly natural materials such as leather and wood veneers, with accents of metal and ceramic. While the available options are not limitless, there are themed, pre-set combinations provided (see figure 8). This pre-made selection ensures a harmonious interior.

For a sustainable alternative, users can choose for Ultrafabrics instead of leather. This polyurethane-based material matches the tactile qualities of leather and offers a soft feel and technical appearance. It is 30 percent lighter and produces only a quarter of the CO_2 during manufacturing compared to traditional leather (Land Rover Media Newsroom, 2021). Additionally, choosing this option introduces another innovative material to the interior. Through the Materiality project, JLR and Kvadrat have developed the Kvadrat wool-blend textile, which is 58 percent lighter than leather and used on the seat backs and headrests.

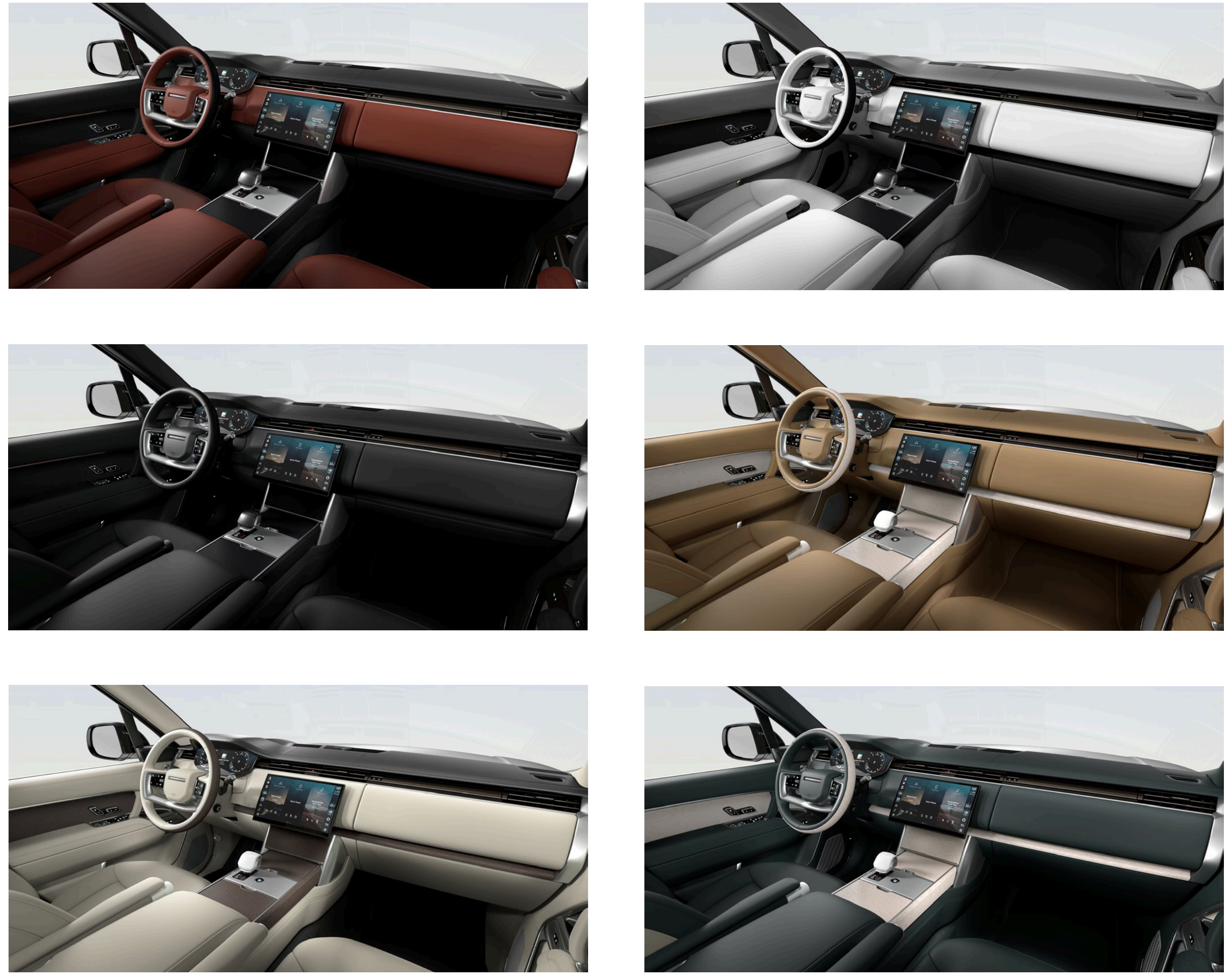


Figure 8: Colour and trim options (Range Rover, n.d.)

Textures
With the use of high-end materials, the tactile experience is as crucial as the aesthetics in shaping the overall experience. The soft leather provides warmth and comfort, the textured wood veneers add a sense of natural luxury, and the cool metal and ceramic accents bring a modern, refined edge. This multi-sensory approach enhances the feeling of luxury and craftsmanship, focusing not only on visual appeal but also on touch.

Figure 9: Mid console (Land Rover, 2021)

Rethinking stowage: Competitor examples

Alfa Romeo 90
Attaché case

In the mid-1980s, Alfa Romeo introduced the Alfa Romeo 90, a car that embodied the era's sophistication and luxury lifestyle. This model showcased the brand's commitment to blending performance with style.

The Alfa Romeo 90 featured unconventional elements such as roof-mounted window controls and a handbrake resembling airplane levers. However, its most distinguished feature was a Valextra attaché case, symbolizing the peak of luxury, prominently displayed in the passenger's view (Fransen, 2022). This attaché case fit seamlessly into a dedicated dashboard slot, serving as a statement piece rather than just an accessory. Offered only as an option, even on the highest trim, it highlighted the Alfa Romeo 90's appeal to those seeking exclusivity and elegance.

For those who did not opt for the attaché case, the dashboard had a large cavity, which limited the otherwise usable space.

Figure 10: Alfa Romeo 90 interior (Fransen, 2022)

Figure 11: Alfa Romeo 90 Case (Fransen, 2022)

Renault Twingo
Flexicase

The Renault Twingo, especially in its earlier generations, introduced several innovative design features that set it apart in the small car segment. One notable feature is the "Flexicase," a flexible and innovative stowage solution designed to enhance the vehicle's practicality and usability for both the driver and passengers. The Flexicase system includes various stowage compartments and configurations that can be adapted to the user's needs. This may involve under-seat drawers, configurable trunk space, and additional compartments in the dashboard or doors (Renault, 2017). The goal is to provide versatile stowage options to accommodate a range of items, from daily essentials to larger objects for trips or special occasions. The Flexicase feature aligns with the Twingo's overall design philosophy, emphasizing efficiency, space maximization, and adaptability within a compact car format.

However, the system presents an "either/or" scenario, where not all stowage options can be used simultaneously.

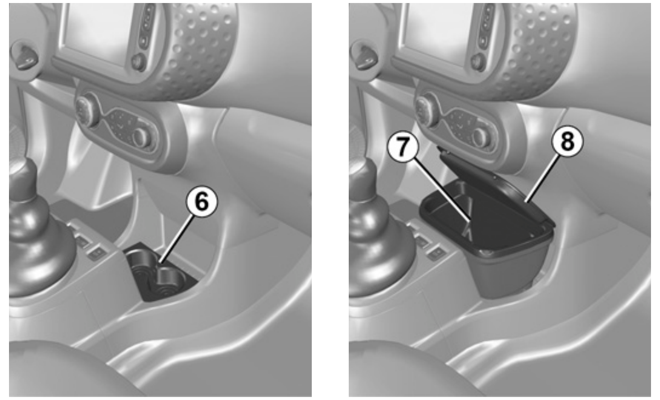


Figure 12: Flexicase inserts (Renault, z.d.)

Figure 13: Flexicase locations (Van Mossel Automotive Group, z.d.)

Volvo XC40
Rethink the conventional

The XC40 took the opportunity to rethink conventional car stowage solutions. From the start, they delved into how people actually use their cars and the essentials they carry (Volvo Cars, 2017).

A dedicated smartphone compartment with wireless charging minimizes clutter. Cup holders remain free by providing specific spots for small items. Tissue boxes and a built-in waste bin cater to common needs, promoting cleanliness. Convenient features include a glove compartment hook, space for larger items by removing door speakers, and organizers for sunglasses and cards. Under-seat stowage and a foldable trunk floor ensure discreet and secure stowage. The result? A tidy, efficient interior that enhances driving focus.

However, these are minor adjustments that do not fully encompass all possibilities a stowage solution could offer.

Figure 14: Volvo XC40 trashbag (NJVOLVO, 2018)

Figure 15: Volvo XC40 bag hook (NJVOLVO, 2018)

Figure 16: Volvo XC40 seat (NJVOLVO, 2018)

1984

2014

2017

Peugeot 308
3D printed inserts

Peugeot took advantage of 3D printing to design inserts for the center console, offering slots for sunglasses, cans, phones, and cards. The objective was to enhance the visibility and appeal of accessories, aiming for products that are not only visually attractive but also tactilely pleasant, lightweight, sturdy, and user-friendly (Stellantis, 2022).

A concern with this solution is that the inserts can be completely removed and do not have a designated stowage space when not in use. For example, on a sunny day, if the user wants to exchange the phone/card insert for the sunglasses insert, there isn't an easy place to store the unused insert. This could lead to the insert being lost or damaged.

Figure 17: Sunglass insert (Stellantis, 2022)

Figure 18: Phone/card insert (Stellantis, 2022)

Figure 19: Can insert (Stellantis, 2022)

Renault Megane E-Tech
Modular stowage

Renault took the opportunity of creating a modular stowage solution for all small personal belongings. The pins can be repositioned along rails bearing the iconic Renault logo, ensuring the secure placement of items.

The primary concern with this solution is cleanability. The rails create many hard-to-reach areas, and given the purpose of the solution, it is likely to get dirty frequently.

Figure 20: Renaults modular stowage (Renault, 2023)

Rolls Royce 103EX Concept Car
Utilization under-bonnet space

This Rolls Royce concept car was designed with ultimate premium luxury in mind and, as a level 5 autonomous vehicle, it showcases some surprising features. To enhance accessibility, suitcases are placed in front of the door, optimizing the process of storing and retrieving luggage. While this design does not consider internal access, it serves as a good example of reimagining traditional stowage locations.

However, the added value of this design is limited, as the luggage is only reachable from the outside and merely changes its stowage location.

Electric cars have the potential to utilize under-bonnet space more effectively, offering opportunities for extra stowage that is within reach. Additionally, an umbrella is conveniently housed in the door, easily reachable upon exiting the vehicle yet neatly stowed while driving.

Figure 21: Luggage compartment (Dunham, 2023)

Figure 22: Umbrella stowage (Caricos, z.d.)

2022

2023

2035

Storyboard

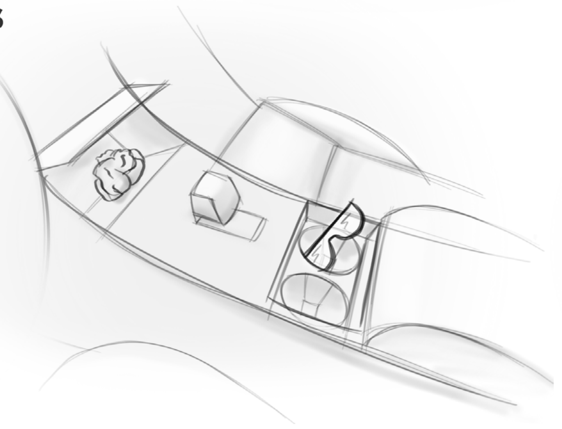
Introduction

A storyboard is outlined to highlight the challenges posed by existing stowage solutions. This storyboard centers around a scenario where current stowage solutions are utilized in a level 3 autonomous car, displaying both problems specific to level 3 autonomy as well as general issues. This choice is made since it potentially exposes more critical situations, given the need for the driver to regain control faster compared to a level 4 autonomous vehicle. The next chapter will delve into the conflicts identified in the storyboard, ultimately leading to design requirements for a new stowage solution.

Storyboard

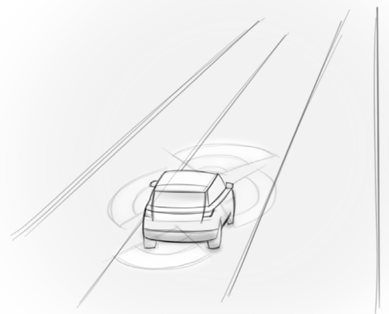
1. Enters the vehicle

Enters the vehicle with personal belongings



2. Puts down belongings

Lacks a specific place to store belongings, leading to improper use of existing compartments.



3. Autonomous mode

The car goes into autonomous mode.

4. Food crumbs

Consumes food, resulting in crumbs scattering throughout the interior.

5. Motion sickness

Experiences motion sickness while attempting to interact with items for NDRAs.

6. Takes back control

Receives a notification from the vehicle to resume manual control, causing anxiety due to the time constrain and disorganized items; some belongings drop on the floor.

7. Delays

Delays in regaining control, creating a dangerous situation.

8. Collision

A collision that triggers the airbags takes place; objects obstructing the area are launched towards the primary user, resulting in serious injuries.

Conflicts

Improper use existing compartments

The issue of cupholders in vehicles is a notable example in this discussion. Over time, cupholders have received considerable criticism. Originally intended to hold beverages, cupholders in many cars have evolved into multipurpose stowage areas for items like parking tickets, mobile phones, and food. This repurposing can lead to safety hazards. For instance, a driver in Vancouver received a fine of $368 because her mobile phone was placed in the cupholder instead of being properly mounted, as reported by Fletcher in 2019.

The placement of cupholders can also be problematic. When located in inconvenient positions, they can hinder a driver's ability to operate the vehicle safely.

Moreover, the misuse of cupholders and other stowage spaces in cars contributes to vehicle-related injuries. Safety Research and Strategies, an accident investigation firm, notes that ordinary objects within cars are linked to approximately 13,000 injuries annually. At a speed of 55 miles per hour, a 20-pound object can exert a force of 1,000 pounds upon impact, capable of causing severe injuries, such as severing the arm of a crash test dummy, a scenario highlighted by Leamy in 2010.

Addressing these issues involves redesigning vehicle interiors to ensure all items have designated, secure stowage spaces. This would allow cupholders to return to their original function—securely holding beverages. This example also shows the importance of designing solutions that do not hinder driving capabilities.

Figure 23: Trash in cupholders (Capicchiano, 2023)

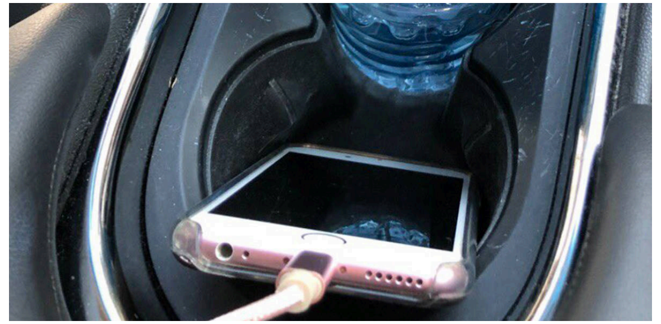


Figure 24: Phone in cupholder (Fletcher, 2019)

Figure 25: Inconvenient placement (Polestar 2, 2022)

Dirty interior

The image of food crumbs scattered around a car is familiar to many. This often happens due to the absence of convenient places to put food and lack of trash bags, which results in crumbs and mess all over the interior. Cleaning is challenging due to the numerous small gaps and hard-to-reach areas.

In contrast, mobility solutions that accommodate both eating and drinking, such as trains and airplanes, typically include a tray table. This feature provides a dedicated space for passengers to place their food and drinks, which helps to keep the surroundings tidier.

Providing a convenient and easy to clean spot for food and drinks can lead to a cleaner car. Additionally, having a specific area for disposing of trash could further maintain the cleanliness of the car, even after eating and drinking.

Figure 26: Trash on dashboard (O'Toole, 2017)

Figure 27: Trash on seats (O'Toole, 2017)

Motion sickness

Addressing motion sickness in the design of autonomous vehicle interiors is a complex issue. It is caused by the sensory conflict that occurs when the body feels movement different from what the eyes see, called the "neural mismatch theory" (Oman, 1990). In a traditional driving scenario, the driver's focus on the road typically maintains harmony between visual and vestibular perceptions.

In autonomous vehicles, engaging in non-driving related activities (NDRAs) like reading, especially when external views are obstructed as in night travel, can increase the likelihood of passengers experiencing motion sickness. This occurs because their eyes, fixated on a static object within the vehicle, don't register the movement that their vestibular system senses (Rolnick & Lubow, 1991). While level 3 automation primarily centers on automated highway driving, typically resulting in limited motion sickness, it remains a factor to consider.

To counteract this, seating arrangements that face forward and provide clear external views can help synchronize the visual and physical experiences of motion. Moreover, for activities requiring downward focus, strategically placing items at eye level can prevent sickness (Diels, 2014). It's critical to ensure that these design choices do not impede peripheral vision, which is essential for recognizing and processing external motion cues.

This requirement also aligns with legislation stating that controls and displays must be positioned in a manner that prevents the driver from needing to make eye movements exceeding 30° (Radakrishnan et al., 2016). Although the dynamics of autonomous driving differ and do not demand constant visual attention to the road, adhering to this requirement still enhances safety by allowing the driver to maintain awareness of surrounding events. In this manner, as an OEM, you are also not dependent on legislative changes.

Takeover reaction time (TOrt)

JLR has determined that the takeover reaction time (TOrt) for a driver to fully assume control from an SAE level 3 automated vehicle is 10 seconds following an alert (JLR, personal communication, 2024). While a 10-second window may initially appear to be adequate, research suggest otherwise. A study conducted by Eriksson and Stanton (2017) indicates that while the median takeover time was 6 seconds for participants engaged in a secondary task (NDRA), the slowest person required over 20 seconds to respond. This research suggests that vehicle manufacturers should not solely rely on median or mean values from TOrt studies, but instead look at a more inclusive approach to TOrt's in automated vehicle design to avoid exclusion. During JLRs own TOrt user trials, a TOrt of approximately 90 seconds was measured, with a gaming NDRA that was close to the driving scenario (JLR, personal communication, 2024).

To address this, the project aims to develop automated stowage solutions that aid the driver during the takeover process. By automating the stowage of items used during NDRAs, the driver is relieved of this task, potentially reducing the TOrt and enhancing the safety of level 3 automated driving.

Airbag

Airbags, introduced in the 1970s, are designed to enhance vehicle safety (M. U. Khan & Moatamedi, 2008). While they are widely recognized for protecting passengers during collisions, they also present their own set of risks. These include the potential for sensor malfunctions that could result in airbags failing to deploy or deploying at the wrong time, respiratory difficulties from the chemicals released upon deployment, serious eye damage from the force of deployment, and the possibility of shrapnel injuries to the occupants of the vehicle (Bieber, 2022). Thus, when designing the interiors of autonomous vehicles, careful consideration must be given to the placement and presence of objects that support NDRAs, like tray tables, to avoid compromising safety.

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3

NON-DRIVING RELATED ACTIVITIES

Motivation

As mentioned before, there's a growing desire for entertainment when driving responsibilities are not in focus. Currently, European drivers already allocate 10% of their time to secondary tasks while driving (Andreahrzic, 2017). This number is expected to rise with the upcoming of automated vehicles. Secondary tasks are often called "Non-Driving Related Activities (NDRAs)" (Pfleging et al., 2015). Understanding the distinction between Driving-Related Activities and NDRAs is fundamental to comprehending how automation is reshaping our interaction with vehicles. Additionally, recognizing the prevalent NDRAs and user preferences associated with them is crucial for designing the interiors of automated vehicles. These insights can guide the development of stowage concepts tailored to accommodate specific items, thereby enhancing the overall user experience.

Key Requirement Insights

Integrate **"Entertainment"** features into the autonomous vehicle design to meet the high user preference for entertainment across all surveyed transportation modes.

Include **"Productivity"** enhancing features in the design to cater to the notably higher preference for productivity among JLR users compared to general Level 3 and 4 autonomy research.

Incorporate provisions for **"Eating and Drinking"** activities in the final design, despite the generally low recorded interest in these activities. Although challenging, effectively addressing this aspect could greatly enhance the overall design value.

Introduction

DRAs and NDRAs

Driving-Related Activities involve safely controlling the vehicle, including steering, accelerating, and monitoring both the vehicle's operation and its surroundings. Automation reduces the time and effort required for these tasks, possibly reducing them to only setting the destination in fully autonomous vehicles.

Non-Driving Related Activities (NDRAs), on the other hand, are unrelated to vehicle operation. These may include using infotainment systems (such as navigation), communication with others (online or offline), and consuming food and drinks. As automation progresses, occupants can participate in activities like reading or sleeping while the vehicle autonomously drives. (Pfleging et al., 2015)

This chapter's research focuses exclusively on NDRAs.

Primary, secondary and tertiary tasks

Interactive tasks within cars can be categorized into three classes: primary, secondary, and tertiary tasks (Tönnis et al., 2006):

Primary tasks involve manoeuvring the vehicle itself, such as controlling steering, speed, and distance from other cars or objects.

Secondary tasks relate to additional functions like activating turning signals and windshield wipers.

Tertiary tasks center around entertainment and informational features. While not essential for driving, these features offer additional services that cater to the preferences of todays users.

The distribution of interactive tasks has moved away from just primary and secondary tasks to a notable presence of tertiary tasks. This trend is anticipated to escalate with the continuous advancement of automated vehicles.

SAE level 3 and 4 autonomy

Introduction

This chapter presents an analysis conducted on NDRAs in the context of automated car interior design. The study builds on the research conducted by Yuing Cai from TU Delft, as outlined in her thesis titled "Automated Car Interior Layout Design Based on User Activities" (2023). Cai's analysis encompasses levels 3, 4, and 5 autonomy and utilizes a counting method to identify prevalent activities. The goal is to enhance and elaborate on Cai's analysis, specifically focusing on SAE automation levels 3 and 4.

This study aims to provide insights into the most desired NDRAs and is not intended as a scientifically correct meta-analysis.

Methodology: Selection of research

Starting point N = 47
The starting point for this analysis is Appendix C from Cai's thesis, referred to as the "Data extraction form".

SAE level N = 21
All 47 papers undergo evaluation based on their stated SAE autonomy level, excluding those focused on SAE level 5 automation or where the level is unclear, since this is not included in the scope of this project.

Individual review and validation N = 21
Each paper discussing levels 3 and 4 undergoes individual review and validation, and some corrections are made to any inaccuracies identified.

Supplementary research N = 23
In addition to Cai's thesis, supplementary papers are discovered during the selection process to enhance the dataset.

Percentage listed N = 16
Due to time constraints, Cai employed a frequency-based approach, counting all activities based on their mentions across studies. To ensure greater accuracy, only studies offering percentages per activity are considered, recognizing that a higher percentage for a particular activity in a study must outweigh a lower percentage.

Split surveys from observations N = 24
Research that incorporated both surveys/interviews and observations is segregated. This segregation facilitates the comparison between individuals' intentions and their actual behaviours. Given the novelty of autonomy, there are few individuals who have actually experienced it, making it challenging to fully understand the context. This approach offers the opportunity to explore an additional dimension, examining whether intentions align with behaviors or not.

Methodology: Calculation

Cluster
Since all research lists different use cases, clusters are made to make it possible to compare similar NDRAs (these culsters can be found in appendix A).

Combine
The percentages of all activities listed within each cluster are combined in a way that each research totals 100% of all clusters combined.

Weighted objective
A weighted objective is calculated to ensure more accuracy, acknowledging that a high percentage from one research doesn't necessarily outweigh a slightly lower percentage from various research discussing the same NDRA. The entire calculation can be found in appendix B & C.

Results

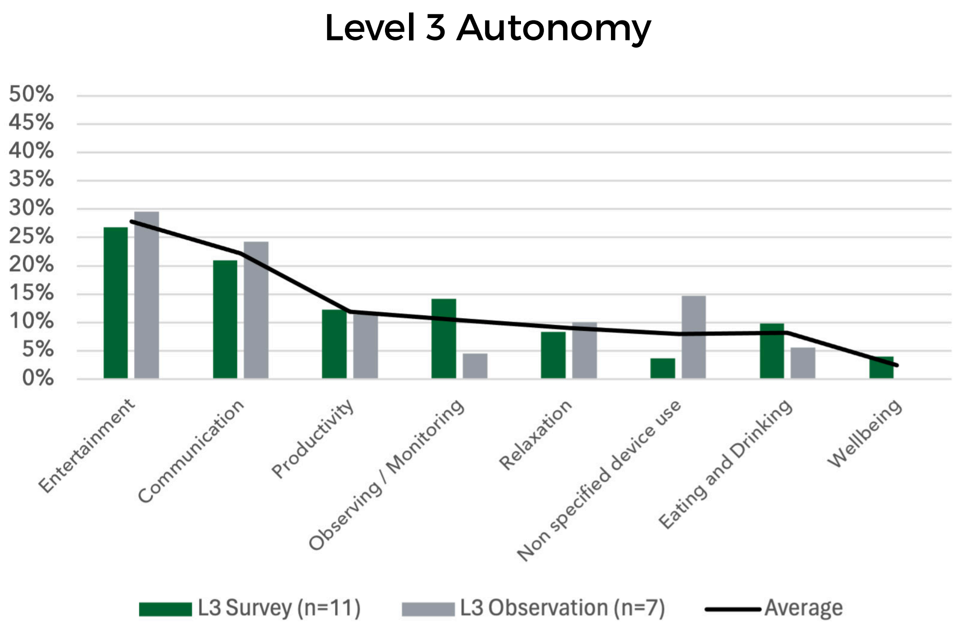

Chart 1: NDRA activities at level 3 autonomy

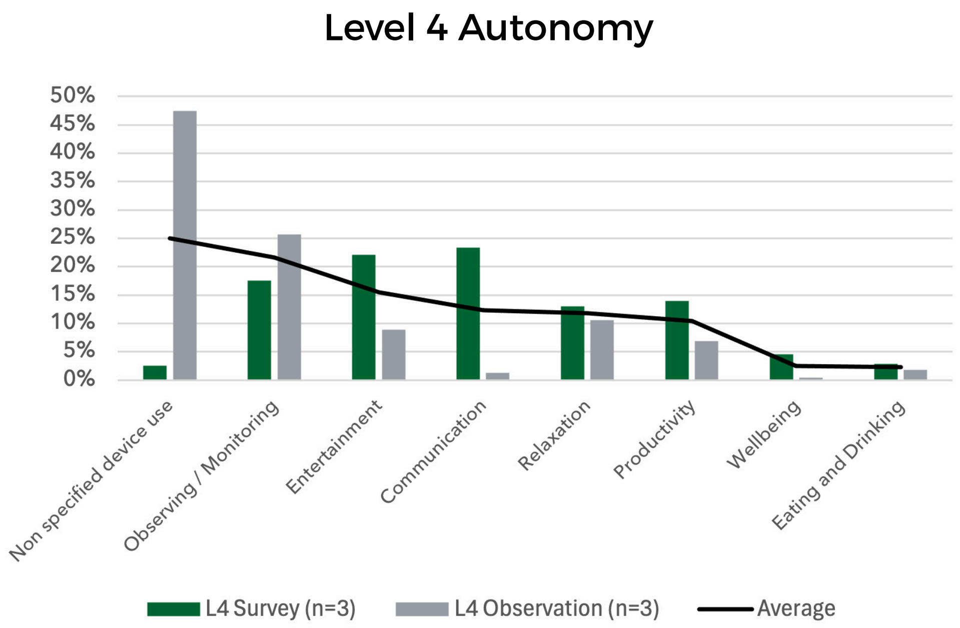

Chart 2: NDRA activities at level 4 autonomy

Conclusion

Most common activities
In level 3 autonomous vehicles, users engage in various activities, but 'Entertainment' emerges as the most frequent, followed by 'Communication' and 'Productivity'. This shifts noticeably at level 4 autonomy, where 'Non-specified device use' dominates. This cluster's prominence suggests that mainly during the observation studies, it was often unclear what the device was used for, or it wasn't listed by the researcher.

Survey/interview vs. observation
The alignment between the level 3 survey and level 3 observation data shows more consistency than at level 4 autonomy. Interestingly, 'Entertainment' is lower in the survey studies compared to observations, whereas 'Productivity' enjoys a higher report rate in the survey than what was observed. At level 4 autonomy, a larger difference is shown, especially in the "Non-specified device use" category, which is observed much more frequently than reported in a survey.

Discussion

Given that the majority of studies rely on surveys or interviews, the novelty and not yet widely grasped concept of autonomy could influence the accuracy of the findings. The significant differences between the survey/ interview results and observational data support this uncertainty.

Additionally, most observational studies occur within driving simulations, which differs significantly from real-world scenarios. For instance, individuals may not fully foresee challenges such as motion sickness that could influence their ability to participate in NDRAs while traveling in an autonomous vehicle. This vulnerability is especially pronounced when individuals shift from being drivers to passengers, losing control over the vehicle's movements and intensifying sensory conflicts that contribute to motion sickness (Iskander et al., 2019). Therefore, the actual experience of autonomy in practice may differ from the predicted behaviours reported in these studies.

Other ways of Transport

Introduction

The limitations of the NDRA research on level 3 and 4 autonomous vehicles are due to the unfamiliarity with autonomy and the use of driving simulations that may fail to capture real-world conditions, possibly missing issues such as motion sickness. Consequently, the decision was made to broaden the research to include alternative transportation modes, such as public transport and airplanes. This expanded approach aims to validate earlier findings by using the participants' easier imagination in survey studies and enabling direct observational studies without the need for simulations, potentially leading to more accurate results.

Methodology

The same calculation methodology used for the level 3 and 4 autonomy studies will be utilized, including both surveys and observational studies. When selecting research, the goal is to encompass a diverse range of locations and public transportation modes, achieving a balance between rapid analysis and preserving a comprehensive perspective. The calculation can be found in appendix D & E.

Results

Public Transport

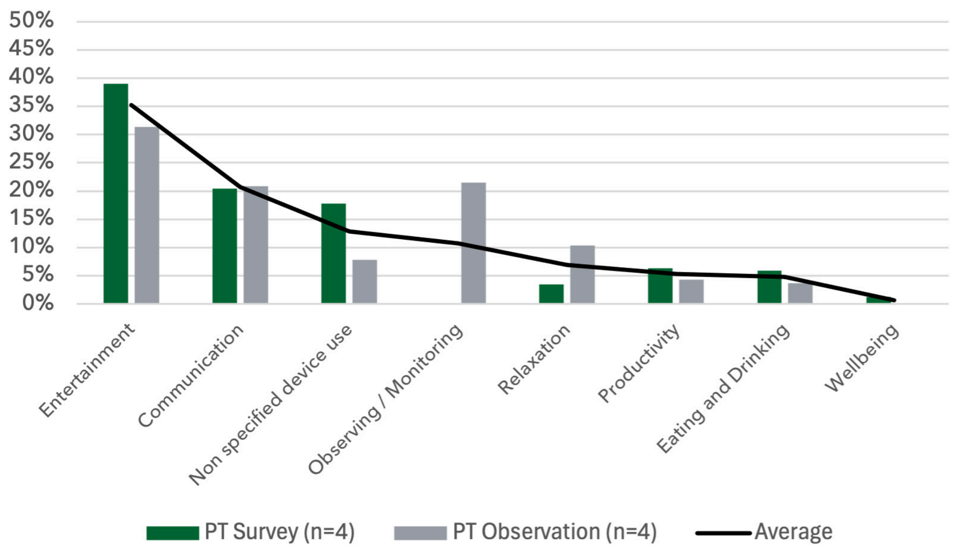

Chart 3: Activity research public transport

Airplane

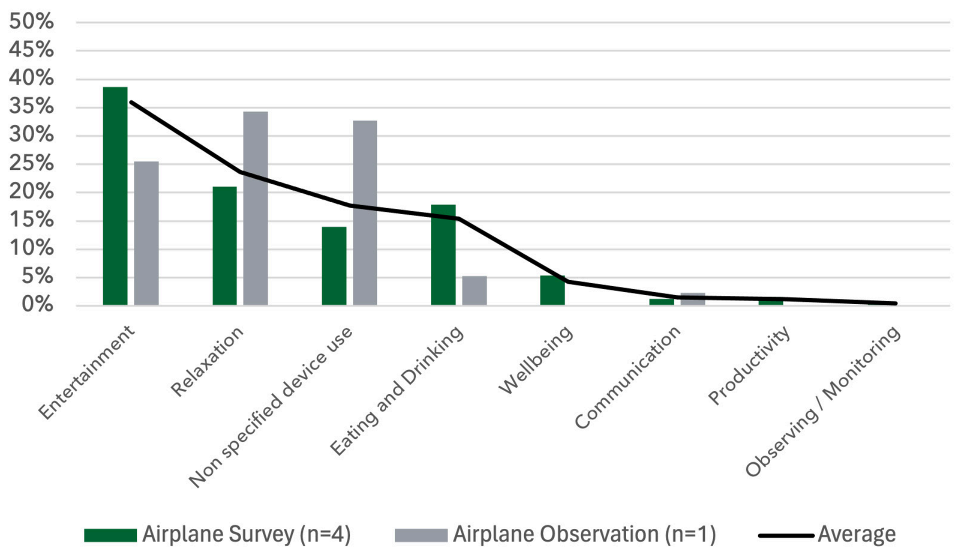

Chart 4: Activity research airplane

Conclusion

Most common activities
On both airplanes and public transport, 'Entertainment' is the leading activity, as shown in the data. Public transport users engage more in 'Communication', making it the second most frequent activity. Airplane passengers rarely show communication activities, likely partly due to connectivity constraints such as no cellular service and limited Wi-Fi availability, or the limited privacy during conversations with neighbours. In the case of air travel, 'Relaxation' takes the place of 'Communication', becoming the second most recorded activity, which points to a significant amount of time spent sleeping or simply relaxing during flights.

Survey/interview vs. observation
In the case of public transport, the data points showed a notable difference in the 'Observing/Monitoring' category, with observations indicating that more than 20% of passengers actually spent time looking at their surroundings, a figure not mirrored in participant expectations. For air travel, the data is limited to a single observation study, which constrains the ability to draw robust comparisons between survey responses and observational data.

Discussion

Public transport
As public transport operates within a shared space, desires for autonomous driving may vary, since this is a private space. Moreover, certain activities such as eating and drinking may be prohibited, resulting in a lower percentage than anticipated when solely considering users' preferences.

Airplane
When considering airplane studies in relation to autonomous driving in a JLR car, those focusing on first/business class travel are most relevant. However, the majority of studies tend to concentrate on economy class. Additionally, flight durations are typically longer than periods of autonomous driving, necessitating different activities. Vink et al. (2017) explain that travelers opt for business class tickets to ensure proper sleep and arrive at their destination well-rested. As this aspect is not applicable to this project, sleeping is excluded from the results, leading to outcomes that may differ from reality.

Conclusion

NDRA cluster choice

For the NDRA cluster selection, three specific clusters will be chosen as focal points for the design. These clusters will later be linked to various items, that the final design will take into account.

Based on the results, it appears that **'Entertainment'** ranks within the top three preferences across all surveyed modes of transportation, making it a significant area of interest for users in diverse contexts. While interest in entertainment like NDRAs for level 4 autonomy appears to be relatively low, this is partly due to the high prevalence of the "non-specified device use" cluster. This suggests that during much of the research, it was either unclear or not documented what the devices were being used for. In numerous other studies, it was observed that devices were frequently utilized for entertainment purposes, implying that the percentage of entertainment-related activities in level 4 autonomy scenarios may be considerably higher than indicated. Therefore, designing solutions to facilitate user engagement in entertainment activities is vital, making it a key cluster choice for the design.

Additionally, there is a notable discrepancy when it comes to **'Productivity'** with JLR users showing a higher preference compared to those in general Level 3 and 4 autonomy research. This suggests that JLR users have a distinct inclination towards being more productive, possibly by engaging in work-related activities. This observation is consistent with previous studies conducted by JLR (chart 8), underscoring the significance of productivity for their user demographic. Consequently, to tailor the design to JLRs user base's specific needs, productivity is selected as the second cluster of focus for the design.

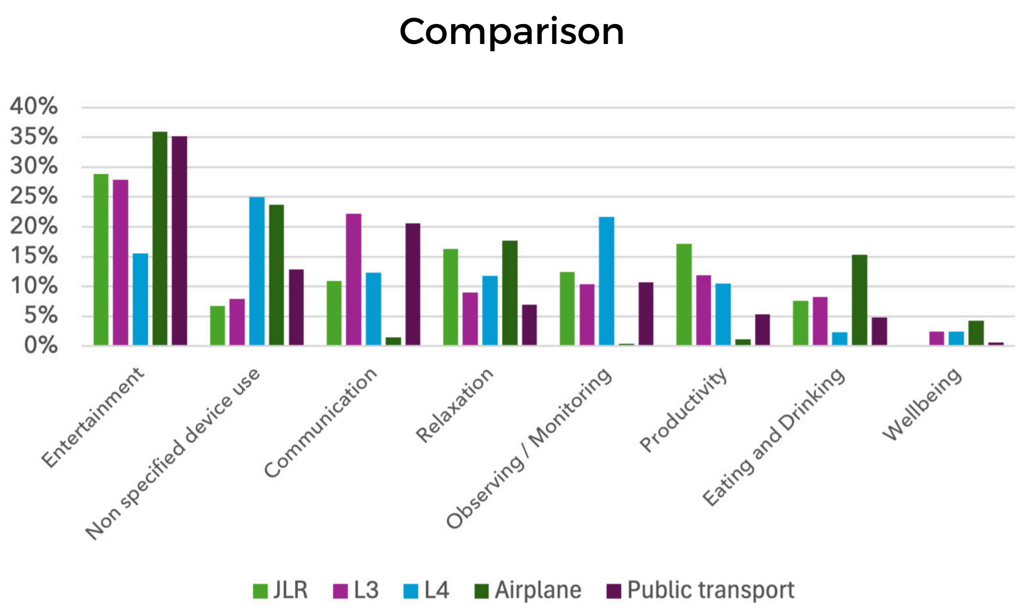

Chart 7: Comparison activities across all modes of transportation

On the other hand, interest in **"Eating and Drinking"** activities is notably low across all surveyed research areas, suggesting it may not be a primary concern for users of autonomous driving and other transport modes. However, considering the limitations of this study and the fact that eating is often prohibited in many transport modes, the decision is made to still include this category in the final design. The presence of cup holders in current vehicles highlights the relevance of this aspect, despite it being one of the most challenging areas to design for. This challenge is evident in the storyboard, which illustrates the potential mess and difficulty of eating and drinking in a moving vehicle. Nonetheless, JLRs commitment to a bold design approach means that effectively addressing eating and drinking could significantly enhance the overall design value.

In conclusion, the primary NDRA clusters that the design will prioritize are entertainment, productivity, and eating and drinking; however, any chance to incorporate additional clusters will be regarded as an added bonus for the concept and will definitely be considered.

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LOCATION IDEATION

4

Concept I - “Gearbox”
Concept II - “Under the Bonnet”
Concept III - “Seat”
Weighted objectives method
References

Motivation

This chapter explores three potential stowage locations. The choice to start by selecting a location arises from insights gained from the storyboard. One key conflict shows the necessity for intuitive placement that does not impede the driver’s abilities. Additionally, a significant requirement identified from another conflict suggests that an automatic stowage solution can substantially shorten the time needed for a driver to regain control. With these considerations in mind, the placement of the stowage solution should be logical and enable fast and easy deployment. Selecting an appropriate location lays a solid foundation for further development.

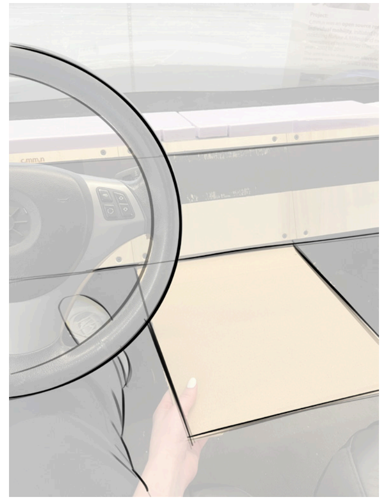
Key Requirement Insights

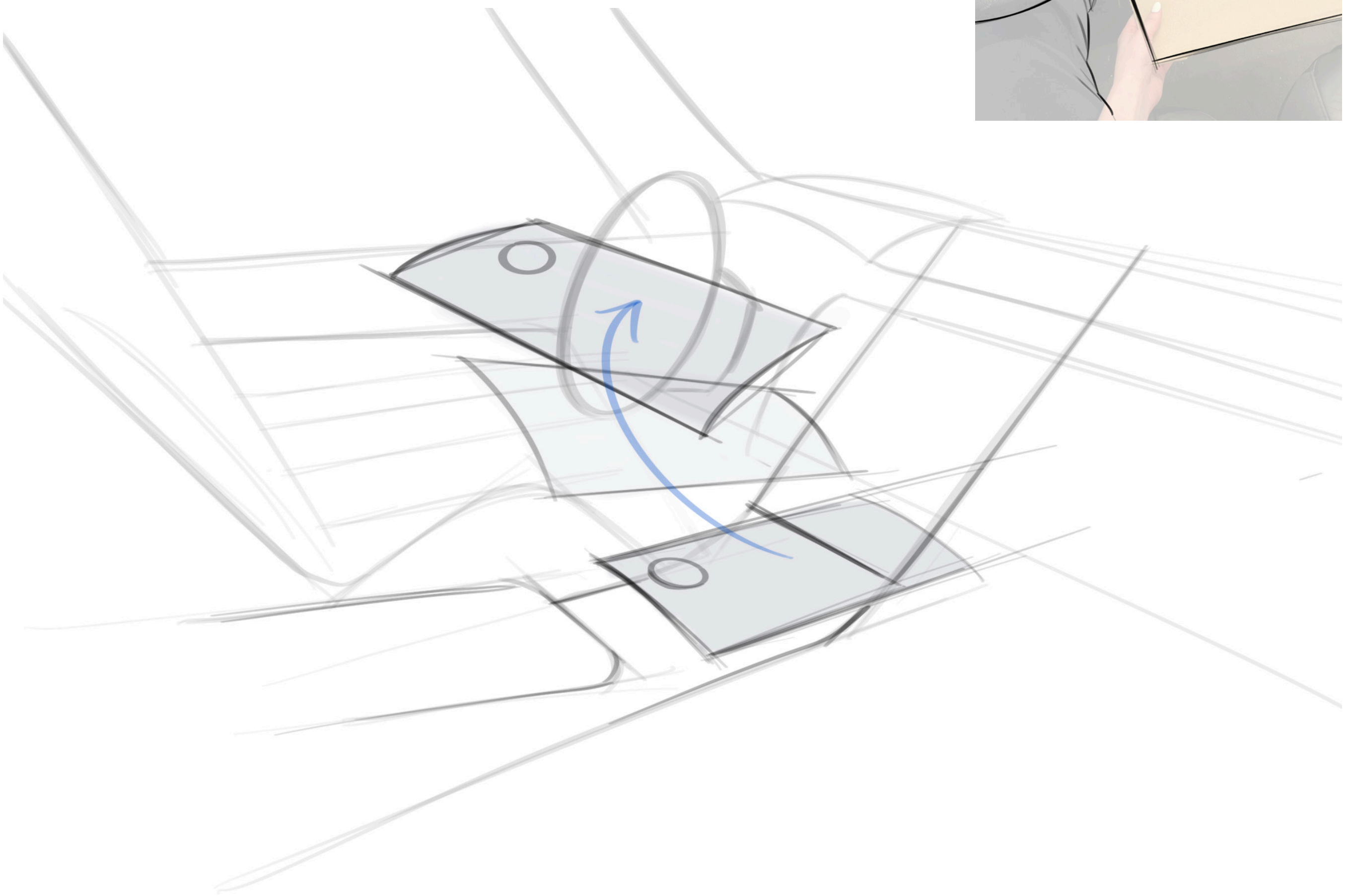
Proceed with the **“Under the Bonnet”** concept, deploying the stowage solution from the front. This concept is chosen for its fresh approach, introducing new considerations not previously explored by JLR or competitors, aligning with the primary aim of taking a bold step forward to showcase new possibilities.

Concept I - "Gearbox"

EVs don't have a conventional gearbox, clearing up the space between the leg area of the two front seats (Goodwin, 2021). This space is already differently utilized in some electric cars. Taking the BMW i3 as an example; this urban-centric automobile has left the gearbox space intentionally empty, resulting in a flat floor from left to right (Matebese, 2016). The design choice aims to enhance the interior spaciousness of the compact vehicle and ensures that the driver can exit the car on the opposite side if the driver's door is blocked, a common scenario in tight city parking situations (Davies, 2013).

This solution also presents an opportunity for partial utilization by the driver while driving. Certain components could be accessible from the centre console, while others could be intentionally concealed and only revealed during automated driving.

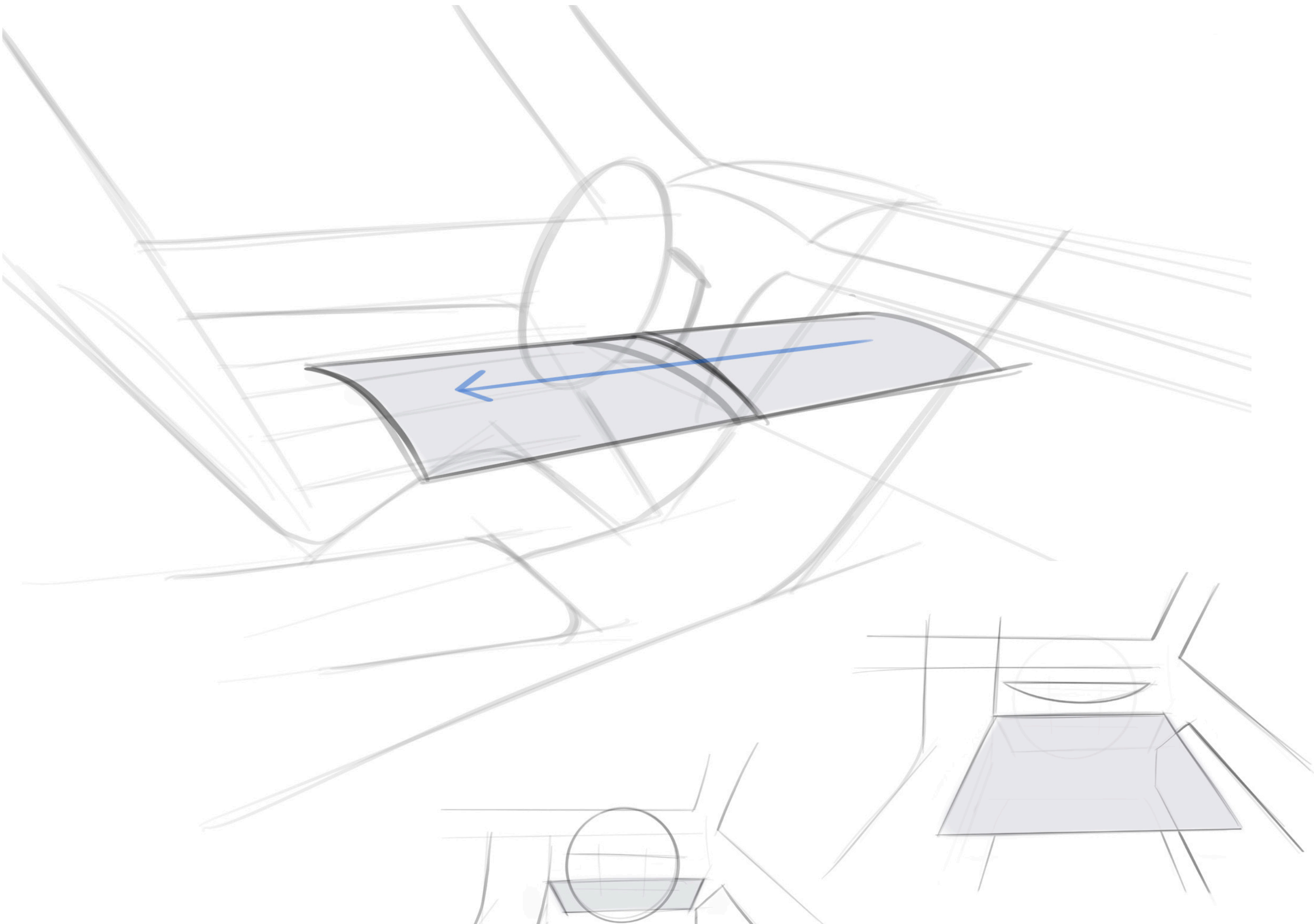


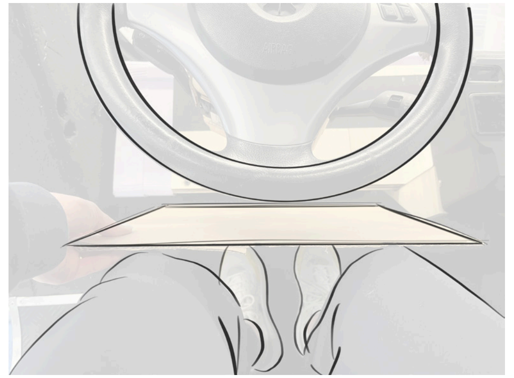


Concept II - "Under the Bonnet"

Since electric vehicles lack a traditional combustion engine typically housed in the front of the car, the layout under the hood undergoes significant changes. As exemplified by Tesla vehicles, the "frunk" (front trunk) serves as supplementary stowage (Dunne, 2016). With some reconfiguration, this area could even be accessible from inside the vehicle, creating additional stowage beneath the steering wheel.

It's important to consider the space between the driver's legs and the steering wheel; when utilizing the stowage solution, there's limited room in this area. One potential solution is to either adjust the position and/or orientation of the steering wheel or lower the seat to create more space.

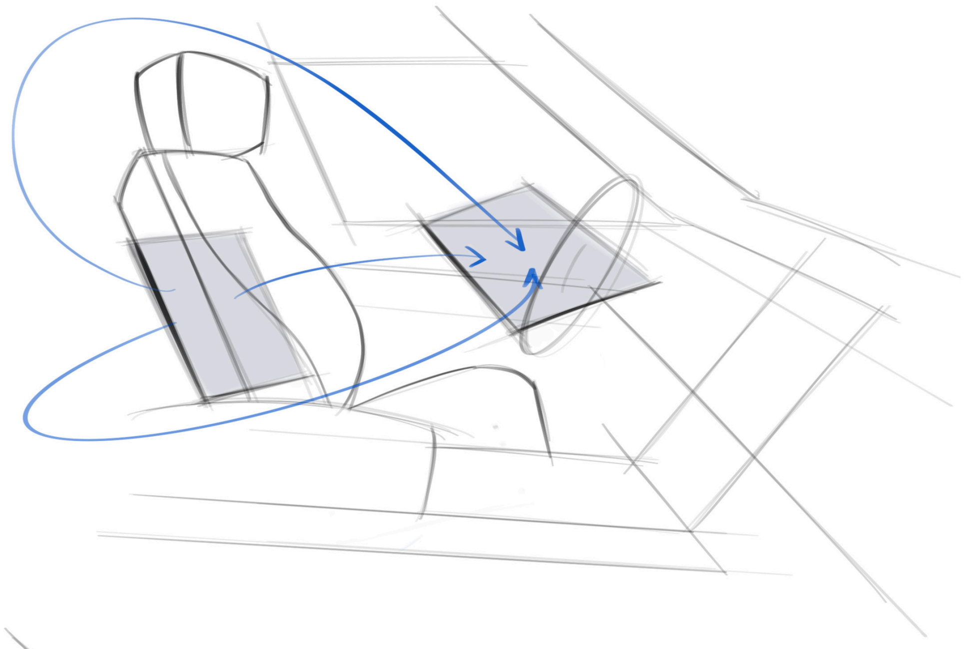


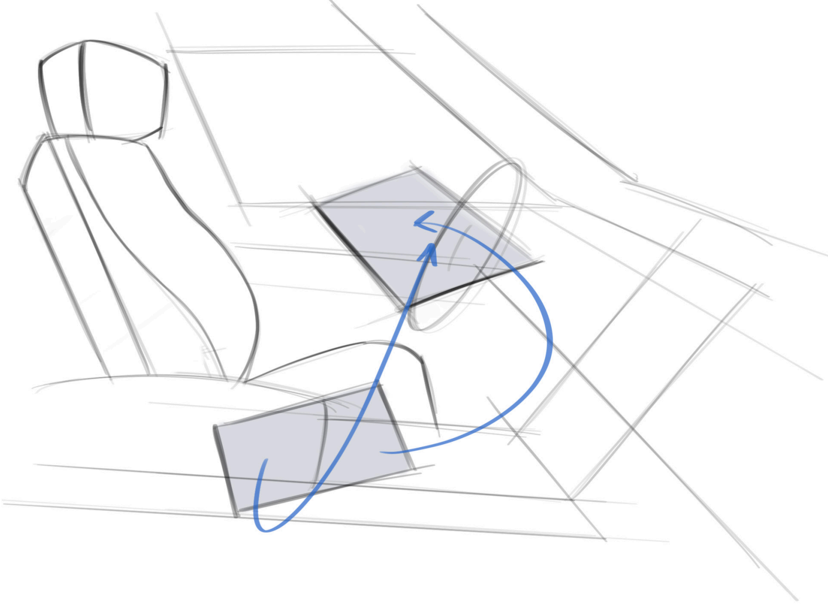


Concept III - “Seat”

A less invasive alternative would involve stowage at the rear or underside of the seat; JLR currently provides an additional stowage solution that can be attached to the back of the seat, indicating that this location has already been considered and justified (Jaguar Land Rover Classic Parts, n.d.).

However, there could be constraints regarding the path it needs to follow when autonomously deployed from behind or beneath the seat to in front of the driver. When deployed from behind the seat, it must either fit between the two front seats, between the seat and the door or above the primary users head. If deployed from beneath the seat, the legs of the primary user could pose an additional obstacle. A potential solution might be to deploy the solution “through” the center console, necessitating a redesign of the center console. However, this might diminish the benefit of this direction being less invasive.





Weighted objectives method

Introduction

To identify the most promising design direction, the weighted objectives method is used. This approach involves identifying various design criteria and assigning each a specific weight, as outlined by Van Boeijen et al. (2014). The weight of each criterion indicates its importance—the higher the weight, the more crucial the criterion. Each design concept is then rated on a scale from 1 (not met) to 4 (fully met), and a score is calculated based on these ratings.

Criteria

The main challenge in this design is ensuring that the user can quickly and effortlessly assume control, highlighting the need for straightforward deployment (criterion 1). This approach maintains simplicity and safety, preventing unnecessary complexity. Additionally, the design must provide enough space to store all the user’s desired items; otherwise, it lacks practical value (criterion 2). With a focus on level 3 and 4 autonomous vehicles, emphasizing ease of implementation is essential to justify the design to all stakeholders (criterion 3). Minimizing interference enables consistency and familiarity, which aids in seamless integration. Vertical stowage poses additional challenges in keeping everything into place, while horizontal stowage reduces necessary movements, aligning with the core aim of easy deployment (criterion 4). Furthermore, the design’s versatility, for example allowing use during driving, enhances its attractiveness and overall value (criterion 5).

Criterion	Weight	"Gearbox"	"Under the Bonnet"	"Seat"
Easy deployment Deployment requiring limited movements.	20	3	4	1
		60	80	20
Space available Sufficient space available to store the solution.	15	3	4	2
		45	60	30
Minimal interference Minimal interference with existing structures or operations.	15	3	2	4
		45	30	60
Horizontal stowage Possibility for horizontal storage.	10	4	4	1
		40	40	10
Versatility Capability for multiple uses, including usability during driving.	10	4	3	2
		40	30	20
Score	**70**	**230**	**240**	**140**

Table 1: Weigted objectives method

Conclusion

Table 1 demonstrates a subtle contrast between the “Gearbox” and “Under the Bonnet” concepts, with “Under the Bonnet” slightly edging ahead. Each concept boasts its own distinctive advantages. The key appeal of “Gearbox” lies in its versatility, offering partial utilization even in traditional driving scenarios. On the other hand, “Under the Bonnet” capitalizes on an underutilized space, with minimal deployment movement requirements. Following the midterm presentation of all concept directions to JLR, a decision has been made to proceed with the “Under the Bonnet” concept.

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CONCEPT IDEATION

5

Motivation

After determining the optimal location for the stowage solution, the next step is to delve into the details of the design. This begins with conducting additional research to identify and address any conflicts that emerged from the chosen location. With these potential issues in mind, initial sketches are created to explore various design possibilities. These sketches unveiled new opportunities, highlighting the need to start prototyping to gain further insights. Prototyping allows for practical evaluation and refinement of the design, ultimately enabling informed decision-making.

From this point on, the focus will be solely on level 3 autonomy. This choice is driven by the challenges presented by level 3 vehicles, which can manage most driving tasks but still require driver intervention in complex situations. Designing effectively for level 3 autonomy offers a clearer pathway for scaling up to level 4, rather than scaling down a level 4 design to meet the more demanding requirements of level 3 within this scope.

Key Requirement Insights

Integrate **two distinct layers** into the design to separate clean and dirty activities and lock items in place.

Incorporate a **touchscreen** on top of the design.

Tilt the design slightly to prevent misuse, reduce motion sickness, and enhance ergonomics.

Round off all edges of the design to ensure safety.

Taper the shape of design slightly to ensure accessibility to all other car features.

Deploy the concept from **below** the steering wheel.

Steering solutions

Introduction

In the "Under the bonnet" concept direction, a key consideration is the available space between the primary user's legs and the steering wheel. Although solutions such as adjusting the position or orientation of the steering wheel, or lowering the seat to create more space have been suggested, there may be other potential alternatives. To address this issue comprehensively, further research is being conducted to explore additional opportunities for resolving this space constraint.

Flatten steering wheels

Flat steering wheels, originally popularized in the racing scene, have made a notable comeback and are now commonly featured in many modern vehicle designs. Initially adopted for their space-saving benefits in the confined interiors of race cars, these steering wheels are ideal for cramped cockpits or single-seater vehicles. Beyond taking up less space, flat steering wheels are believed to enhance grip, which can lead to a more ergonomic and safer driving experience (Sparco, n.d.). An additional benefit includes a clearer view of the instrument cluster and increased legroom, both of which are advantageous for this concept.

Figure 28: 2024 Peugeot 3008 flatten steering wheel (Padeanu, 2023)

Steer by wire

Steer-by-wire, a relatively recent innovation in automotive technology, eliminates traditional mechanical steering systems, replacing them with electronic counterparts. In steer-by-wire systems, steering wheel movements are detected through sensors and electronically relayed to actuators that precisely control the wheels' orientation. These systems provide several advantages, including the elimination of oil leaks, more flexible car interior designs, spacious cabins, and reduced injury risks in accidents (Fahami et al., 2013).

The new Lexus RZ450e, unveiled in 2022, showcases one of the added benefits of steer-by-wire technology through its One Motion Grip system. This system dynamically adjusts the steering gear ratio according to the driving situation. This continuous adaptation ensures precise steering performance tailored to different scenarios. For example, it eliminates the need for hand-over-hand manoeuvres during parking and enhances stability during highway driving. As a result, the car offers the option of a unique yoke steering wheel, recognizable by its flatter profile compared to traditional steering wheels (Clifford, 2022).

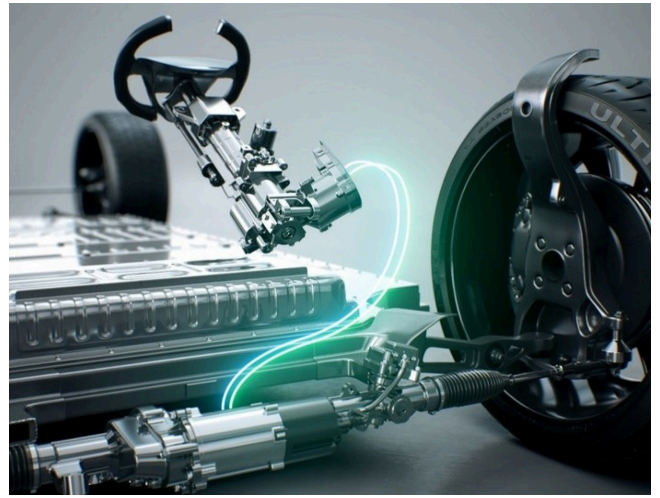


Figure 29: Steer by wire (Assembly Magazine, 2021)

Figure 30: Lexus Yoke (Moldrich, 2022)

Foldable steering wheels

For sailing yachts, space is a limited commodity. This is why smart solutions need to be designed to create more space when necessary. An example of this is a folding steering wheel, that allows easy passage when docked. It's a fairly simple mechanism, that locks into place with screw thread on two of the spokes. When slightly adjusted, a comparable mechanism could also be implemented in other forms of transport to create the space that is needed.

This concept has already found its way into the automotive industry. In 2018, Ford applied for a patent for a design that allows the steering wheel to be converted into a laptop mount (Krok, 2018). The steering wheel is equipped with hinges that enable it to transform into a flat surface suitable for supporting a laptop. While it might seem this design is intended for autonomous vehicles, it actually targets more immediate practical uses. Specifically, it caters to individuals who might need to work on their laptops in their cars, perhaps when arriving early for a meeting.

Figure 31: Foldable steering wheel (Force 4, n.d.)

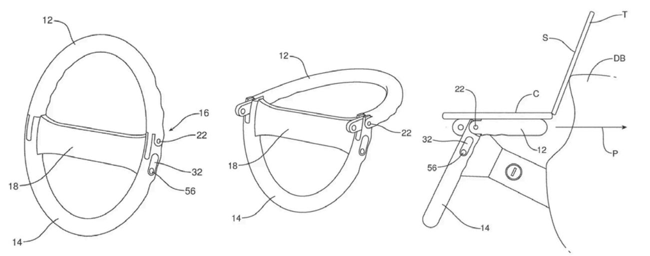


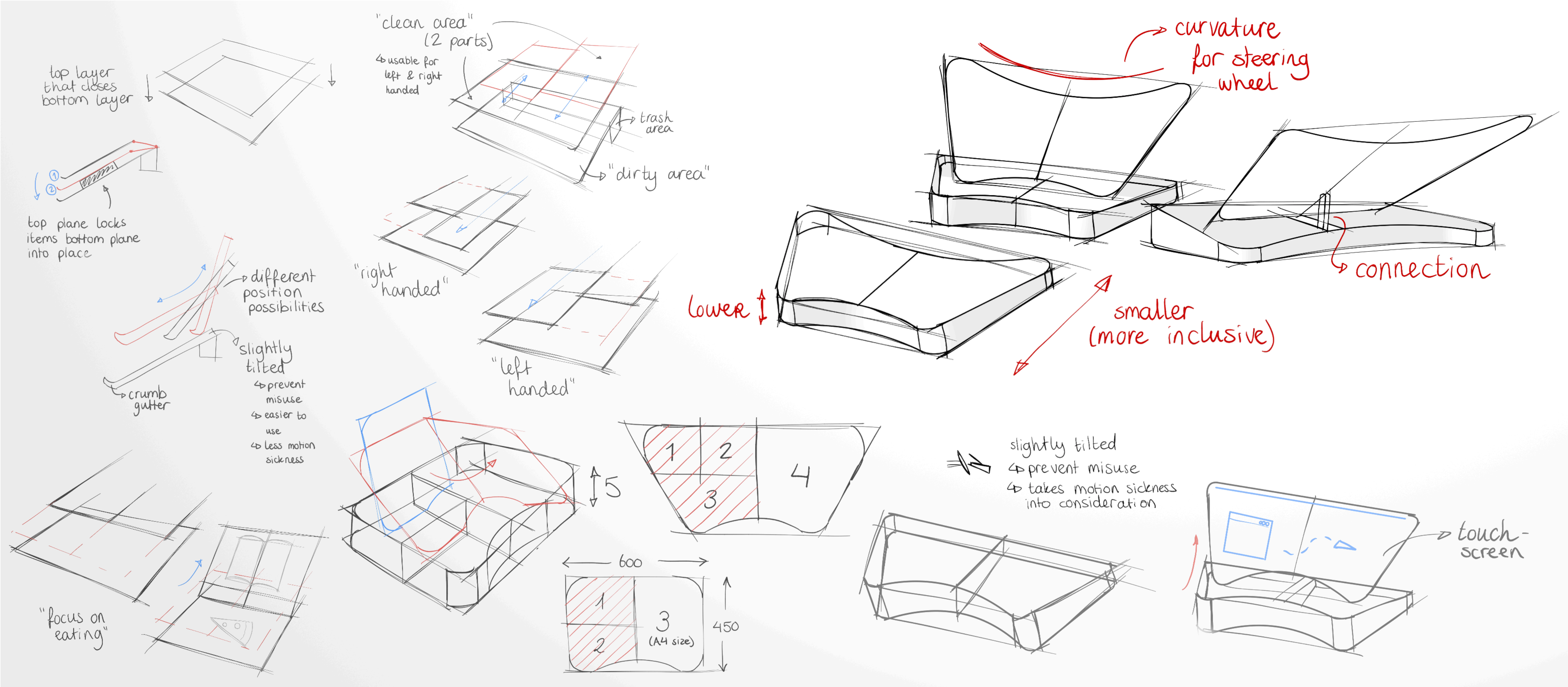
Figure 32: Ford laptop mount (Krok, 2018)

Exploration

Before initiating the ideation for the concept, all conflicts identified in the storyboard were considered to ensure comprehensive resolution. The sketches on the right illustrate the steps leading to the development of the initial concept.

The ideation process started with the decision to integrate **two distinct layers** into the design. The upper layer not only secures items in the lower layer but also distinguishes between 'clean' and 'dirty' areas, a distinction informed by insights from the storyboard. As the design evolved, it was decided to transform the top layer into a touchscreen with designated stowage beneath, separated into clean and dirty sections. This enhancement adds value to the design by allowing users to interact with a device that integrates seamlessly with their own, reducing the need to reach for personal devices. This feature helps avoid complications that might arise from users needing to resume manual control or from compliance with legislation. Additionally, it prevents the improper placement of items on the concept that cannot be securely locked in place.

From the outset, the design also incorporated a **slight tilt**, which was informed by several considerations. Given that the concept locks certain items out of reach while driving, it is impractical to store every item within it. For



instance, a thermos of coffee should remain accessible during both driving and non-driving periods. The tilt ensures that a coffee cup would tip over if placed on the concept, prompting users to place it in the center console instead, thereby preventing misuse. Additionally, tilting the concept towards the user improves ergonomics by enabling a more natural reach and viewing angle. This reduces physical strain and can decrease motion sickness by allowing the user to maintain a more natural posture, rest their head against the headrest, and view more of the environment.

The **shape** of the design features rounded edges on all sides to comply with automotive regulations regarding rounded corners. The curvature is strategically implemented: one side accommodates the user, and the other side aligns with the steering wheel. This design maximizes the usable surface area without encroaching on the user's space or hindering the use of the steering wheel. Additionally, the rounded edges provide a convenient place for users to rest their wrists during use. The design's tapered shape ensures that both the center console and the door remain easily accessible.

Deployment from Above or Below

Introduction

During discussions about the concept direction, it quickly became clear that the placement of the steering wheel in relation to the concept can also be considered. Until now, the focus has been solely on deployment from below the steering wheel. Yet, to effectively manage the limited space between the user's legs and the steering wheel, introducing the concept from above the steering wheel emerges as an extra potential solution.

Deployment from below

The steering solutions proposed in the previous chapter offer the possibility of deploying from below the steering wheel, potentially creating significant space between the wheel and the user's legs. By incorporating a flat steering wheel with a foldable bottom section, approximately 15 centimeters of space can be gained compared to the current 38 centimeters of a medium Range Rover steering wheel. This design allows the entire steering wheel to be usable during driving periods. When non-driving periods begin, part of the steering wheel can be folded in to create the necessary space. Importantly, this adjustment ensures that the top part of the steering wheel, including the airbag, remains visible and accessible even when the concept is deployed.

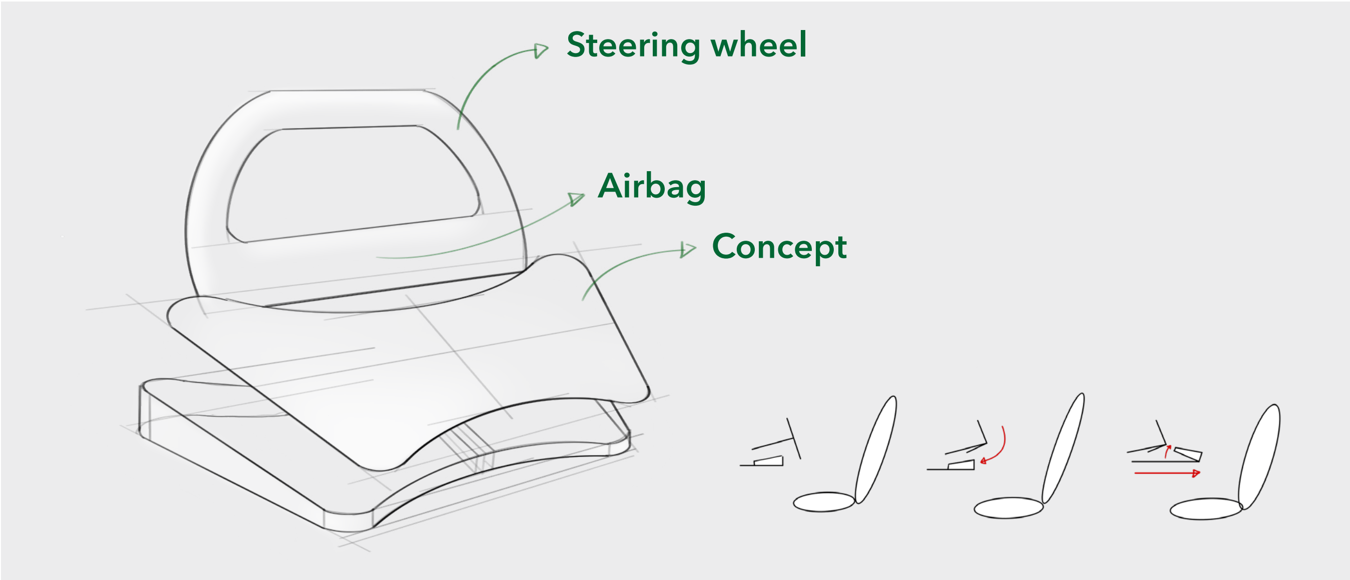


Figure 33: Deployment from below

Deployment from above

Deploying the concept from above the steering wheel presents an alternative solution. In this configuration, the space between the bottom of the steering wheel and the user's legs is not a concern. However, to ensure sufficient space above the steering wheel, the top part of the steering wheel would need to be foldable. Unlike deployment from below, this approach keeps the bottom part of the steering wheel within easy reach.

An important consideration with this direction is the head-up display. Modifications will be necessary to keep all information visible to the user during both driving and non-driving periods. A potential benefit of deploying from above is related to the placement of the concept post-deployment. JLR has stressed the importance of mitigating motion sickness, a concern noted in the storyboard. Positioning the concept high enough after deployment could help reduce motion sickness factors.

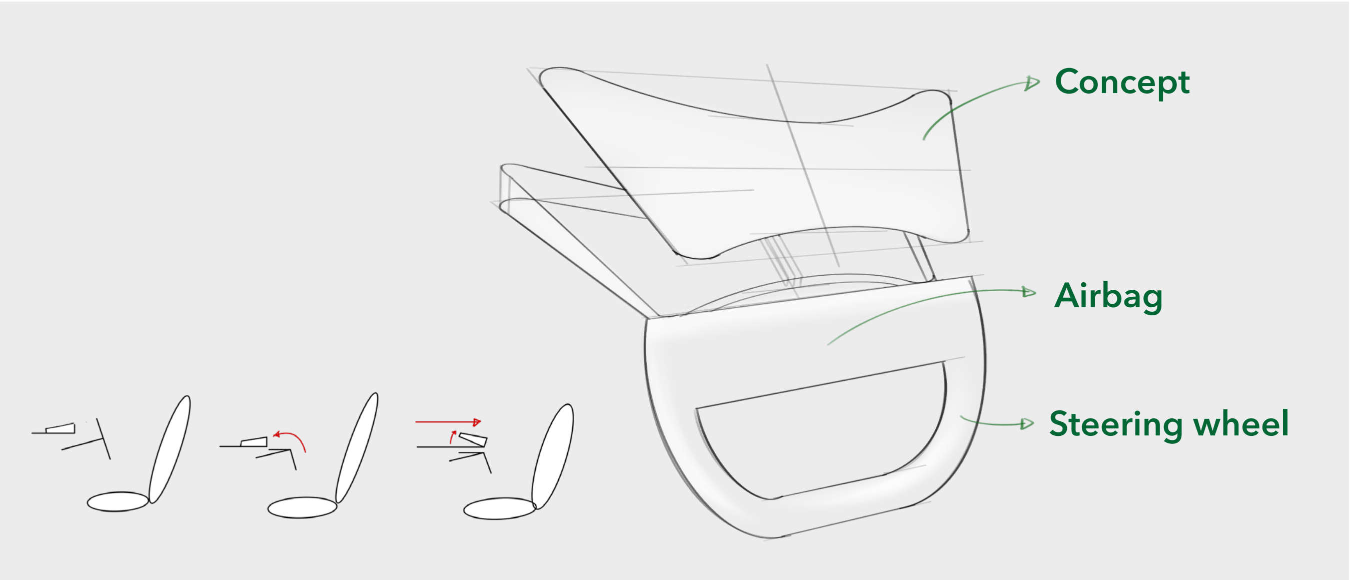


Figure 34: Deployment from above

Choice

Making a final choice requires considering both comfort and safety. A significant distinction between the two concept directions is accessibility to different parts of the steering wheel. With deployment from below, the top part of the steering wheel remains accessible at all times. On the other hand, with deployment from above, the bottom part is always within reach. Prototyping and testing will be vital to determine which concept best meets all requirements.

Observations from videos showing Tesla drivers using autopilot suggest that many people instinctively reach for the bottom of the steering wheel when they need to take over control (Whole Mars Catalog, 2020). Typically, nothing obstructs the space between the user and the steering wheel in these situations, and drivers often rest their hands on their legs, making the bottom of the steering wheel the closest and most accessible part. However, with the implementation of this concept, the dynamics could change entirely, and only through testing can we gain a clear understanding of the likely outcomes.

Prototyping

Introduction

The goal of the prototyping phase is to gain insights that can't be achieved through drawings alone and to conduct some initial testing. This exploratory testing aims to gather preliminary insights and provide a proof of concept for an entirely new design direction.

Steering wheel

To accommodate the deployment of the concept, a standard steering wheel does not provide sufficient space between the wheel and the user's legs. As previously mentioned, a foldable steering wheel could create the necessary space to address this issue. For deployment from above, the top of the steering wheel will fold, and for deployment from below, the bottom will fold. To test both configurations, a single prototype steering wheel has been designed to rotate, allowing the testing of both concept directions. This prototype is made from seven laser-cut wooden plates, glued together and filed down, and it connects to the shaft with four of these layers. The steering wheel is painted black to enhance realism.

Figure 35: Front steering wheel

Figure 36: Back steering wheel

Concepts

Similar to the steering wheel, the outlines of the two concepts have been laser-cut. The width of both prototypes is based on the width of the seat. The depth of the two concepts is based on different products: the 300 cm depth accommodates an A5 notebook on one side of the hinge mechanism, while the 200 cm depth provides a usable area on top comparable to an iPad. When creating the laser-cut document, the difference in depth did not seem significant, but it became immediately apparent that the difference was larger than expected. A hinge mechanism is constructed between the plates, allowing for different orientations of the top "touchscreen" layer. These concepts have also been painted black to blend with the environment and reduce the wooden appearance.

A decision has been made to exclude the borders of the lower part of the concept from the prototype. This is because, for now, interaction with the top part and the overall measurements are more important, and both can be achieved without the borders.

Figure 37: 200 x 500mm concept deployed

Figure 38: Comparison both concepts

Connections

To allow for different sizing possibilities for both the steering wheel and the concept, an adjustable shaft holder has been constructed. Both shafts are connected in the same way and can be slid in from the central opening. A bolt can be slid through the pre-made openings, and wing nuts allow for easy adjustments during testing. Pre-marked sizes on both the shaft and holder streamline the process, ensuring more accurate measurements between tests.

The hinge mechanism between the two layers of the concept is facilitated by two simple bolts and wing nuts. The concept is connected to the shaft using a pre-made scaffolding connection, all of which can be tightened to secure a specific orientation during testing.

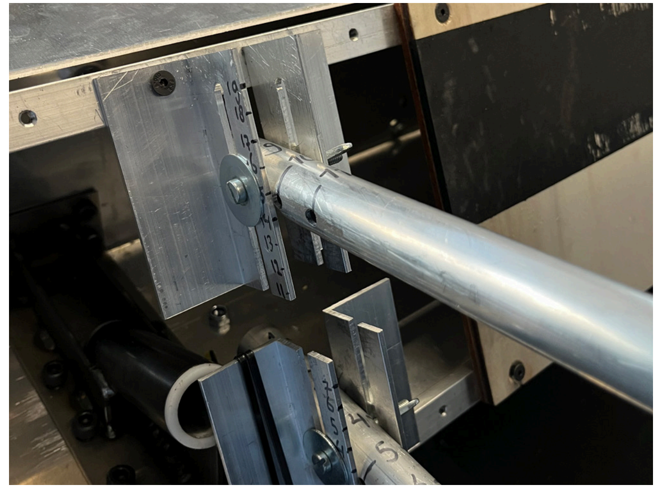


Figure 39: Connection to dashboard

Figure 40: Connections

Conclusion

After completing the prototype, it became evident that deploying from above is not feasible. Even the smaller prototype ended up higher than anticipated, partly obstructing the windshield view. Additionally, using the concept requires users to lift their arms uncomfortably high. Given these issues, the disadvantages outweighed the benefits. Consequently, the decision is made to focus solely on testing deployment from below, concentrating on sizing, positioning, and substantiating the proof of concept.

Figure 41: Deployment from above

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PROTOTYPE TESTING

6

Motivation

With initial decisions in place, the prototyping phase highlighted the advantages of creating physical models over working solely on paper. To build on these insights, additional testing has been conducted to gather more information and refine the final design requirements. The goal of this study is to explore the feasibility and effectiveness of the designed stowage solution for level 3 autonomous vehicles, requiring a proof of concept to assess its value and functionality. This testing aimed to determine the optimal position and size for an automatic stowage solution that balances safety, comfort, and accessibility.

Key Requirement Insights

Ensure the steering wheel can **move** at least 16 centimeters back and 7 centimeters up when the concept is deployed.

Allow all users to **rest their legs** on the seat, ensuring sufficient room for the concept and steering wheel.

Align the **horizontal distance** of the concept with where users' hands rest when their arms are on the bolsters.

Position the **vertical distance** between the user's legs and the steering wheel, without touching the user.

Limit the difference in **vertical distance of the steering wheel** to prevent muscle memory difficulties.

Ensure the **screen on top** does not obstruct access to the stowage area.

Ensure all participants can **take control** in under 4 seconds.

The concept must ensure the steering wheel can **rotate** at least 10 degrees in both directions during emergency situations.

Deploy the design only when the **expected usage time** exceeds a few minutes.

Provide **notifications** to alert users if items are left in the concept.

Ensure items are easily reachable when **exiting** the car.

Introduction

Objective

This innovative direction, currently not featured in vehicles, requires a proof of concept to understand its value and functionality, particularly for level 3 autonomous cars where user intervention may still be necessary. For JLR, the takeover time is currently set at 10 seconds. This means the autonomous system cannot continue driving after this period, requiring the user to be in a driving position, aware of their surroundings, and ready to fully take control.

Purpose
This test serves as exploratory research, aiming to generate initial insights for further development rather than testing a specific hypothesis. The focus is on qualitative research rather than quantitative.

Comfort Assessment
This test evaluates several key elements. Firstly, the comfort of the concept will be assessed based on two factors: the size and placement of the stowage solution. Two different designs will be tested: a 200x500 mm and a 300x500 mm design. These dimensions are determined by various considerations. The width is determined by the current L460 Range Rover seat, ensuring it fits within the dimensions from the door to the center console. The 200 mm depth is designed to match the depth of the top layer (touchscreen) to that of an 11-inch iPad Air touchscreen. Although the width results in a larger overall surface, the depth is currently prioritized to potentially accommodate a keyboard on the lower half of the touchscreen during use. The 300 mm depth accommodates the stowage of an A5 notebook on the bottom layer of the design. This takes into account the hinge mechanism in the middle, which allows the touchscreen to be lifted to the preferred position while providing access to the stowage area on the bottom layer.

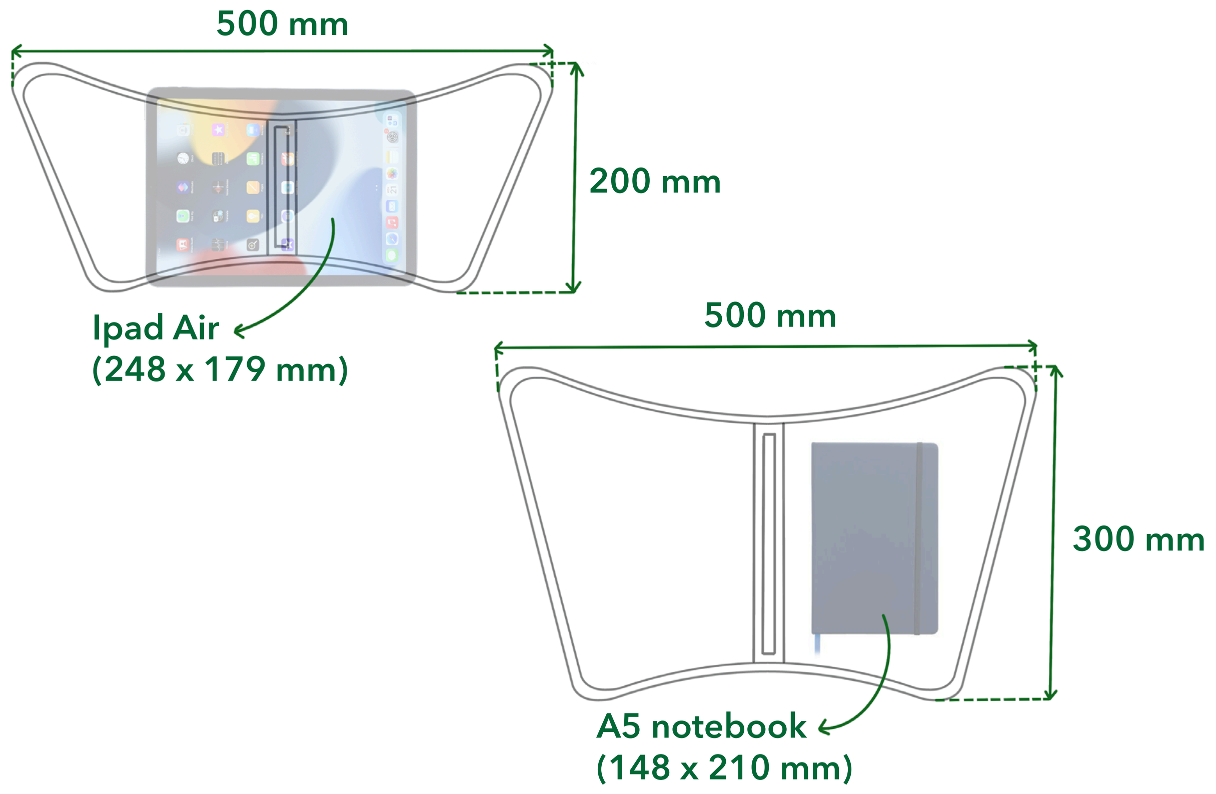


Figure 42: Various sizes and derivations

Both these designs will be tested by various participants to determine how size and location affect comfort.

Safety Evaluation
Secondly, the safety of the concept will be evaluated by measuring participants' reaction times to take control of the steering wheel when required. Participants will watch a 40-second video on a large screen in front of the windscreen (see figure XX), which includes an evasive maneuver after 30 seconds. The participants will engage in writing or drawing on the concept to simulate a realistic scenario. The reaction time from the start of the video to when participants take control will be recorded, allowing the calculation of the total reaction time from the beginning of the evasive maneuver to having their hands back on the steering wheel.

Participant Data Collection
In addition, both general information and specific body measurements of participants will be collected. The general information will primarily focus on obtaining background details from the participants and gathering information related to the items that need to be linked to the chosen NDRA clusters. This data will help explore potential relations between individual characteristics and their preferences for the concept's placement, as well as provide other valuable insights.

Overall Opinion
Lastly, overall opinions regarding the concept were collected after testing to understand its added value and identify potential improvements not covered by the test.

Participants

The study included 15 participants, all aged between 18 and 70 years, who hold a valid driving license.

Research Question

"What is the most comfortable position and size for an automatic stowage solution placed between the user and the steering wheel, ensuring both safety and convenience while maintaining easy access to the steering wheel?"

Materials

To closely replicate the real life environment, a buck is employed. A buck is a full-scale model of a car, typically crafted from materials such as wood, clay, or foam. It is used during the design process to provide designers and engineers with a tangible representation of the vehicle, and for testing purposes as in this scenario. While this particular buck does not match the exact dimensions of the latest Range Rover model (which is the starting point for this project), it still offers a realistic setting for participants to experience during testing.

Within this buck, a Range Rover seat, the L460, has been installed. This setup ensures that ergonomic assessments conducted during testing are as accurate and reflective of actual conditions as possible.

All the materials used during testing, including the test set-up, are shown in figure 35 and 36.

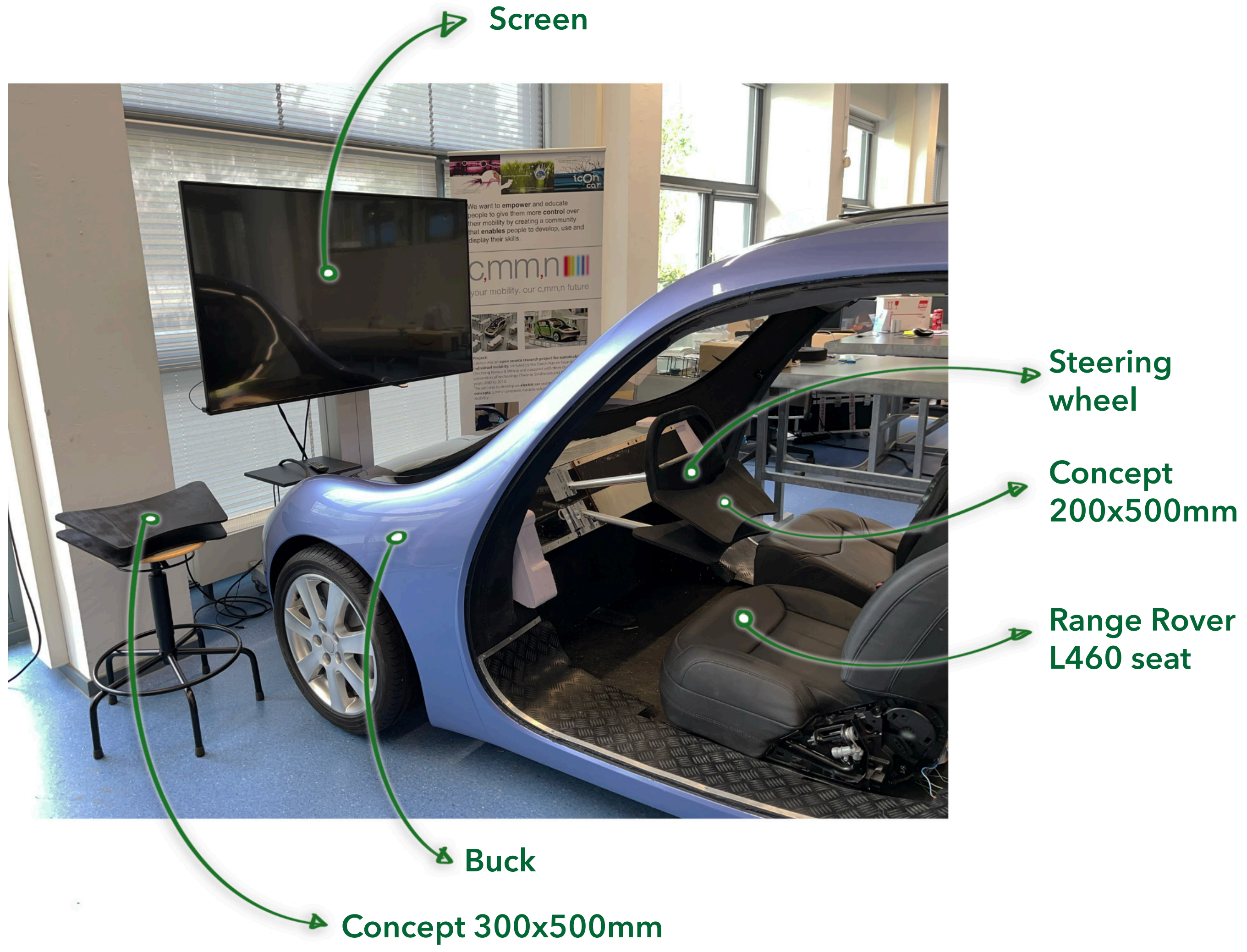


Figure 43: Test setup including materials

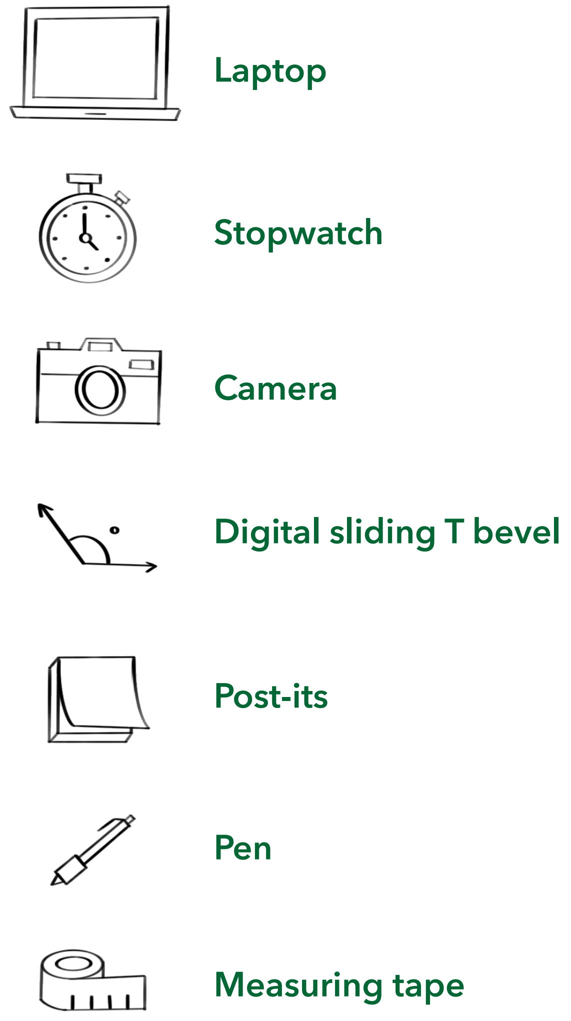


Figure 44: Additional materials

Procedure

Initial testing procedure

This chapter outlines the initial testing procedure. Following the first few tests, several modifications were implemented.

1. Introduction and informed consent
To begin, the study was verbally explained as follows, and participants were asked to complete the consent form, located in appendix F:

"We're conducting tests on a new concept for level 3 autonomous vehicles, ensuring that users will always be available to resume control if necessary. This concept features a tray table-like design aimed at enhancing user experience during non-driving periods. We're evaluating two key aspects of this design: its size and position. Throughout the testing process, you will be asked to interact with and adjust various interior components as necessary. Testing can be paused at any time if required. You are encouraged to vocalize your thoughts."

2. Information collection
The participant was instructed to sit on the designated chair outside of the buck. At this stage, preliminary questions were posed, focusing on basic personal information, the participant's experience and willingness to utilize autonomous vehicles, and various NDRA item-specific queries. General outcomes are discussed in the results chapter; however, individual participant background results have been excluded from appendix G due to privacy constraints.

3. Bodily measurements
Participants were requested to stand while measuring tape is used to obtain five different body measurements, as depicted in figure 45. Three measurements were taken while the participant was standing, and two were taken while seated. The seated measurements were conducted outside of the buck.

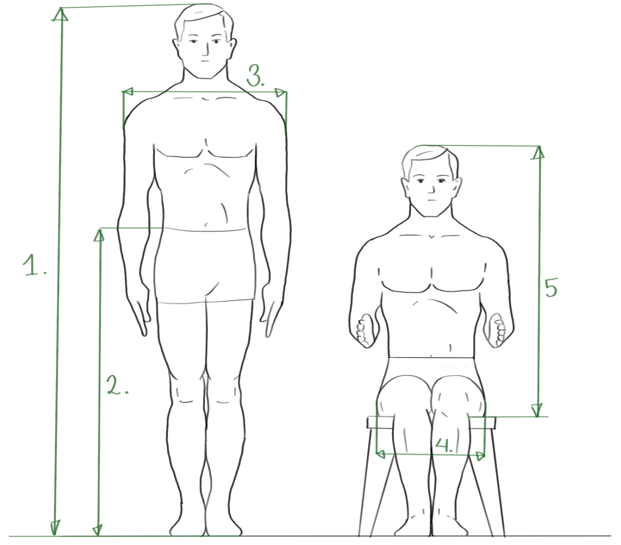


Figure 45: All bodily measurements taken during test

4. Steering wheel adjustment
Participants were instructed to enter the buck, where the steering wheel was already installed. They were then asked to adjust the steering wheel to their preferred comfort level, and all corresponding measurements were noted.

5. 1st concept installation and adjustment
One of two design concepts was randomly selected for each participant, ensuring an even distribution. Once the selected concept was installed, participants were invited to adjust its position to suit their comfort. They were also informed that if it becomes necessary to adjust the steering wheel to comfortably position the concept, they were free to do so. The positions of both the concept and the steering wheel were documented, and a picture was taken from the side.

6. 1st concept testing
Participants were informed that the car was operating in autonomous mode but might require manual takeover by gripping the wheel. They were asked to write or draw on the post-it that was placed on top of the concept. The dashcam video demonstrating an evasive manoeuvre was displayed on the screen in front of the windshield. The stopwatch began the moment the video started playing and was stopped once the participant had their hands on the steering wheel. This duration

was carefully recorded. Following this, the participant was questioned about any obstacles they may have encountered and whether they found the task easy to perform.

7. 2nd concept installation and adjustment
The first concept was swapped out for the second one. Participants are then asked if adjustments were necessary for both the new concept and the steering wheel. Steps 5 and 6 were conducted again with the second concept, during which a different video was shown to the participants.

8. End
The participant was asked for his/her final thoughts, and thanked for the participation.

Figure 46: Step 6 of the testing procedure

Figure 47: Step 6 of the testing procedure

Figure 48: Snippets from evasive maneuver video

Initial testing outcome

Testing of the first three participants quickly revealed that the larger concept size (300x500 cm) was impractical. Regardless of the participant's bodily measurements, positioning the concept comfortably was unfeasible as it invariably made contact with them. For taller participants, it even hindered normal arm placement when touching the steering wheel (see figure 49). As a result, it was decided to proceed exclusively with the smaller concept (200x500 cm) and eliminate step 7 from the protocol. This streamlines the procedure and allows for quicker sessions, accommodating more participants.

Figure 49: Larger concept in use

Figure 51: Larger concept in use

Figure 50: Larger concept in use

Results

Participant group

The average age of the participants was 27 years. The group consisted of 8 females and 7 males, resulting in an almost equal gender distribution. All participants were used to driving on the right side of the road and were familiar with autopilot or self-driving features in cars. Of the participants, 53% had used autopilot or self-driving capabilities before, and everyone expressed a willingness to drive level 3 autonomous cars in the future, though some mentioned they would likely be late adopters.

Items

To build upon the NDRA research, all participants were asked what items they like to use for the three identified NDRA focus clusters: Entertainment, Productivity, and Eating and Drinking. These items can then be used to ensure the concept accommodates as many as possible.

Entertainment
As shown in chart 9, digital items are most preferred for winding down. Participants who listed a book were asked if they would consider reading digitally in the car. 83% responded positively, citing the convenience of having everything in one place instead of juggling multiple items. This indicates the potential for replacing larger items, such as books and notebooks, with digital alternatives where possible. This insight could potentially be applied to other NDRA clusters as well.

Productivity
All participants (100%) listed a laptop as essential for work and/or study, indicating a strong need for this item in this NDRA cluster (see chart 10). Additionally, more than half of the participants listed a notebook and pen, as well as something to drink, as essential items.

Eating and Drinking
For eating and drinking, drinks (either hot or cold) were listed more frequently than food-related items (see chart 11). When asked why, 73% of participants mentioned they were concerned about crumbs and mess in the car, preferring to eat outside during a trip. Conversely, 27% did not mind, arguing that a car is a tool to travel from A to B, and can always be cleaned.

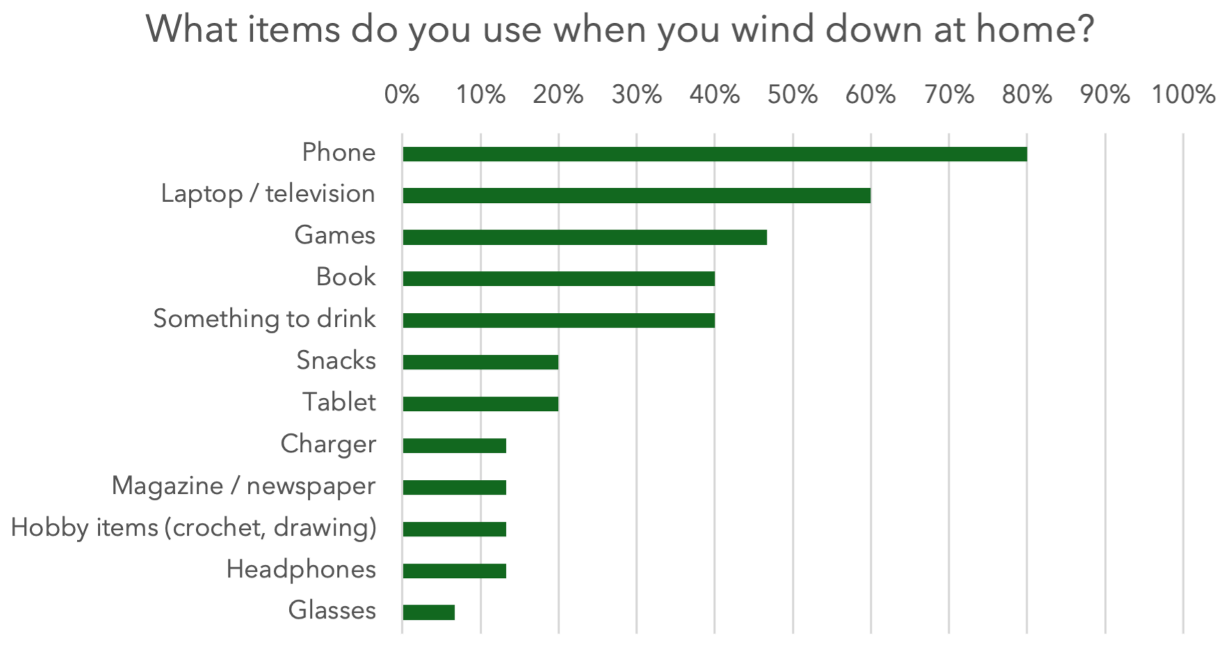


Chart 9: Items related to "Entertainment"

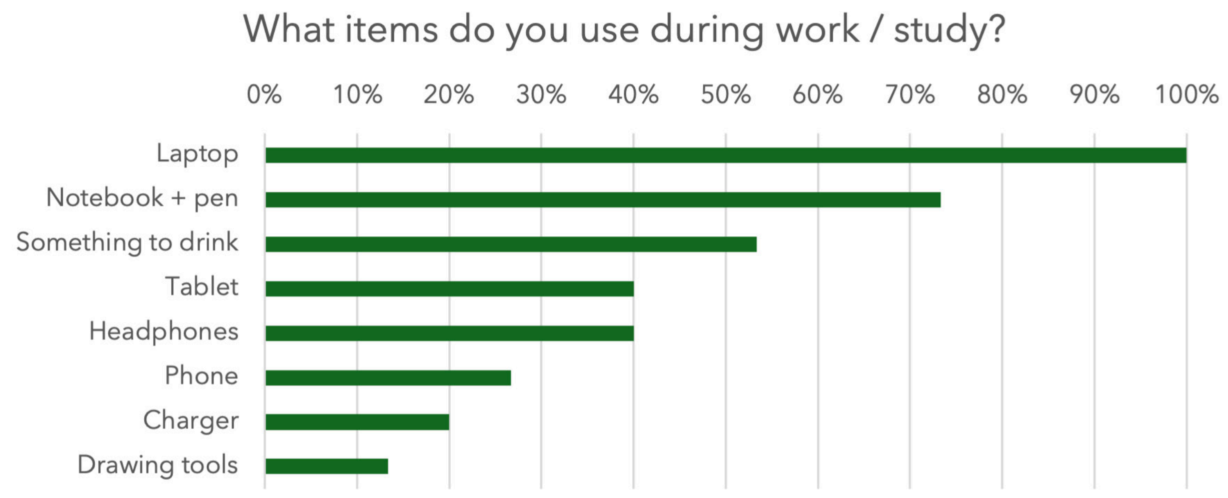


Chart 10: Items related to "Productivity"

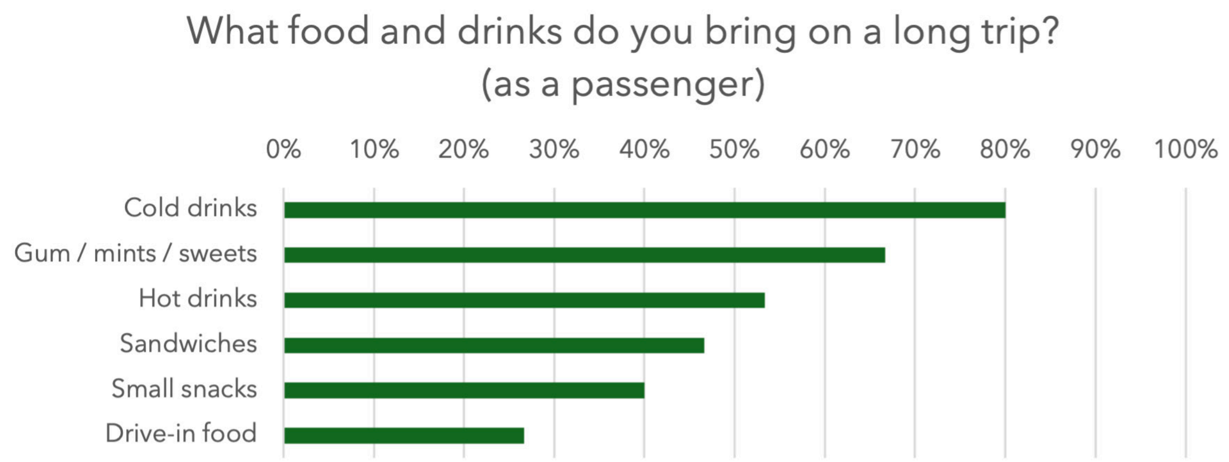


Chart 11: Items related to "Eating and Drinking"

Position

To determine the most comfortable position of the steering wheel, both with and without the concept, as well as the concept itself, the angle, length, and height were recorded during the test. Using the lowest possible point in the shaft holder as the axis start, the final positions for all individual participants can be calculated (see appendix G for calculations). In both figures, each dot per category represents an individual participant. Chart 12 provides an abstract illustration of the average measurements for each category.

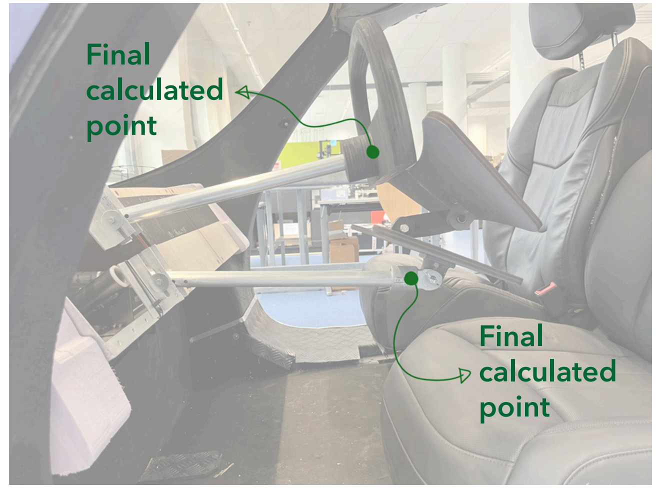


Figure 52: Calculated position per item

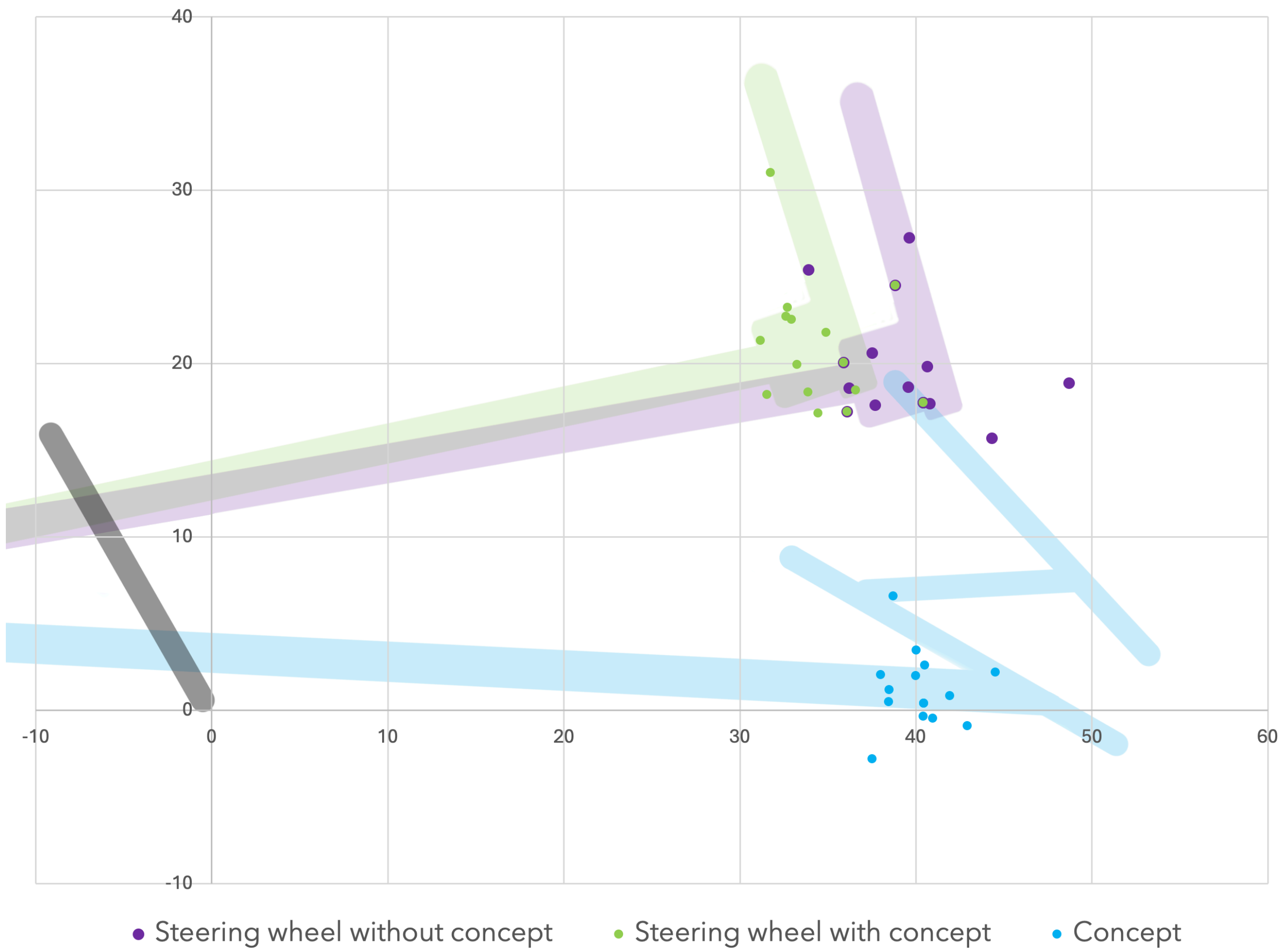


Chart 12: Abstract illustration of the average measurements

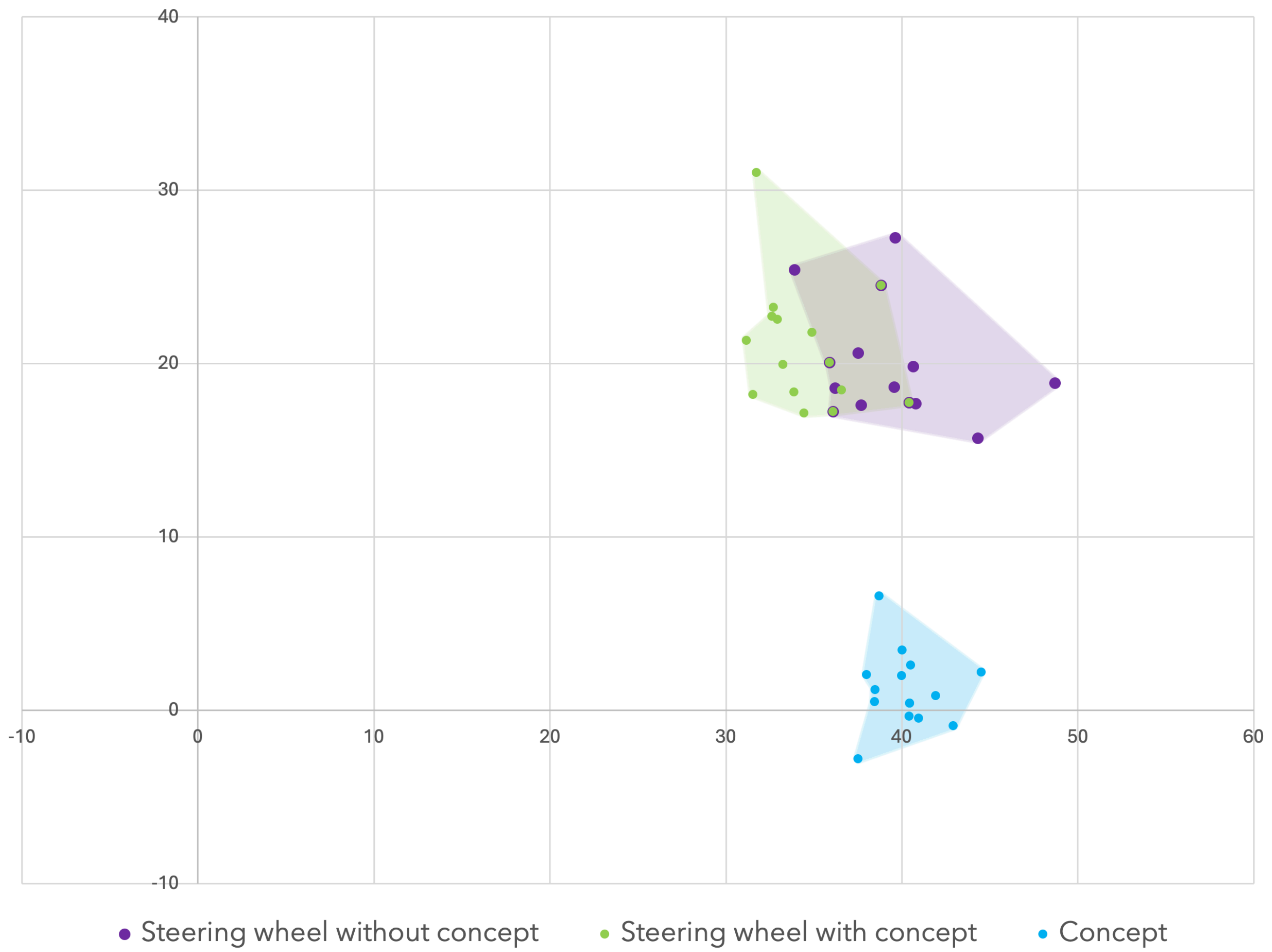


Chart 13: Distribution of all participants

Chart 13 illustrates the distribution of all participants across each category, highlighting potential outliers and variations. These insights reveal whether participants felt the need to adjust the steering wheel when the concept was deployed (and if so, where), as well as the positional differences between participants. In this case, all overlapping dots indicate that the participants did not feel the need to adjust the steering wheel after the concept was introduced. This was observed in four participants.

Steering wheel
Chart 12 reveals that many participants felt the need to adjust the steering wheel after the concept was introduced. The abstract visualization indicates that the steering wheel and the concept collided for many participants, necessitating adjustments. On average, participants moved the steering wheel 5 cm back and 1 cm up, with the maximum adjustment being 16 cm in depth and 7 cm in height. Overall, 73% of the participants felt the need to adjust the steering wheel after the concept was introduced into the buck.

Concept
The concept was positioned much lower than expected, with most participants preferring it almost resting on their legs. Several participants explained this was related to arm placement. The prominent bolsters of the Range Rover L460 seat provide substantial support during driving. However, when the concept was positioned too close, the bolsters pushed the participants' arms forward, resulting in an uncomfortable wrist orientation. Conversely, when placed further away and lower, participants could use the bolsters as armrests, resulting in an ergonomically comfortable arm position while allowing them to rest their hands on the edges of the concept, as shown in figure 53 and 54.

Spread
The steering wheel's position without the concept showed the greatest depth variation among participants, with a range of 15 cm. Contrary to expectations, the concept itself exhibited limited variation in position preferences despite significant differences in participants' body measurements. The spread was 10 cm in height and 6 cm in depth.

Figure 53: Using bolsters as armrests

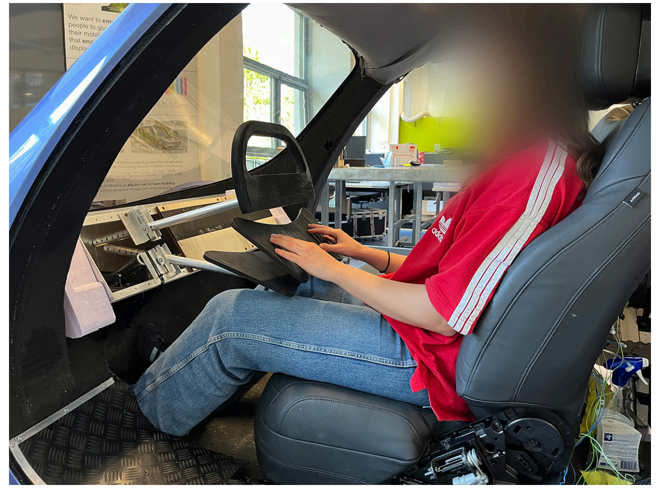


Figure 54: Using bolsters as armrests

Reaction time

Chart 14 illustrates the distribution and average reaction time from the start of the collision shown on the dashcam video to the moment participants took control of the steering wheel during testing. It shows that all participants managed to take control in under 4 seconds, with an average reaction time of 1.7 seconds. While this falls within JLR's 10-second takeover time, it's important to note that the timer was stopped when the participant grabbed the wheel. This does not have to equate to full control, which also includes fully observing the environment, having feet on the pedals, and being ready to take over completely. Therefore, even though the takeover time is well below the 10-second limit, additional time may be needed for the user to assume full control of all driving aspects.

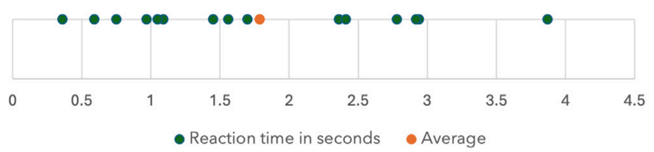


Chart 14: Distribution reaction time with average

Shape

Steering wheel
Some participants mentioned that they primarily hold the bottom of the steering wheel on highways but grab the top when extra attention is needed, such as during heavy rain. During the reaction time testing, everyone instantly reached for the top part of the steering wheel (see figure 55), indicating no issues for drivers who usually hold the bottom.

Concept
The curvature on both the participant's side and the concept side aims to create more space where needed. However, some participants reported that the edges of the concept poked their legs when the concept was positioned too low (see figure 56). Additionally, the curvature intended for the steering wheel didn't always provide enough room, sometimes making it impossible to turn the wheel. These concerns must be addressed in the final design.

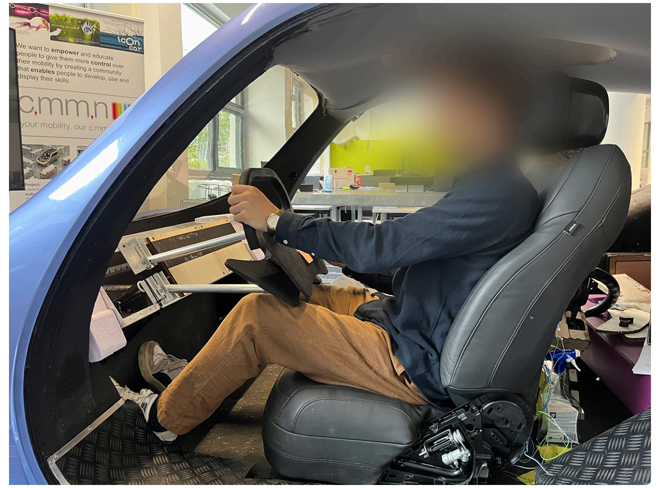


Figure 55: Participant reaching for top steering wheel

Figure 56: Bottom concept poking in legs participant

Final thoughts

Overall, most participants recognized the added value of this concept, especially for longer road trips. One participant noted, "I'm not sure if I would use it for just a few minutes, but for longer periods on a quiet highway, I would **definitely be open to trying it**." A regular Tesla driver saw the added value in **having everything within reach**: "For me, reaching for the screen is always quite a hassle. Everything is integrated into the touchscreen, but even something as simple as changing the temperature requires so much effort."

One participant suggested improving the **reachability of the bottom layer**: "If a border is included, I may not be able to reach the bottom layer to store my belongings." Another participant raised a concern about **reachability when exiting the car**: "What if I leave some sandwiches in there, and they get stored in the front of my car without me knowing? If I come back after a week and everything is smelly and moldy, I won't ever use this again." Both these concerns should be considered for the final design.

Discussion

Main findings

Concept
For the concept, the smaller design with dimensions of 200x500mm proved to be the only feasible option. The placement of the concept showed minimal variation among participants, while allowing them to comfortably use the bolsters as armrests.

All larger items the concept needs to accommodate can be turned into digital alternatives when possible. The concept needs some adjustments in shape to accommodate both the user and the steering wheel. Additionally, it is important to alert the user about the items inside when leaving the car and to make it easy to empty.

The design should also minimize the scattering of crumbs during eating and be easy to clean. It should only be deployed when the expected use time is longer than a few minutes.

Steering wheel
Having only the top of the steering wheel within reach while using the concept proved to be feasible. Additionally, the steering wheel should be adjustable during the use of the concept to ensure optimal comfort and functionality.

Limitations

Participant group
As previously mentioned, this test was exploratory, aimed at gathering initial insights. Future tests should involve a more diverse participant group and a more accurate testing environment.

Prototype
As illustrated in figure 57, the steering wheel with the concept had one notable outlier, likely due to prototype limitations. Figure 58 highlights this participant, who had a recorded standing height of 189 centimeters. Since the seat was locked in a fixed position, the participant lacked proper legroom, necessitating raising both the concept and the steering wheel higher than preferred. Additionally, the dashboard prototype offered limited space for sliding in the shafts. The participant felt the need to move the steering wheel further forward, which was only achievable by also raising it. These limitations likely skewed the final results, creating a notable outlier. Without these prototype constraints, the participant's results would likely have been positioned more to the left (indicating less depth) and lower (indicating less height). The same participant also struggled during the reaction time test. The higher-than-preferred steering wheel made it harder

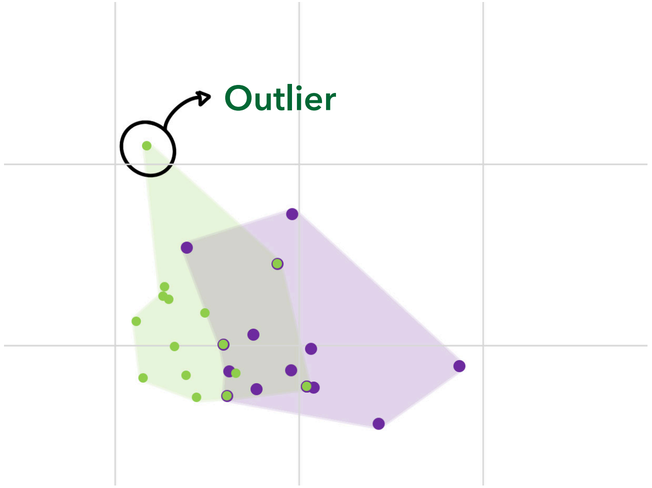


Figure 57: Outlier

Figure 58: Participant

to grab by muscle memory, resulting in the slowest takeover time of all participants and highlighting the importance of muscle memory during takeover.

Reaction time
For the reaction time testing, several limitations could have skewed the results. Since the video lasted only 40 seconds and participants knew something could happen, reaction times might be longer in a real-life situation. On the other hand, the test environment lacked warnings and sound, which could help shorten reaction times. Additionally, some participants complained about the reflection of the dashboard on the windscreen, which impaired their view. To obtain more accurate results, this test needs to be redone in a more realistic setting.

Steering wheel adjustment
The adjustment findings can be compared with previous research by Fleischer and Rongqian (2021), who investigated the spatial requirements for different NDRAs in level 3 autonomous vehicles. Their study suggested that for using a tablet, a sufficient distance between the chest and steering wheel is 410 mm, with a comfortable distance being 560 mm. In this test, the average distance between the steering wheel and seat was 550 mm when the concept was deployed, indicating a slightly lower distance from the steering wheel to the chest. This suggests that the obtained results may fall below the sufficient distance, indicating an even greater need for moving the steering wheel back.

Conclusion

Goal

The goal of this research was to generate initial insights for further development of the stowage solution concept, focusing on comfort, safety, and overall value. The research provided insights that exceeded expectations, suggesting potential design improvements. This chapter outlines these proposed improvements as both new and newly supported requirements for the concept, which can be implemented in the final design. These new requirements will ensure functionality, user comfort, and safety.

Recommendations

New requirements
- The steering wheel must be at least able to move 16 centimeters back and 7 centimeter up when the concept is deployed (maximum difference during testing).
- All users must be able to rest their legs on the seat, ensuring sufficient room for the concept and steering wheel.
- Align the horizontal distance of the concept with where users' hands rest when their arms are on the bolsters.
- Position the vertical distance between the user's legs and the steering wheel, without touching the user.
- Limit the difference in vertical distance of the steering wheel to prevent muscle memory difficulties.
- Ensure the screen on top does not obstruct access to the stowage area.
- The design must ensure that all participants can take control in under 4 seconds.
- The concept must ensure the steering wheel can rotate at least 10 degrees in both directions during emergency situations.
- The design should be deployed only when the expected usage time exceeds a few minutes.
- Notifications should alert users if items are left in the concept.
- Items should be easily reachable when exiting the car.

Requirements now supported
- A touchscreen surface that can seamlessly connect to all personal devices must be included.
- Features like cupholders should be in the center console, accessible during both driving and non-driving periods.
- Crumb scattering should be minimized during eating.

References

Fleischer, M., & Rongqian, L. (2021). Spatial needs for non-driving related activities. In Lecture notes in networks and systems (pp. 282–287). https://doi.org/10.1007/978-3-030-79763-8_34

FINAL CONCEPT

Overview
Features
Deployment
Shape and Orientation
Details
Getting in and out
Safety

Motivation

With all the final requirements outlined, a final concept has been developed. The design focuses on demonstrating a proof of concept, highlighting the added value during periods of non-driving.

Overview

The concept aims to support users during periods of autonomous driving while still being able to take control of the vehicle when necessary. It guarantees that all essential elements are within easy reach, whether for operating the car or engaging in digital or non-digital activities. The design considers aesthetics, ergonomics, and safety to provide a seamless and comfortable experience.

Features

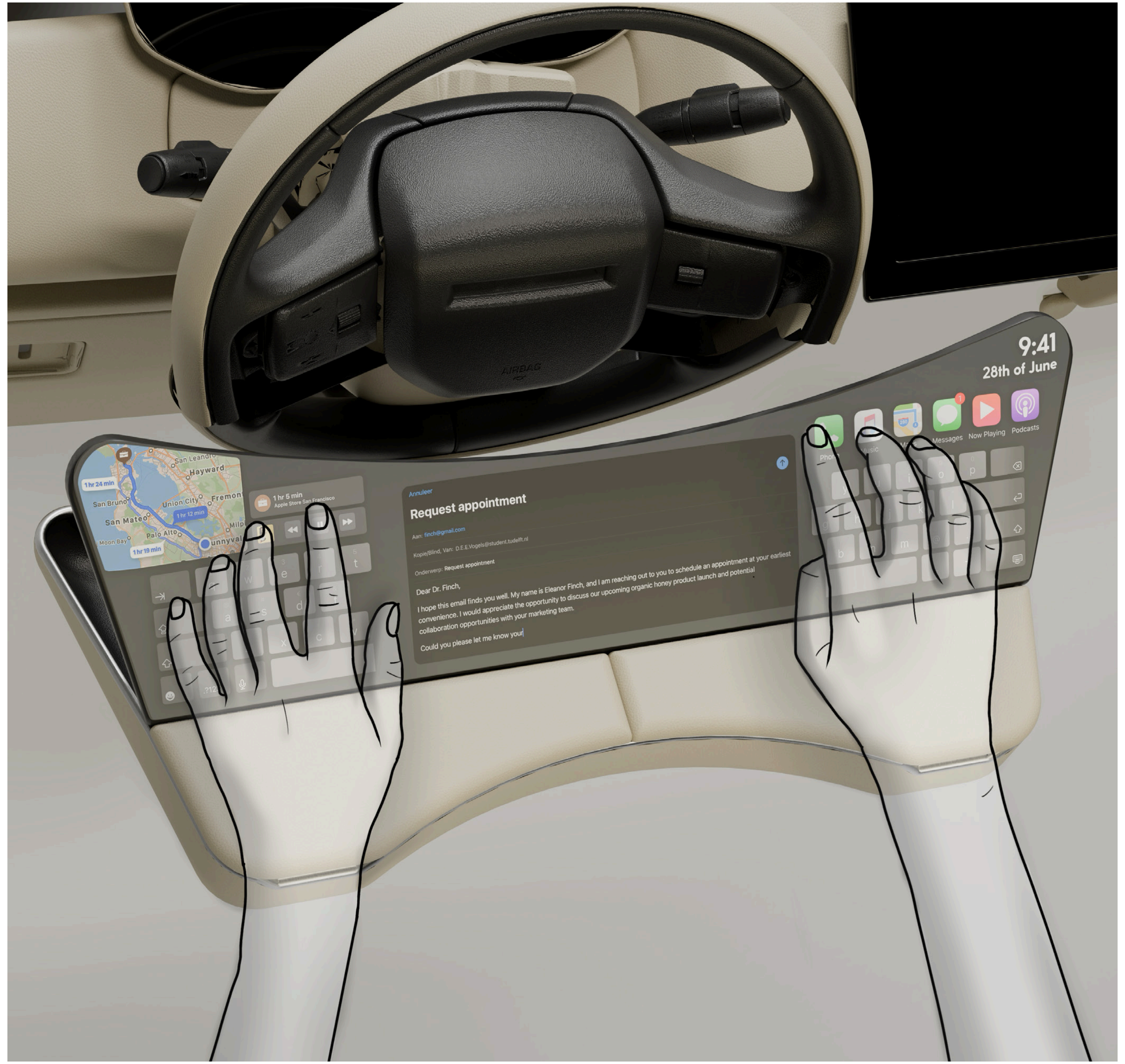
The concept is designed to support both digital and non-digital activities through a versatile, two-layer configuration. The top layer is optimized for digital activities, while the bottom layer focusses on non-digital needs.

The top layer features a touchscreen that easily connects to personal devices, allowing them to be stored out of immediate reach. For added comfort, wrist rests are provided at the front.

The bottom layer includes four compartments. Two of these compartments, located beneath the wrist rests, are easily accessible and ideal for storing taller items up to 7 cm in height. The other two compartments, designed for shorter and wider items, are situated beneath the touchscreen. These can be accessed by tilting the touchscreen to a horizontal position, ensuring the steering wheel remains easily operable.

An effort has been made to balance the amount of compartments. These compartments are not dedicated to specific items, allowing the concept to accommodate a variety of NDRAs without requiring modifications. On the other hand, it still ensures all items are securely stored with minimal risk of damage from contact within each compartment.

Together, these compartments provide up to



10 square centimeters of stowage space and have rounded edges for easy cleaning. They are intended for smaller items that typically cause clutter. Larger items are excluded for two main reasons.

Firstly, if larger compartments were included, it would encourage the stowage of bulkier items, potentially complicating handovers and making it difficult to store them fast enough. Additionally, some larger items, such as coffee cups, are inconvenient to store in this stowage solution as they need to be accessible during both driving and non-driving periods. Therefore, storing them in the center console or door compartments is more practical.

Secondly, many test participants recognized the value of keeping as many items in one area, making them open to transitioning from analog to digital alternatives in this context. This allows for the integration of items like notebooks and magazines into the touchscreen area, maintaining a clutter-free and organized space.

Productivity use case

On the right, an example illustrates how the concept can be utilized for various NDRAs simultaneously, with in this case a focus on productivity. This setup accommodates activities such as eating and drinking while working. During testing, it became apparent that users often prefer to have snacks and drinks nearby while engaging in productive tasks.

In this case, the front compartments hold items commonly used during periods of productivity, while the rear compartments include snacks and everyday essentials. This arrangement shows how users can perform multiple NDRAs, all in the same place.

Furthermore, the separation between compartments ensures that "dirty" activities, such as eating a snack, are kept apart from other items. This layout prevents crumbs and moisture from contaminating other compartments, thereby protecting other items.

A digital pencil can be included to enhance the use of the touchscreen for various purposes. It allows for quick sketches or quickly writing down notes without the need for typing. Wireless charging can be included to support these items, ensuring they are always ready for use.

Relaxation use case

In this example, the concept is demonstrated in a scenario where the user is unwinding during non-driving periods.

This example showcases the concepts flexibility by accommodating NDRAs beyond its initial scope. For instance, the right front compartment contains a makeup bag, which is ideal for well-being activities that complement periods of relaxation. Additionally, the other compartments include breakfast and a game, enabling the user to unwind, engage in entertainment, and enjoy a meal, all without needing to access items outside the concept.

Items that are not supported by this setup, such as a coffee mug or a water bottle, can be conveniently stored in the center console, ensuring they remain easily accessible during both driving and non-driving periods.

Entertainment activities beyond the game can be explored using the touchscreen on top, such as watching a movie, playing music, or listening to a podcast.

Deployment

The concept features a hidden aspect that reveals itself and its compartments only when needed. This approach aligns with the current Range Rover design, which also conceals elements when not in use, resulting in a clean and uncluttered look.

The stowage solution is stored under the bonnet and deployed from below the steering wheel when the car switches to autonomous mode. This only happens when the expected use time exceeds a few minutes. Before the stowage solution is deployed, the steering wheel moves slightly back to create space, facilitated by a steer-by-wire system that offers more freedom for the steering wheel's movement. However, this movement is kept to a minimum to ensure that muscle memory for grabbing the wheel remains intact, preventing potential dangerous situations.

Once deployed, users can easily adjust the position of the stowage solution and can save their preferred configuration for future use. Throughout the deployment, usage, and retraction phases, the top of the steering wheel remains within reach, ensuring the design complies with level 3 autonomous driving requirements.

Shape and Orientation

To ensure the new stowage solution aligns with JLR's design philosophy, the concept uses a combination of curved and straight lines, reflecting the design characteristics of the 2024 Range Rover SV. This design consistency helps maintain a cohesive look and feel within the vehicle's interior.

To avoid any discomfort to the user's legs, all bottom edges of the stowage solution are rounded. Moreover, the curved contours at the front and rear ensure that the concept does not invade the user's personal space, while also allowing for easy turning of the steering wheel. All edges that might contact the user are rounded to a minimum radius of 2.5 mm. This is the set amount within the automotive industry to ensure safety.

Preventing misuse is a critical aspect of the current approach. If items that are too tall are placed in the compartments, the concept may not close properly, posing potential safety hazards. To avoid this, the stowage solution is designed with a slight tilt and rounded bottom inside, causing excessively tall items to tip over and fall out. This orientation also ensures more ergonomic use. Additionally, the concept has side sensors that detect if any items exceed the designated boundaries. If this happens, the user receives an alert to adjust the item's placement.

Details

The material selection for the new stowage solution mirrors that of the current Range Rover models, using similar high-quality materials to maintain consistency. By blending warm, soft elements with textured, hard materials, it achieves the same textural experience. Additionally, the same cool metal accents are added for a modern, refined touch. This approach ensures the stowage solution is visually coherent with JLR's standards, thereby enhancing comfort and the overall sensory experience within the vehicle.

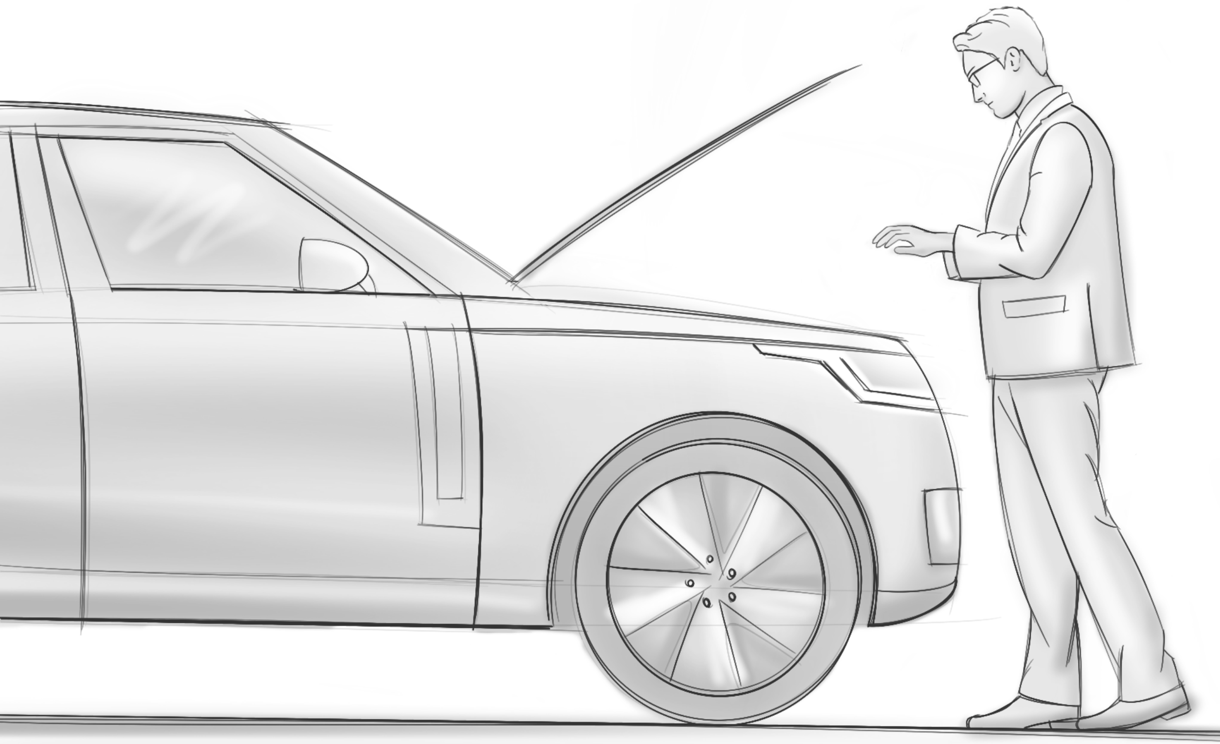
Careful attention has been given to ensure all design details are consistent. This is shown in the design of the handle used to lift the wrist rests. The shape and finish of this handle match a handle found in the current center console, creating a uniform appearance throughout the interior.

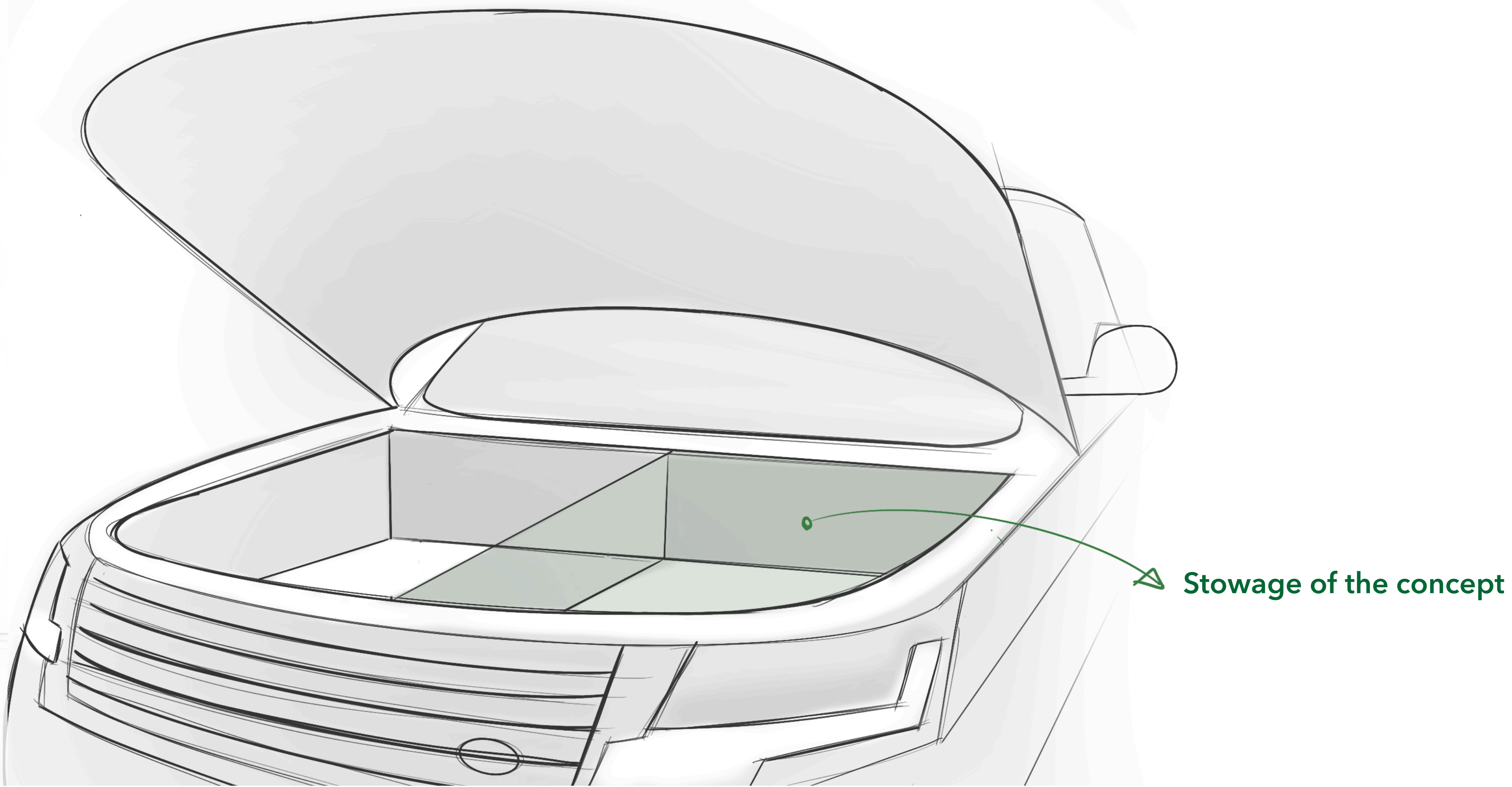
Getting in and out

The location chosen for the concept proposes an extra added value. The stowage solution is designed to facilitate easy access for placing items before driving and retrieving them before leaving.

Before entering the car, users can conveniently store smaller personal items in the frunk, with the option to pre-load specific items for non-driving periods within the concept.

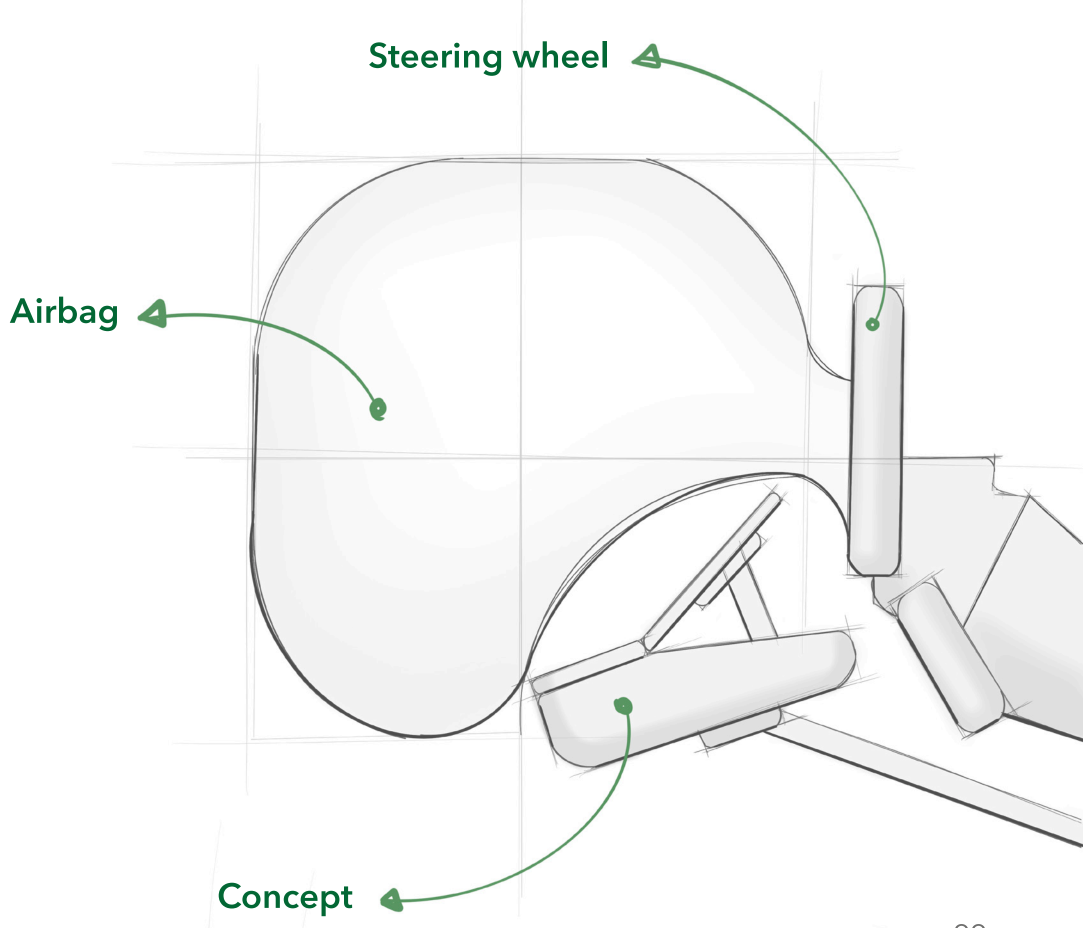
Upon exiting the vehicle, users receive alerts regarding any items left in the stowage solution. Accessible from under the hood, the stowage allows for quick retrieval, enabling a seamless grab-and-go experience.





Safety

To ensure safety, the airbag within the steering wheel will remain functional at all times. It is designed to deploy around the concept, preventing any items from coming into contact with the user, even when the concept is open. To accomodate this, the airbag has an adusted shape, allowing it to wrap around the concept securely.



CONCLUSION & DISCUSSION

8

Conclusion
Recommendations
Personal reflection

Motivation

This chapter focuses on the accomplishments and limitations of the current concept. Given the scope of this project, further steps are necessary to develop a fully functional product.

Conclusion

The project began with the following design brief:

"To create potential stowage solutions for the primary user, that enable a range of objects, which enable at least 3 clusters of non-driving related activities, in level 3 and 4 autonomous vehicles, during a handover situation from vehicle to driver."

Following the ideation phase, the decision was made to solely focus on level 3 autonomy. This decision was made to simplify the decision-making process during the convergence phase. Level 4 autonomy states that the vehicle is capable of performing all driving functions under certain conditions, where the driver may have the option to control the vehicle. In contrast, level 3 autonomy presents more challenges, as the driver is still required and must always be prepared to take control of the vehicle upon notification. For JLR, this notification period is set at 10 seconds, meaning that in level 3 autonomous mode, the system can only manage driving functions for 10 seconds before requiring the driver to take over.

However, during non-driving periods, the driver is not required to monitor the environment, allowing them to engage in various NDRAs. These activities can range from working or watching a movie to doing makeup. To narrow the project scope, three out of the seven identified clusters of NDRAs were selected. Research in chapter 3 revealed that participating in entertainment-related NDRAs is a significant area of interest. Additionally, it became clear that JLR users have a higher preference for productivity-related activities, making it the second focus area to tailor the design to JLR's specific user needs. Lastly, eating and drinking were chosen as the third cluster, despite initial low interest levels. This decision took into consideration the study's limitations and the potential for creating overall design value by focusing on this area. In conclusion, the primary NDRA clusters prioritized in the design are entertainment, productivity, and eating and drinking. However, any chance to incorporate additional clusters will be regarded as an added bonus for the concept and will definitely be considered.

The final design demonstrates the ability to support NDRAs beyond the initial scope due to its versatile compartment system. The compartments are not dedicated to specific items, allowing for the secure stowage of a variety of objects with minimal risk of damage from contact within each compartment.

The design ensures that the top of the steering wheel is always within reach. Testing revealed that all participants were able to grasp the wheel within 4 seconds with the concept deployed, which is well within JLR's 10-second takeover time. However, it is important to note that the timer stopped once the participant grabbed the wheel. Full control of the vehicle, which includes thoroughly observing the environment, having feet on the pedals, and being prepared to take complete control, may require additional time beyond merely grabbing the wheel.

In conclusion, the concept exceeded its initial scope by not only providing a stowage solution for quickly storing items but also by supporting the user during non-driving periods. It enables the user to participate in both digital and non-digital NDRAs, all in one convenient location in front. The concept addresses its limitations by providing stowage specifically for items used during non-driving periods, while using the mid console and door compartments for items that are needed during both driving and non-driving times. The concept demonstrates its versatility by accommodating a range of items used for NDRAs beyond the initial scope, while also enabling users to smoothly transition to driving control when needed. All items can be conveniently placed and retrieved before and after driving, facilitating a quick and efficient grab-and-go experience. Both the design philosophy and aesthetics are specifically tailored to JLR, establishing a strong proof of concept for future development.

Recommendations

Traditionally, stowage solutions in vehicles undergo only minor adjustments from one model year to the next, such as altering the orientation of cup holders or resizing door stowage compartments. Significant changes are rare. This project, driven by JLR's desire for a bold approach, seeks fresh perspectives that can inspire valuable discussions. Throughout the design process, decisions favored options that pushed boundaries rather than mainly sticking to existing limitations.

With a solid proof of concept now established, it is time to revisit those boundaries and carefully consider all limitations to develop not only a desirable and viable product but also a fully feasible one. While feasibility has not been entirely overlooked, the project's focus has been on generating a groundbreaking idea rather than a production-ready product. Given that regulations for autonomous mobility are still evolving, they will significantly impact the final concept. This innovative approach is not seen yet in the industry and involves more than simple modifications of existing designs, leading to a potentially lengthy development process.

Safety
The prototype test served as exploratory research and provided valuable insights for the initial design. However, the automotive industry's strict safety regulations require more comprehensive research. Future tests should be conducted in a realistic setting, involving a larger and more diverse group of participants, and using quantitative methods to gather data. Ensuring compliance with all safety standards is crucial.

Compartments
Currently, the design attempts to balance the number and size of compartments. Further research is needed to determine which specific items users will need to store, ensuring the design accommodates all necessary objects. This may lead to either fewer compartments that can hold larger items or more compartments for better organization and securing of smaller items.

Design for different markets
JLR has emphasized the necessity of creating different interiors tailored to various cultures and markets. In Asian markets, crowded living conditions often result in cars being used as an extension of living space (JLR, personal communication, 2024). As a result, the design may need to accommodate different items compared to those typically used during autonomous driving. Therefore, a comprehensive market analysis is essential, and the design must be adapted to meet the specific needs and preferences of each market.

Sizing
Initial testing provided a rough idea of comfortable sizing, but additional tests are needed to find the best balance between safety and comfort. The height of the concept affects how quickly users can reach the steering wheel, while the depth influences user comfort. These dimensions need to be fine-tuned to ensure the design is both safe and comfortable.

Comply with new models
The current concept is designed based on the 2024 Range Rover SV. To ensure it fits future models, a new detailed analysis will be necessary. This may involve changes in color and trim, design details, and surfaces to keep the concept compatible with new vehicle environments.

Stowage of the concept
Discussions with JLR have considered storing the concept under the bonnet and making it accessible from there. However, this will require significant adjustments to nearby components, such as the air-conditioning unit, which is still present even without a traditional combustion engine. These adjustments must be carefully planned to ensure the concept integrates smoothly.

Deployment
So far, the design focus has primarily been on the concept itself rather than its integration with the vehicle. The mechanical team at JLR needs to conduct analyses to calculate the strength and determine the best way to move, hold and secure the concept. This will ensure the deployment mechanism is robust and reliable.

Steering wheel
To provide sufficient space for the deployment of the concept, the design now includes a folding mechanism for the bottom of the steering wheel. Implementing this in future models will require a complete redesign of the steering wheel to incorporate the folding mechanism effectively. Currently, the existing steering wheel is cut in half to illustrate the concept, but this is not the most aesthetically pleasing or technically feasible solution.

By addressing these recommendations, the project can progress towards developing a stowage solution that is not only innovative but also practical and compliant with the automotive industry's requirements.

Personal reflection

I have been fascinated by cars for as long as I can remember. At the beginning of my master's program, my passion for the automotive industry waned slightly, and I began exploring other possibilities. Despite trying different projects, I always gravitated back to mobility-related ones. For my graduation project, I knew I wanted to return to the automotive field, and thus began my search for the perfect project.

I sought a project with a clearly defined scope, as my strength lies in deeply exploring specific topics rather than tackling broad, vague subjects. In my first meeting with Andy, it was evident that JLR was looking for a similar approach. They had concrete topics that needed exploration, but lacked the time to delve into them, and this project was one of those topics. Initially, I wasn't sure what to expect, but I felt it was easier to broaden a specific subject than to narrow down a vague one, so we proceeded.

My goals for this project included both technical and soft skills. I wanted to master certain visualization software and improve my project management skills. In both my bachelor's and master's programs, most projects were group work, so I was rarely pushed out of my comfort zone. In group settings, I usually served as the connector of various specialties, which meant I never became an expert in any specific area of design. While my drawing and 3D modeling skills were adequate, I had never mastered them.

For this project, I aimed to learn Procreate (a tablet drawing software) and Blender (a 3D rendering software). Previously, I used a Wacom tablet connected to my computer, so transitioning to drawing on an iPad was a new challenge. I made it a point to complete all drawings for this project in Procreate, and you can see the improvement in my work throughout the report. I left the midterm drawings (location ideation) in their original form to reflect the growth in my drawing skills and the evolution of the concept over time. I have always used underlays for my drawings, as I find it a quick way to convincingly put ideas on paper, especially when building upon existing products.

After creating the final 3D models in Solidworks, I decided to try rendering in Blender. With some initial help, we materialized all the individual parts and made some initial renders. Later, I created new renders on my own with different views and lighting. My next goal is to create 3D models directly in Blender to fully exploit the software's capabilities.

All in all, this graduation project has reminded me why I am always drawn to mobility projects. I have a strong affinity for this field and enjoy the complexity that comes with designing within a confined space. For now, I plan to take some time over the next few months to consider my next steps. I thoroughly enjoyed the last few months, and people around me have noticed how relaxed I have been, especially considering this was a graduation project. As we say in Dutch, "die kan je in je broekzak steken!" (loosely translated: "that's one you can put in your pocket!").

APPENDIX
A - I

9

Appendix A - Clusters

Cluster	Related use cases
Entertainment	- Listening to music/podcasts/audiobooks - Watching movies/videos/TV shows - Reading books/newspapers/magazines - Playing games - Pursuing hobbies - Taking selfies
Communication	- (Video) Calling - Talking - Emailing - Chatting - Socializing
Productivity	- Working/Studying - Making to-do lists - Planning - Taking care of others - Shopping
Observing / Monitoring	- Monitoring the driving - Observing surroundings - Enjoying scenery - Using onboard navigation systems - Looking out of windows
Eating and Drinking	- Eating - Drinking - Preparing food/drinks
Relaxation	- Sleeping - Closing eyes - Resting - Meditating - Smoking
Wellbeing	- Personal hygiene - Exercising - Using cosmetics - Changing clothes

Appendix B - NDRA calculation Level 3 autonomy (1/2)

Year	Participants	Source	Listed in paper	Corresponding use case	Survey	Percentage	Combined	Percentage
2016	n=1500 (500 German, 500 US, 500 Japanese)	Dungs, J., Stegmüller, S., Duwe, D., & Hermann, F. (2016). The value of time - potential for user-centered services offered by autonomous driving. ResearchGate. https://www.researchgate.net/publication/344769668_The_Value_of_Time_-_Potential_for_user-centered_services_offered_by_autonomous_driving	Online information search	Productivity	900	60%	4920	35%
			Shopping for daily requirements		840	56%		
			Organization		735	49%		
			Work		720	48%		
			Product information		660	44%		
			Training		540	36%		
			Consultations		525	35%		
			Wellness	Wellbeing	705	47%	3330	23%
			Beauty		615	41%		
			Health		585	39%		
			Fitness		510	34%		
			Changing clothes		495	33%		
			Washing / cleaning		420	28%		
			Private communication	Communication	1110	74%	1695	12%
			Social networks / interest groups		585	39%		
			Passive entertainment	Entertainment	870	58%	1635	12%
			Games		435	29%		
			Artistic activities		330	22%		
			Surrounding / route information	Observing / Monitoring	960	64%	960	7%
			Eating/drinking	Eating and Drinking	960	64%	960	7%
			Sleep	Relaxation	690	46%	690	5%
2015	n=4886 (40 different countries)	Kyriakidis, M., Happee, R., & De Winter, J. (2015). Public opinion on automated driving: results of an international questionnaire among 5000 respondents. Transportation Research Part F: Traffic Psychology and Behaviour, 32, 127–140. https://doi.org/10.1016/j.trf.2015.04.014	Listen to music/radio	Entertainment	2663	55%	4954	36%
			Reading a book, newspaper, magazine		1163	24%		
			Watching movies		1129	23%		
			Using mobile phone for texting and making phone calls	Communication	1925	39%	4075	30%
			Interaction with other passengers		2150	44%		
			Observing the scenery	Observing / Monitoring	2077	43%	2077	15%
			Checking emails/surfing on the internet	Productivity	1866	38%	1866	14%
			Rest/sleep	Relaxation	782	16%	782	6%
			Doing nothing at all		645	13%		
2022	n=400 (U.S.)	Teodorovicz, T., Kun, A. L., Sadun, R., & Shaer, O. (2022). Multitasking While Driving: A time use study of commuting knowledge workers to assess current and future uses. International Journal of Human-Computer Studies, 162, 102789. https://doi.org/10.1016/j.ijhcs.2022.102789	Reading emails	Communication	72	18%	238	29%
			Replying emails		38	10%		
			Phone call (with one person)		30	8%		
			Conference call (with two people or more)		19	5%		
			Video-conference		15	4%		
			In-person meeting		11	3%		
			Reading/replying email		15	4%		
			Phone call		39	10%		
			Reading	Productivity	36	9%	233	29%
			Thinking / reflecting		28	7%		
			Planning		28	7%		
			Making a to-do list		26	7%		
			Analyzing		26	6%		
			Listening to podcast/audio book/lecture		23	6%		
			Preparing		22	5%		
			Programming		16	4%		
			Writing/editing		13	3%		
			Making a to-do list		17	4%		
			Listening to music/radio	Entertainment	135	34%	196	24%
			Listening to podcast/audio book		37	9%		
			Watching videos/tv		12	3%		
			Reading		12	3%		
			Thinking / reflecting	Relaxation	67	17%	98	12%
			Praying/mediating/worshipping		16	4%		
			Relaxing/resting/sleeping		15	4%		
			Browsing/social media/messaging	Entertainment / Productivity / Communication	23	6%	42	5%
			Browsing/social media/messaging		20	5%		
			Exercising	Wellbeing	6	2%	6	1%
			No secondary activity		52	13%		
			Other activity		6	2%		
			Other activity		2	1%		
2022	n=214 (China)	Li, Q., Wang, Z., Wang, W., & Yuan, Q. (2022). Understanding driver preferences for secondary tasks in highly autonomous vehicles. In Lecture notes in electrical engineering (pp. 126–133). https://doi.org/10.1007/978-981-19-4786-5_18	Talking to passengers	Communication	139	65%	347	32%
			Making a call		107	50%		
			Typing and chatting on a smartphone		64	30%		
			Attending an online meeting		36	17%		
			Listening to music	Entertainment	143	67%	304	28%
			Watching videos on a smartphone		60	28%		
			Watching videos with onboard devices		45	21%		
			Reading		30	14%		
			Playing video games on a smartphone		26	12%		
			Enjoying the scenery outside windows	Observing / Monitoring	124	58%	186	17%
			Using onboard navigation system		62	29%		
			Drinking water or eating	Eating and Drinking	113	53%	113	10%
			Using a computer for entertainment or work	Entertainment / Productivity / Communication	39	18%	64	6%
			Using Ipad for entertainment or work		26	12%		
			Smoking	Relaxation	32	15%	49	5%
			Sleeping		17	8%		
			Making up	Wellbeing	21	10%	21	2%

2020	n=3771 (8 EU countries)	Nordhoff, S., Louw, T., Innamaa, S., Lehtonen, E., Beuster, A., Torrão, G., Bjorvatn, A., Kessel, T., Malin, F., Happee, R., & Merat, N. (2020). Using the UTAUT2 model to explain public acceptance of conditionally automated (L3) cars: a questionnaire study among 9,118 car drivers from eight European countries. Transportation Research Part F: Traffic Psychology and Behaviour, 74, 280–297	Talking to my fellow travelers	Communication	1688	45%	2682	26%
			Socialising with friends or family (online)		994	26%		
			Surfing on the internet, watching videos or TV shows	Entertainment	1659	44%	2594	25%
			Reading a book		554	15%		
			Playing games (video or board)		381	10%		
			Observing the landscape	Observing / Monitoring	1573	42%	1573	15%
			Relaxing and resting	Relaxation	1298	34%	1298	12%
			Taking care of children	Productivity	504	13%	1148	11%
			Working		643	17%		
			Eating and drinking	Eating and Drinking	1090	29%	1090	10%
2021	n=147 (BASt institute)	Metz, B., Wörle, J., Zerbe, A., & Tivesten, E. (2021). L3Pilot Deliverable 7.2: L3-L4 Long-term Study about user experiences. ResearchGate. https://www.researchgate.net/publication/355734570_L3Pilot_Deliverable_72_L3-L4_long-term_study_about_user_experiences	Drinking	Eating and Drinking	107	73%	201	26%
			Eating		94	64%		
			Texting	Communication	101	69%	197	26%
			Phone call		96	65%		
			Watching environment	Observing / Monitoring	126	86%	126	16%
			Watching a movie	Entertainment	48	33%	96	12%
			Gaming on smartphone/tablet		48	32%		
			App usage	Entertainment / Productivity / Communication	91	62%	91	12%
			Office work	Productivity	60	41%	60	8%
2021	n=44 (China)	Sun, X., Cao, S., & Tang, P. (2021). Shaping driver-vehicle interaction in autonomous vehicles: How the new in-vehicle systems match the human needs. Applied Ergonomics, 90, 103238. https://doi.org/10.1016/j.apergo.2020.103238	Listen to music	Entertainment	22	50%	66	32%
			Watch films / videos		15	34%		
			Listen to / read news		5	11%		
			Read a book		3	7%		
			Take selfie		1	2%		
			Play with mobile phone		8	18%		
			Play video game		7	16%		
			Play board game		5	11%		
			Monitor the driving	Observing / Monitoring	24	55%	34	17%
			Look out		10	23%		
			Make phone calls / video calls	Communication	15	34%	25	12%
			Talk to each other		6	14%		
			Communicate with other vehicles		4	9%		
			Online shopping	Productivity	8	18%	25	12%
			Work / study		16	36%		
			Trade stocks		1	2%		
			Eat, drink	Eating and Drinking	18	41%	24	12%
			Prepare food or drink		6	14%		
			Sleep / rest	Relaxation	19	43%	19	9%
			Personal hygiene	Wellbeing	4	9%	12	6%
			Make up		2	5%		
			Change clothes		1	2%		
			Simple sports		5	11%		
2020	n=16 (China)	Tang, P., Sun, X., & Cao, S. (2020). Investigating user activities and the corresponding requirements for information and functions in autonomous vehicles of the future. International Journal of Industrial Ergonomics, 80, 103044. https://doi.org/10.1016/j.ergon.2020.103044	Listen to music	Entertainment	12	74%	36	35%
			Watch film / video		8	50%		
			Listen to / read news		3	20%		
			Read a book		1	6%		
			Take selfies		1	5%		
			Play on a mobile phone		6	38%		
			Play video games		4	25%		
			Play board game		1	5%		
			Monitor the driving	Observing / Monitoring	14	88%	18	18%
			Look outside the vehicle		4	25%		
			Make audio / video calls	Communication	11	69%	13	13%
			Communicate with other vehicles		2	13%		
			Eat / drink	Eating and Drinking	9	58%	11	11%
			Preparing food or dink		2	12%		
			Online shopping	Productivity	2	12%	10	10%
			Work / study		7	44%		
			Trade stocks		1	5%		
			Sleep / rest	Relaxation	8	50%	8	8%
			Simple sports	Wellbeing	3	20%	6	6%
			Personal hygiene		1	5%		
			Make up		1	5%		
			Change clothes		1	5%		
2020	n=14 (China)	Tang, P., Sun, X., & Cao, S. (2020). Investigating user activities and the corresponding requirements for information and functions in autonomous vehicles of the future. International Journal of Industrial Ergonomics, 80, 103044. https://doi.org/10.1016/j.ergon.2020.103044	Listen to music	Entertainment	10	71%	32	31%
			Watch film / video		7	50%		
			Listen to / read news		2	15%		
			Read a book		2	15%		
			Play video games		5	36%		
			Play board game		4	29%		
			Play on a mobile phone		2	14%		
			Monitor the driving	Observing / Monitoring	10	71%	16	15%
			Look outside the vehicle		6	42%		
			Online shopping	Productivity	6	43%	15	14%
			Work / study		9	65%		
			Eat / drink	Eating and Drinking	9	64%	13	13%
			Preparing food or dink		4	30%		
			Talk to each other	Communication	6	42%	12	11%
			Make audio / video calls		4	29%		
			Communicate with other vehicles		2	15%		
			Sleep / rest	Relaxation	11	79%	11	11%
			Personal hygiene	Wellbeing	3	21%	6	6%
			Make up		1	6%		
			Simple sports		2	15%		

Appendix B - NDRA calculation Level 3 autonomy (2/2)

2021	n=39 (Germany)	Shi, E., & Frey, A. (2021). Non-driving-related tasks during Level 3 automated driving phases–measuring what users will be likely to do. Technology, mind, and behavior, 2(2). https://doi.org/10.1037/tmb0000006	Making phone calls	Communication	4	10%	9	35%
			Reading and writing messages		3	8%		
			Making conversation		2	5%		
			Reading	Entertainment	6	16%	6	23%
			Using smartphone	Entertainment / Productivity / Communication	3	9%	3	13%
			Taking a look at the environment	Observing / Monitoring	3	7%	3	11%
			Drinking	Eating and Drinking	2	6%	2	9%
			Sleeping	Relaxation	1	3%	2	8%
			Relaxing		1	2%		
2019	n=24 (Korea)	Li, S., Blythe, P., Guo, W., & Namdeo, A. (2019). Investigation of older drivers' requirements of the human-machine interaction in highly automated vehicles. Transportation Research Part F: Traffic Psychology and Behaviour, 62, 546–563. https://doi.org/10.1016/j.trf.2019.02.009	Reading	Entertainment	16	67%	28	36%
			Listening to radio		8	33%		
			Watching TV and films		2	8%		
			Doing crosswords		2	8%		
			Monitor the driving	Observing / Monitoring	12	50%	19	24%
			Looking at scenery		7	29%		
			Relaxing not demanding tasks	Relaxation	10	42%	13	17%
			Thinking		2	8%		
			Meditation and breathing		1	4%		
			Eat and drink	Eating and Drinking	8	33%	8	10%
			Talking to others	Communication	4	17%	4	5%
			Using mobile phone	Entertainment / Productivity / Communication	3	13%	3	4%
			Work	Productivity	2	8%	2	3%
			Doing exercise	Wellbeing	1	4%	1	1%

Year	Participants	Source	Listed in paper	Corresponding use case	Observation	Percentage	Combined	Percentage
2019	n=20 (Germany)	Hecht, T., Feldhütter, A., Draeger, K., & Bengler, K. (2019). What do you do? An analysis of non-driving related activities during a 60 minutes conditionally automated highway drive. In Advances in intelligent systems and computing (pp. 28–34). https://doi.org/10.1007/978-3-030-25629-6_5	Reading	Entertainment	12	60%	40	44%
			Videos (tablet)		9	45%		
			Audio books		7	35%		
			Music (tablet)		7	35%		
			Music (phone)		2	10%		
			Games (tablet)		3	15%		
			Phone usage	Entertainment / Productivity / Communication	15	75%	28	31%
			Laptop usage		3	15%		
			Tablet browsing		10	50%		
			Surroundings	Observing / Monitoring	20	100%	20	22%
			Sleeping	Relaxation	1	5%	1	1%
			Phone calls	Communication	1	5%	1	1%
			Others		20	100%		
2021	n=58 (7 European countries)	Weber, H., Hiller, J., Metz, B., & Eckstein, L. (2021). L3Pilot Deliverable 7.3: Pilot Evaluation results. ResearchGate. https://www.researchgate.net/publication/355734411_L3Pilot_Deliverable_73_Pilot_Evaluation_Results	Texting	Communication	23	40%	78	40%
			Calling		21	37%		
			Interacting with a passenger		33	57%		
			Social media	Entertainment	8	14%	58	30%
			Music, radio, audiobooks		37	64%		
			Watching movies		13	22%		
			Browsing the internet	Productivity	26	45%	36	19%
			Office/work tasks		10	17%		
			Eating or drinking	Eating and Drinking	15	26%	15	8%
			Sleep	Relaxation	7	12%	7	4%
2021	n=236 (7 European countries)	Weber, H., Hiller, J., Metz, B., & Eckstein, L. (2021). L3Pilot Deliverable 7.3: Pilot Evaluation results. ResearchGate. https://www.researchgate.net/publication/355734411_L3Pilot_Deliverable_73_Pilot_Evaluation_Results	Interacting with a passenger	Communication	229	97%	552	39%
			Calling		163	69%		
			Texting		160	68%		
			Social media	Entertainment	123	52%	427	31%
			Music, radio, audiobooks		222	94%		
			Watching movies		83	35%		
			Browsing the internet	Productivity	158	67%	264	19%
			Office/work tasks		106	45%		
			Eating or drinking	Eating and Drinking	123	52%	123	9%
			Sleep	Relaxation	33	14%	33	2%
2021	n=60 (7 European countries)	Weber, H., Hiller, J., Metz, B., & Eckstein, L. (2021). L3Pilot Deliverable 7.3: Pilot Evaluation results. ResearchGate. https://www.researchgate.net/publication/355734411_L3Pilot_Deliverable_73_Pilot_Evaluation_Results	Interacting with a passenger	Communication	55	92%	132	39%
			Texting		47	78%		
			Calling		30	50%		
			Social media	Entertainment	30	50%	97	29%
			Music, radio, audiobooks		56	93%		
			Watching movies		11	18%		
			Browsing the internet	Productivity	43	72%	64	19%
			Office/work tasks		20	34%		
			Eating or drinking	Eating and Drinking	36	60%	36	11%
			Sleep	Relaxation	9	15%	9	3%
2021	n=175 (7 European countries)	Weber, H., Hiller, J., Metz, B., & Eckstein, L. (2021). L3Pilot Deliverable 7.3: Pilot Evaluation results. ResearchGate. https://www.researchgate.net/publication/355734411_L3Pilot_Deliverable_73_Pilot_Evaluation_Results	Interacting with a passenger	Communication	152	87%	334	38%
			Calling		114	65%		
			Texting		68	39%		
			Social media	Entertainment	75	43%	280	32%
			Music, radio, audiobooks		159	91%		
			Watching movies		46	26%		
			Browsing the internet	Productivity	79	45%	140	16%
			Office/work tasks		61	35%		
			Eating or drinking	Eating and Drinking	107	61%	107	12%
			Sleep	Relaxation	25	14%	25	3%

2021	n=44 (China)	Sun, X., Cao, S., & Tang, P. (2021). Shaping driver-vehicle interaction in autonomous vehicles: How the new in-vehicle systems match the human needs. Applied Ergonomics, 90, 103238.	Resting	Relaxation	24	54%	24	58%
			Playing on a mobile phone	Entertainment / Productivity / Communication	11	25%	11	27%
			Talking	Communication	5	11%	5	12%
			Look around	Observing / Monitoring	1	3%	1	3%
			Drinking/eating, writing, etc.		3	7%		
2021	n=39 (Germany)	Shi, E., & Frey, A. (2021). Non-driving-related tasks during Level 3 automated driving phases–measuring what users will be likely to do. Technology, mind, and behavior, 2(2). https://doi.org/10.1037/tmb0000006	Smartphone	Entertainment / Productivity / Communication	8	45%	8	45%
			Magazines	Entertainment	4	24%	7	41%
			Book		2	9%		
			Knitting needles		1	6%		
			Ebook		1	3%		
			Writing using a pen	Productivity	1	8%	1	8%
			Steady gaze to the outside	Observing / Monitoring	1	6%	1	6%

Clusters	Survey (n=11)	Mentioned	Weighted average	Observation (n=7)	Mentioned	Weighted average
Entertainment	27%	11	27%	34%	6	30%
Communication	21%	11	21%	28%	6	24%
Productivity	15%	9	12%	16%	5	11%
Observing / Monitoring	16%	10	14%	10%	3	4%
Eating and Drinking	12%	9	10%	10%	4	6%
Relaxation	9%	10	8%	12%	6	10%
Wellbeing	6%	7	4%	0%	0	0%
Entertainment / Productivity / Communication	8%	5	4%	34%	3	15%

Appendix C - NDRA calculation Level 4 autonomy

Year	Participants	Source	Listed in paper	Corresponding use case	Survey	Percentage	Combined	Percentage
2016	n=347 (U.S.)	Bansal, P., Kockelman, K. M., & Singh, A. K. (2016). Assessing public opinions of and interest in new vehicle technologies: An Austin perspective. Transportation Research	Look out the windows of the vehicle	Observing / Monitoring	267	77%	267	25%
			Text or Talk	Communication	257	74%	257	24%
			Work	Productivity	187	54%	187	18%
			Sleep	Relaxation	180	52%	180	17%
			Watching movies or play games	Entertainment	160	46%	160	15%
2022	n=566 (U.K., U.S., Canada, Australia)	Wilson, C., Gyi, D. E., Morris, A., Bateman, R. P., & Tanaka, H. (2022). Non-Driving related tasks and journey types for future autonomous vehicle owners. Transportation Research Part F: Traffic Psychology and Behaviour,	Be productive	Productivity	357	63%	594	24%
			Work with a colleague		238	42%		
			Leisure activity	Entertainment	498	88%	498	20%
			Rest and sleep	Relaxation	419	74%	419	17%
			Socialise	Communication	396	70%	396	16%
			Ramain in the driving position	Observing / Monitoring	294	52%	294	12%
			Morning routine	Wellbeing	260	46%	260	11%
2022	n=214 (China)	Li, Q., Wang, Z., Wang, W., & Yuan, Q. (2022). Understanding driver preferences for secondary tasks in highly autonomous vehicles. In Lecture notes in electrical engineering (pp. 126–133). https://doi.org/10.1007/978-981-19-4786-5_18	Listening to music	Entertainment	167	78%	439	31%
			Watching videos on a smartphone		96	45%		
			Watching videos with onboard devices		71	33%		
			Reading		51	24%		
			Playing video games on a smartphone		54	25%		
			Talking to passengers	Communication	137	64%	422	30%
			Making a call		124	58%		
			Typing and chatting on a smartphone		109	51%		
			Attending an online meeting		51	24%		
			Enjoying the scenery outside windows	Observing / Monitoring	135	63%	218	15%
			Using onboard navigation system		83	39%		
			Drinking water or eating	Eating and Drinking	120	56%	120	8%
			Using a computer for entertainment or work	Entertainment / Productivity / Communication	58	27%	109	8%
			Using Ipad for entertainment or work		51	24%		
			Smoking	Relaxation	39	18%	71	5%
			Sleeping		32	15%		
			Making up	Wellbeing	43	20%	43	3%

Year	Participants	Source	Listed in paper	Corresponding use case	Observation	Percentage	Combined	Percentage
2021	n= 17 (trustful drivers, U.S.)	Manchon, J., Bueno, M., & Navarro, J. (2021, May 4). How the Initial Level of Trust in Automated Driving Impacts Drivers' Behaviour and Early Trust Construction. https://doi.org/10.31234/	Mobile use	Entertainment / Productivity / Communication	6	33%	9	57%
			Tablet use		3	20%		
			Reading	Relaxation	4	21%	4	23%
			Environment monitoring	Observing / Monitoring	2	11%	2	12%
			Radio use	Entertainment	1	8%	1	8%
			Other					
2021	n=19 (distrusful drivers, U.S.)	Manchon, J., Bueno, M., & Navarro, J. (2021, May 4). How the Initial Level of Trust in Automated Driving Impacts Drivers' Behaviour and Early Trust Construction. https://doi.org/10.31234/	Mobile use	Entertainment / Productivity / Communication	6	34%	9	55%
			Tablet use		3	14%		
			Environment monitoring	Observing / Monitoring	6	33%	6	37%
			Reading	Relaxation	1	7%	1	8%
			Radio use	Entertainment	0	0%		
			Other					
2020	n=12 (Germany)	Henrik Detjen, Bastian Pfleging, and Stefan Schneegass. 2020. A Wizard of Oz Field Study to Understand Non-Driving-Related Activities, Trust, and Acceptance of Automated Vehicles. In 12th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '20). Association for Computing Machinery, New York, NY, USA, 19–29. https://doi.org/10.1145/3409120.3410662	Smartphone Typing/Texting	Entertainment / Productivity / Communication	5	38%	13	30%
			Smartphone Use/Internet/Social Media		8	67%		
			Watching out of the Window	Observing / Monitoring	11	96%	11	28%
			Office Tasks	Productivity	2	15%	8	21%
			Writing		7	56%		
			Listen to Music/Radio/Audiobooks	Entertainment	1	6%	4	10%
			Reading a Book		2	13%		
			Take Pictures		2	15%		
			Talk to passengers	Communication	1	4%	2	4%
			Calling		1	8%		
			Interact with Passengers		0	0%		
			Eating and Drinking	Eating and Drinking	2	19%	2	5%
			Cosmetics	Wellbeing	1	4%	1	1%
			Sleeping	Relaxation	0	2%	0	1%

Clusters	Survey (n=3)	Mentioned	Weighted average	Observation (n=3)	Mentioned	Weighted average
Entertainment	22%	3	22%	9%	3	9%
Communication	23%	3	23%	4%	1	1%
Productivity	21%	2	14%	21%	1	7%
Observing / Monitoring	18%	3	18%	26%	3	26%
Eating and Drinking	8%	1	3%	5%	1	2%
Relaxation	13%	3	13%	11%	3	11%
Wellbeing	7%	2	5%	1%	1	0%
Entertainment / Productivity / Communication	8%	1	3%	47%	3	47%

Appendix D - Calculation Public transport

Year	Participants	Source	Listed in paper	Corresponding use case	Survey	Percentage	Combined	Percentage
Bus, United Kingdom, 2016	n=840	Clayton, W., Jain, J., & Parkhurst, G. (2016). An ideal journey: making bus travel desirable. Mobilities, 12(5), 706–725. https://doi.org/10.1080/17450101.2016.1156424	Metro newspaper	Entertainment	296	35%	683	54%
			Personal music player / radio		280	33%		
			Reading book		65	8%		
			Other newspaper		15	2%		
			Magazine		12	1%		
			Electronic game		16	2%		
			Mobile phone	Entertainment / Productivity / Communication	443	53%	455	36%
			Laptop		4	1%		
			PDA		8	1%		
			Food / drink	Eating and Drinking	83	10%	83	7%
			Textbook	Productivity	31	4%	44	3%
			Paperwork		13	2%		
Train, United Kingdom, 2010	n=19715	Susilo, Y. O., Lyons, G., Jain, J., & Atkins, S. (2012). Rail Passengers' Time Use and Utility Assessment: 2010 Findings from Great Britain with Multivariate Analysis. Transportation Research Record, 2323(1), 99-109. https://doi.org/10.3141/2323-12	Newspaper	Entertainment	6329	32%	14924	51%
			Reading book		4140	21%		
			MP3 player / personal stereo		2563	13%		
			Magazine		1301	7%		
			Portable DVD player		59	0%		
			Games / puzzles		434	2%		
			Games console		99	1%		
			Mobile phone	Entertainment / Productivity / Communication	7373	37%	8438	29%
			Laptop computer		690	4%		
			eBook/iPad		256	1%		
			Netbook		118	1%		
			Food/drink	Eating and Drinking	3214	16%	3214	11%
			Paperwork	Productivity	2070	11%	2642	9%
			Text book		572	3%		
Train, China, 2018	n=885	Wang, B., & Loo, B. P. (2018). Travel time use and its impact on high-speed-railway passengers' travel satisfaction in the e-society. International Journal of Sustainable Transportation, 13(3), 197–209. https://doi.org/10.1080/15568318.2018.1459968	Listening to music	Entertainment	266	30%	731	37%
			E-reading (leisure)		236	27%		
			Watching videos		113	13%		
			Paper-reading (leisure)		38	4%		
			E-games		77	9%		
			E-communication (personal)	Communication	317	36%	665	34%
			E-communication (work)		275	31%		
			Talking (f2f)		73	8%		
			Sleeping / Staring	Relaxation	273	31%	273	14%
			E-shopping	Productivity	42	5%	240	12%
			E-working		152	17%		
			Paper-working		46	5%		
			Eating / drinking	Eating and Drinking	58	7%	58	3%
Metro/Tram/Bus, Belgium, 2019	n=1214	Keserü, I., Heyndels, E., Ton, T., & Macharis, C. (2020). Multitasking on the Go: An observation study on local public transport in Brussels. Travel Behaviour and Society, 18, 106–116. https://doi.org/10.1016/j.tbs.2019.10.003	Talking on the phone	Communication	84	6.9%	709	48%
			Talking with other passengers		463	38.1%		
			Messaging		163	13.4%		
			Doing nothing and/or gazing ou	Observering / Monitoring	348	28.7%	348	24%
			Social media	Entertainment	35	2.9%	204	14%
			Playing games on ICT devices		8	0.7%		
			Listening to music or radio		132	10.9%		
			Reading books		19	1.6%		
			Reading newspapers		8	0.7%		
			Browsing on tablet	Entertainment / Productivity / Communication	6	0.5%	95	6%
			Browsing on phone		89	7.3%		
			Children, family or personal ca	Wellbeing	70	5.8%	70	5%
			Eating and/or drinking	Eating and Drinking	42	3.5%	42	3%
			Study	Productivity	6	0.5%	8	1%
			Working		2	0.2%		
			Sleeping or taking a nap	Relaxation	2	0.2%	2	0%

Year	Participants	Source	Listed in paper	Corresponding use case	Observation	Percentage	Combined	Percentage
Bus, New Zealand, 2011	n=353	Russell, M., Price, R. M., Signal, L., Stanley, J., Gerring, Z., & Cumming, J. (2011). What do passengers do during travel time? Structured observations on buses and trains. Journal of public transportation, 14(3), 123–146. https://doi.org/10.5038/2375-0901.14.3.7	Looking ahead/out window	Observing / Monitoring	270	76%	270	53%
			Headphones in	Entertainment	60	17%	119	24%
			Reading		44	12%		
			Sleeping/eyes closed		15	4%		
			Talking	Communication	48	14%	77	15%
			Texting		29	8%		
			Handling wallet, etc.	Productivity	16	5%	20	4%
			Writing		4	1%		
			Eating/drinking	Eating and Drinking	13	4%	13	3%
			On phone	Entertainment / Productivity / Communication	6	2%	7	1%
			Using computer		1	0%		
			Other		15	4%		
Train, New Zealand, 2011	n=459	Russell, M., Price, R. M., Signal, L., Stanley, J., Gerring, Z., & Cumming, J. (2011). What do passengers do during travel time? Structured observations on buses and trains. Journal of public transportation, 14(3), 123–146. https://doi.org/10.5038/2375-0901.14.3.7	Looking ahead/out window	Observing / Monitoring	260	57%	260	33%
			Reading	Entertainment	132	29%	228	29%
			Headphones in		96	21%		
			Talking	Communication	77	17%	123	15%
			Texting		46	10%		
			Handling wallet, etc.	Productivity	42	9%	64	8%
			Writing		22	5%		
			Sleeping/eyes closed	Relaxation	57	12%	57	7%
			Using computer	Entertainment / Productivity / Communication	34	7%	40	5%
			On phone		6	1%		
			Eating/drinking	Eating and Drinking	25	5%	25	3%
			Other		28	6%		
Train, the Netherlands, 2019	n=786	Groenesteijn, L., Hiemstra-van Mastrigt, S., Gallais, C., Blok, M., Kuijt-Evers, L., Vink, P., 2014. Activities, postures and comfort perception of train passengers as input for train seat design. Ergonomics 57(8): 1154–1165. https://doi.org/10.1080/00140139.2014.914577	Listening music	Entertainment	31	4%	236	31%
			Reading from paper		204	26%		
			Staring or sleeping	Relaxation	197	25%	197	26%
			Working on laptop	Entertainment / Productivity / Communication	134	17%	189	25%
			Using PDA		55	7%		
			Talking	Communication	79	10%	86	11%
			Making phone call		8	1%		
			Eating / drinking	Eating and Drinking	31	4%	31	4%
			Writing	Productivity	16	2%	16	2%
			Other		24	3%		
Train, the Netherlands, 2009	n=358	Van Der Waerden, P., Timmermans, H., & Van Neerven, R. (2009). Extent, nature, and covariates of multitasking of rail passengers in an urban corridor. Transportation Research Record, 2110(1), 106–111. https://doi.org/10.3141/2110-13	Reading newspaper	Entertainment	125	35%	222	42%
			Listening to music		75	21%		
			Reading book		9	3%		
			Reading magazine		4	1%		
			Cracking a puzzle		9	3%		
			Talking, socially	Communication	172	48%	218	41%
			Text messaging		23	6%		
			Phoning, socially		18	5%		
			Talking, professionally		4	1%		
			Phoning, professionaly		1	0%		
			Sleeping / Snoozing	Relaxation	40	11%	44	8%
			Romancing		4	1%		
			Eating	Eating and Drinking	19	5%	26	5%
			Drinking		7	2%		
			Working on computer	Productivity	2	1%	17	3%
			Studying		10	3%		
			Working on paper		5	1%		
			Personal care	Wellbeing	1	0%	1	0%
			Doing nothing		248	69%		

Clusters	Observation (n=4)	Mentioned	Weighted average	Survey (n=4)	Mentioned	Weighted average
Entertainment	39%	4	39%	31%	4	31%
Communication	41%	2	20%	21%	4	21%
Productivity	6%	4	6%	4%	4	4%
Observing / Monitoring		0	0%	43%	2	21%
Eating and Drinking	6%	4	6%	4%	4	4%
Relaxation	7%	2	4%	14%	3	10%
Wellbeing	5%	1	1%	0%	1	0%
Entertainment / Productivity / Communication	24%	3	18%	10%	3	8%

Appendix E - Calculation Airplane

Country or area, Year	Participants	Source	Listed in paper	Corresponding use case	Survey	Percentage	Combined	Percentage
the Netherlands, 2018	n=149	Bouwens, J. (2018). Design Considerations for Airplane Passenger Comfort. [Dissertation (TU Delft), Delft University of Technology]. https://doi.org/10.4233/uuid:306dd9f8-fab9-4f1f-8c1a-1a208e815c21	Music	Entertainment	107	72%	305	60%
			Read		100	67%		
			Watch		64	43%		
			Game		34	23%		
			Sleep	Relaxation	113	76%	113	22%
			Food	Eating and Drinking	88	59%	88	17%
			Bored		94	63%		
			Walking		89	60%		
Brazil, 2012	n=287	Greghi, F., Rossi, N. F., Souza, G., & Menegon, L. (2012). Contributions from the activity analysis to the products development project: case study based on a project of innovation and comfort in aircraft's cabins. Work-a Journal of Prevention Assessment & Rehabilitation,	Eating	Eating and Drinking	261	91%	261	29%
			Resting and Sleeping	Relaxation	239	83%	239	27%
			Reading, Writing and Working	Entertainment / Productivity / Communication	231	81%	231	26%
			Entertainment Activity	Entertainment	161	56%	161	18%
			Going to the toilet					
the Netherlands, 2015	n=152	Alberda, W., Kampinga, O., Kassels, R., Van Kester, R., Noriega, J., & Vink, P. (2015). Access improvement to aircraft passengers' hand luggage. Work-a Journal of Prevention Assessment & Rehabilitation, 50(4), 659–667. https://doi.org/10.3233/wor-141829	Magazines	Entertainment	82	54%	231	33%
			Books		76	50%		
			Ipod/mp3		73	48%		
			Phone	Entertainment / Productivity / Communication	134	88%	208	30%
			Laptop/tablet		74	49%		
			Food	Eating and Drinking	58	38%	111	16%
			Drinks		53	35%		
			Personal hygiene	Wellbeing	76	50%	149	21%
			Clothes		73	48%		
			Wallet		143	94%		
			Keys		116	76%		
			Glasses		79	52%		
the Netherlands, 2017	n=10	Vink, P., Vledder, G., Smulders, M., Bronkhorst, R.E., & Hiemstra-van Mastrigt, S. (2017). KLM World businessclass seat study (confidential). Delft University of Technology/IPSOS.	Watching IFE	Entertainment	3	34%	4	43%
			Reading		1	7%		
			Watch / play entertainment on devi		0	2%		
			Sleeping	Relaxation	4	35%	4	35%
			Eating / Drinking	Eating and Drinking	1	9%	1	9%
			Working	Productivity	1	5%	1	6%
			Working on device		0	1%		
			Chatting with others	Communication	1	5%	1	5%
			Looking out of the window	Observing / Monitoring	0	2%	0	2%

Country or area, Year	Participants	Source	Listed in paper	Corresponding use case	Observation	Percentage	Combined	Percentage
China, 2019	n=18	Liu, J., Yu, S., & Chu, J. (2019). The passengers' comfort improvement by sitting activity and posture analysis in civil Aircraft cabin. Mathematical Problems in Engineering, 2019, 1–10. https://doi.org/10.1155/2019/3278215	Using small electrical devices	Entertainment / Productivity / Communication	6	33%	6	33%
			Sleeping and resting	Relaxation	6	34%	6	34%
			Reading	Entertainment	3	16%	5	26%
			Watching		2	9%		
			Eating/drinking	Eating and Drinking	1	5%	1	5%
			Talking	Communication	0	2%	0	2%

Clusters	Survey (n=4)	Mentioned	Weighted average	Observation (n=1)	Mentioned	Weighted average
Entertainment	39%	4	39%	26%	1	26%
Communication	5%	1	1%	2%	1	2%
Productivity	6%	1	2%		0	0%
Observing / Monitoring	2%	1	1%		0	0%
Eating and Drinking	18%	4	18%	5%	1	5%
Relaxation	28%	3	21%	34%	1	34%
Wellbeing	21%	1	5%		0	0%
Entertainment / Productivity / Communication	28%	2	14%	33%	1	33%

Appendix F - Consent form

Consent form

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION		
1. I have read and understood the study information dated 30-04-2024, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
3. I understand that taking part in the study involves: - Pictures being taken (faces will be blurred) - Questions being asked during the study - Being asked to use the concept - Speak my thoughts out loud	☐	☐
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)		
6. I understand that taking part in the study involves the following risks: physical discomfort. I understand that these will be mitigated by the possibility to stop the experiment at any point.	☐	☐
9. I understand that the following steps will be taken to minimise the threat of a data breach, and protect my identity in the event of such a breach by face blurring in pictures.	☐	☐
10. I understand that personal information collected about me that can identify me, such as my age, occupation, and nationality, will not be shared beyond the study team.	☐	☐
11. I understand that the (identifiable) personal data I provide will be destroyed after 31th of May.	☐	☐
C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		
12. I understand that after the research study the de-identified information I provide will be used for a thesis project, published on TU Delft repository.	☐	☐
13. I agree that my responses, views or other input can be quoted anonymously in research outputs	☐	☐
D: (LONGTERM) DATA STORAGE, ACCESS AND REUSE		
16. I give permission for the de-identified data that I provide to be archived in TU Drlft repository so it can be used for future research and learning.	☐	☐
17. I understand that access to this repository is open.	☐	☐

Signatures

____________________ ____________________ ________

Name of participant Signature Date

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

____________________ ____________________ ________

Researcher name Signature Date

Study contact details for further information:

Daantje Vogels

+31654955879

d.e.e.vogels@student.tudelft.nl

Appendix G - Test results

Sizing participant (in cm)					Steering wheel (without concept)									Concept								
Standing height	Hip height (standing)	Arm to arm (standing)	Sitting height	Hip width (sitting)	Noted height	Actual height (mm)	Height translated to depth (mm)	Noted length	Actual length (mm)	Angle from dashboard (degrees)	Angle from horizontal line (degrees)	Final height (mm)	Final depth (mm)	Noted height	Actual height (mm)	Height translated to depth (mm)	Noted length	Actual length (mm)	Angle from dashboard (degrees)	Angle from horizontal line (degrees)	Final height (mm)	Final depth (mm)
178	112	44	91	36	12	10.4	6	8	47	78	18	25	39	3	2.6	1.5	6	46	60	1	2	44
170	99	41	83	34	12	10.4	6	8	47	69	9	18	40	2	1.7	1	7	44	57	3	-1	43
183	116	42	94	41	11	9.5	5.5	4	55	70	10	19	49	3	2.6	1.5	8	42	57	3	0	40
175	115	47	83	40	12	10.4	6	10	43	71	11	19	36	3	2.6	1.5	10	40	57	3	1	38
179	111	45	92	38	16	13.9	8	7	49	67	7	20	41	4	3.5	2	10	40	58	2	2	38
176	109	42	92	41	14	12.1	7	8	47	68	8	19	40	4	3.5	2	9	42	58	2	2	40
175	107	46	83	35	13	11.3	6.5	10	43	68	8	17	36	4	3.5	2	9	42	60	0	3	40
163	117	42	87	42	13	11.3	6.5	6	51	65	5	16	44	4	3.5	2	10	40	51	9	-3	38
181	105	48	90	39	12	10.4	6	10	43	73	13	20	36	3	2.6	1.5	10	40	58	2	1	38
178	114	48	89	39	14	12.1	7	9	45	67	7	18	38	3	2.6	1.5	8	42	56	4	0	40
189	117	50	108	40	14	12.1	7	10	43	78	18	25	34	2	1.7	1	10	40	67	-7	7	39
182	114	51	91	39	13	11.3	6.5	9	45	72	12	21	38	3	2.6	1.5	9	42	60	0	3	41
160	95	42	86	36	12	10.4	6	8	47	69	9	18	40	4	3.5	2	7	44	57	3	1	42
178	110	47	92	35	11	9.5	5.5	8	47	70	10	18	41	2	1.7	1	8	42	57	3	0	41
169	115	43	81	41	14	12.1	7	7	49	78	18	27	40	3	2.6	1.5	8	42	57	3	0	40
												20	39								1	40

Steering wheel with concept										Response test		
Did the participant move the steering wheel?	Noted height	Actual height (mm)	Height translated to depth (mm)	Noted length	Actual length (mm)	Angle from dashboard (degrees)	Angle from horizontal line (degrees)	Final height (mm)	Final depth (mm)	Did the participant grab the wheel?	If yes: how long did it take?	Response time in sec
No								25	39	Yes	31.45	1.45
Yes	12	10.4	6	10	41	70	10	17	34	Yes	31.09	1.09
Yes	13	11.3	6.5	10	41	76	16	23	33	Yes	32.36	2.36
Yes	11	9.5	5.5	11	43	72	12	18	37	Yes	30.59	0.59
Yes	13	11.3	6.5	10	41	70	10	18	34	Yes	31.05	1.05
Yes	13	11.3	6.5	10	41	77	17	23	33	Yes	30.97	0.97
No								17	36	Yes	31.7	1.7
Yes	14	12.1	7	10	41	75	15	23	33	Yes	32.41	2.41
No								20	36	Yes	30.75	0.75
Yes	14	12.1	7	9	39	69	9	18	32	Yes	32.78	2.78
Yes	11	9.5	5.5	11	43	90	30	31	32	Yes	33.87	3.87
Yes	14	12.1	7	11	43	73	13	22	35	Yes	31.56	1.56
No								18	40	Yes	32.94	2.94
Yes	13	11.3	6.5	9	39	75	15	21	31	Yes	30.36	0.36
Yes	14	12.1	7	10	41	71	11	20	33	Yes	32.92	2.92
								21	34			1.79

Appendix H - Item results

What items do you use when you wind down at home?	Amount of participants	Percentage	Comments
Phone	12	80%	
Laptop / television	9	60%	
Games	7	47%	Mainly with others
Book	6	40%	83% wouldn't mind to do this in a digital manner in a car
Something to drink	6	40%	
Snacks	3	20%	
Tablet	3	20%	
Charger	2	13%	
Magazine / newspaper	2	13%	
Hobby items (crochet, draw	2	13%	
Headphones	2	13%	
Glasses	1	7%	

What items do you use during work?	Amount of participants	Percentage	Comments
Laptop	15	100%	
Notebook + pen	11	73%	
Something to drink	8	53%	
Tablet	6	40%	
Headphones	6	40%	
Phone	4	27%	
Charger	3	20%	
Drawing tools	2	13%	Industrial design background

What food and drinks do you bring on a long trip? (as a passenger)	Amount of participants	Percentage	Comments
Cold drinks	12	80%	
Gum / mints / sweets	10	67%	
Hot drinks	8	53%	
Sandwiches	7	47%	27% doesn't mind crumbs and mess, 73% does
Small snacks	6	40%	
Drive-in food	4	27%	

Appendix I - Project brief (1/2)

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DESIGN FOR our future

IDE Master Graduation Project

Project team, procedural checks and Personal Project Brief

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

- Student defines the team, what the student is going to do/deliver and how that will come about
- Chair of the supervisory team signs, to formally approve the project's setup / Project brief
- SSC E&SA (Shared Service Centre, Education & Student Affairs) report on the student's registration and study progress
- IDE's Board of Examiners confirms the proposed supervisory team on their eligibility, and whether the student is allowed to start the Graduation Project

STUDENT DATA & MASTER PROGRAMME
Complete all fields and indicate which master(s) you are in

Family name: Vogels
Initials:
Given name: Daantje
Student number:

IDE master(s): IPD ☐ DfI ☐ SPD ☐
2nd non-IDE master:
Individual programme (date of approval):
Medisign ☐
HPM ☐

SUPERVISORY TEAM
Fill in he required information of supervisory team members. If applicable, company mentor is added as 2nd mentor

Chair: N. van Nes — dept./section: AED
mentor: E. van Grondelle — dept./section: DA
2nd mentor: A. Cuming
client: Jaguar Land Rover
city: Coventry — country: United Kingdom
optional comments: The project will mainly be done from the Netherlands (remote)

! Ensure a heterogeneous team. In case you wish to include team members from the same section, explain why.
! Chair should request the IDE Board of Examiners for approval when a non-IDE mentor is proposed. Include CV and motivation letter.
! 2nd mentor only applies when a client is involved.

APPROVAL OF CHAIR on PROJECT PROPOSAL / PROJECT BRIEF -> to be filled in **by the Chair** of the supervisory team

Sign for approval (Chair)

Name: Nicole van Nes   Date: 25 Jan 2024   Signature:

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DESIGN FOR our future

Personal Project Brief – IDE Master Graduation Project

Name student Daantje Vogels   **Student number**

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT
Complete all fields, keep information clear, specific and concise

Project title Stowage solutions for seamless handover by the driver in level 3 and 4 autonomous vehicles

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

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

The context of this project lies within the domain of automotive design and innovation, specifically focusing on autonomous vehicle interior solutions for Jaguar Land Rover.

During autonomy the user will have the opportunity to perform non-driving related activities that either expand upon existing use cases or are entirely new. As part of this the user will need to bring additional items to the car to interact with and use during their journey. However these will need to be stored in safe, accessible locations with the ability to quickly stow for the driver in the event of a handover scenario.

Main stakeholders include Jaguar Land Rover, users (drivers/passengers), and potentially regulatory parties. For JLR, interests lie in crafting safe, cost effective and user-centric autonomous vehicles. Users seek convenience, comfort, and seamless integration of daily activities while in transit. Regulatory parties aim to ensure safety standards and compliance.

Opportunities in this domain involve redefining interior spaces to accommodate diverse user activities, enhancing the travel experience while optimizing safety during autonomy. However, limitations may arise from regulatory frameworks, safety concerns regarding item retention, and the challenge of designing adaptable stowage spaces that cater to various user needs without compromising aesthetics and use as little space as possible.

→ *space available for images / figures on next page*

Appendix I - Project brief (2/2)

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Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

The primary problem to address is the design challenge of creating efficient, safe, and adaptable stowage solutions for diverse user activities during level 3 and 4 autonomous driving, within a limited use timeframe of 10 seconds. The goal is to do this for at least three clusters of the by JLR provided use cases. The use cases are; Rest and Relax, Sightseeing, Watch Media, Listen to Media, Productivity (both work based, and hobby based), Sleeping (passenger only), Eating and Drinking, Gaming (physical and virtual), Organising Time (diary-based activities), Socialising with people inside the vehicle, and Socialising with people outside the vehicle.

The main win for stakeholders is ensuring users enjoy a secure and comfortable autonomous journey. They have the freedom to entertain themselves while also retaining the ability to swiftly assume control if needed.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for.
Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence)
As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

To create potential stowage solutions for the primary user, that enable a range of objects, which enable at least 3 clusters of the provided use cases to be completed, in level 3 and 4 autonomous vehicles, during a handover situation from vehicle to driver.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

To accomodate the requirements of both JLR and myself, the outcome of the project prioritizes functionality above aesthetics. Therefore, the primary focus will be on the prototype phase to ensure that all concepts function as intended and undergo comprehensive testing and iterations. The aim is to conclude the research phase as soon as possible and present three initial concepts by the midterm evaluation. This approach allows enough time for iterating on these concepts by using physical prototypes.

Given the numerous functions and objectives of this product, the plan is to employ a morphological chart for idea generation. Initially, I opt for a C-box to make preliminary selections before entering the prototype phase. Following this, the approach will predominantly involve trial and error through practical experimentation and testing.

Project planning and key moments

*To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a **kick-off meeting**, **mid-term evaluation meeting**, **green light meeting** and **graduation ceremony**. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	12 Jan 2024
Mid-term evaluation	22 Mar 2024
Green light meeting	23 May 2024
Graduation ceremony	28 Jun 2024

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	☐
For how many project weeks	20
Number of project days per week	4,0

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

I choose this project due to my fascination with automotive design. However, I sensed a push toward prioritizing aesthetics when applying within this industry. From my perspective, the mobility sector increasingly overlooks functionality, a challenge that students from an industrial design background are equipped to address. This project serves as the ideal balance for me, where functionality is the basis again.

I intend to prove my capabilities through:
- Independently executing a comprehensive design project, from creating its scope to developing a functional prototype.
- Striking the delicate balance between aesthetic appeal and functionality / comfort, addressing a crucial aspect often overlooked in this industry.

The skills I would like to develop during this project are:
- Utilizing 3D modeling techniques within Blender to bring conceptual designs to life.
- Mastering digital sketching methods using Procreate, enhancing my ability to visualize and iterate designs seamlessly.

Appendix J - Planning