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Interaction With In-Vehicle Infotainment Systems

Development of Interaction Tools For In-Vehicle Infotainment Systems During Low-Levels of Automation In Rural Environments

Master's thesis in Interaction Design and Technologies

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Cover: A driving simulator with a tablet representing a head-up display mounted in front of it.

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Abstract

Increasingly more car manufacturers are implementing advanced driver-assistance systems in vehicles. Furthermore, the rise of smart devices has created an environment where people expect more of their devices to be connected to the internet. As a result, the infotainment systems in vehicles are becoming more connected and provide more functionality, e.g., direct messaging. This thesis presents a concept which allows a driver to interact with the communicative tasks of an infotainment system in both non- and partially automated vehicles, driven in rural environments. The concept consists of a trackpad placed to the side of the driver, in an arm rest position, which acts as the input device. A head-up display placed in the front window of the vehicle is used as the output. We believe the concept shows promise, but requires more development in certain areas, such as text-input, and more thorough evaluation in real life environments, in order to properly confirm if the concept is safe enough to use in a vehicle when driving.

Keywords: automotive, interaction design, human-machine interface, autonomous, infotainment, user interface

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Jonas Arvidsson & Jonathan Granström, Gothenburg, June 2018

Contents

Abbrevations

ADAS Advanced Driver-Assistance Systems. 1, 2, 3, 6, 8, 9, 28, 30, 52, 54, 55, 56, 58, 59, 65, 87

CR Completion Rate. 20, 21, 47, 68, 79

GUI Graphical User Interface. 18, 34, 37

HMI Human-Machine Interface. 2, 8, 94
HTA Hierarchical Task Analysis. 17, 28, 33, 44
HUD Head-Up Display. 37, 38, 42, 43, 52, 64, 65, 89, 91, 92, 93

IA Information Architecture. 18, 19, 66, 84, 89, 92
IVIS In-Vehicle Infotainment System. 1, 2, 3, 7, 27, 84, 87, 92, 94

MWL Mental Work Load. 9, 24, 73, 75, 76, 91, 92, 93

OEM Original Equipment Manufacturer. 2, 6, 7, 10

PT Primary Task. 6, 7, 8

RP Retrospective Probing. 24

SA Situational Awareness. 8, 25, 50, 73, 74, 77, 90, 91
SAE Society of Automotive Engineers International. 2, 5
SEER Seamless, Efficient and Enjoyable user-vehicle inteRaction. 1, 2, 3
SEQ Single Ease Question. 22, 23, 47, 48, 69
ST Secondary Task. 2, 7, 8, 9, 28, 31, 33, 55, 56, 57, 58, 59, 60, 61, 94
SUS System Usability Scale. 23, 47, 48, 50, 53, 70, 71, 73, 74, 81, 82
SWAT Subjective Workload Assessment Technique. 24, 50

TBE Time Based Efficiency. 21, 22, 47, 68, 79
TTD Total Task Duration. 21, 22, 24, 47, 68, 79

UX User Experience. 3, 12, 13, 64, 92, 93

Chapter 1

Introduction

Modern vehicles implements a number of different Advanced Driver-Assistance Systems (ADAS) (see section 2.2) to assist with the driving process. As these systems assume more responsibilities, the role of the driver change from an active controller to a supervisor. On one hand, ADAS have the potential to improve driver safety and comfort. On the other hand, the driver might focus too much on other tasks and fail to pay enough attention to the road or traffic.

Worldwide adaptation of portable smart devices has driven the integration and communication between these devices and In-Vehicle Infotainment System (IVIS) (see section 2.3). Drivers increasingly demand vehicles with the same level of connected interaction and infotainment as they find in their smart devices. This demand, in combination with ADAS, further boosts the use of IVIS. However, this growing demand and the availability of in-vehicle applications, makes the cognitive and visual driver distractions more relevant.

1.1 Background

This thesis project is a part of the Seamless, Efficient and Enjoyable user-vehicle inteRaction (SEER) project(2016-2019) [1]. The SEER project is a partnership between Volvo Technology, Volvo Cars, Semcon, and RISE Viktoria, and is partially funded by the swedish innovation agency Vinnova.

The aim of the SEER project is to investigate and gain knowledge in three key areas:

1. How driver's behavior change when ADAS are active.
2. How driver safety and experience change as the driver interacts with Secondary Tasks (STs) (see subsection 2.4.1).
3. How STs should be designed to allow for smooth, efficient, safe, and enjoyable interaction when ADAS are active.

The expected results of the project will serve as assistance for Original Equipment Manufacturers (OEMs) during the design of IVIS in vehicles. The results will also provide recommendations as to how current decisions, standards, and guidelines surrounding the development of IVIS and other vehicle Human-Machine Interfaces (HMIs) should be updated. For the project to achieve its aim, it has been divided into four parts. This thesis project belongs to the second part, which address the design of concepts for interaction with STs.

This thesis project was done in collaboration with Semcon, a multinational technology company with specialization in product development, who mainly cooperate with companies in the automotive, energy, and life science industries. According to Semcon's own research, there is currently much exploration, testing, and implementations involving classic means of interaction with IVIS, e.g., via keyboard, touch, or voice input. As a result, Semcon are looking for concepts with a focus on non-traditional "outside the box" concepts and solutions for driver interaction with STs. The project is divided between two student groups who will focus on two different driving environments, city and highway. This project is focused on highway environments. However, both groups will work work closely together during the research phase and share information and findings.

1.2 Stakeholders

Stakeholders for this thesis project are:

- Semcon
- Volvo Cars
- Volvo Trucks
- RISE Viktora

These companies are the ones executing the project, and are therefore major stakeholders.

Additional stakeholders are:

- We, as students performing this project
- Chalmers University of Technology

1.3 Aim

The aim and expected result for this thesis project is a final evaluated HMI concept which allows a driver to interact with communicative STs, e.g., instant text messaging, found in a typical IVIS. It should be designed for vehicles placed in and below the second level of automated driving, according to the terminology, classification system and definitions provided by the Society of Automotive Engineers International (SAE) standard (see section 2.1). The concept should only adhere to vehicles driven in non-city environments, e.g., highways. The concept should not impair the driver's ability to operate the vehicle to a great extent.

1.4 Limitations

Beyond the limitations set by the aim of the thesis project, the concept will not consider the actual operations of the ADAS in vehicles, just their consequences. The concept is limited to an internal and built-in solution within the vehicle and is not portable or removable. Concepts utilizing voice recognition or eye movement as a main solution will not be considered due to technical limitations in an automotive context, but could be used as a complement.

1.5 Research Question

Addressing the purpose of the SEER project and the aim and limitations of this thesis project, a research question can be established:

"What is an alternative way for interacting with the communicative functionality of an IVIS, such as text messaging, that is safe, efficient, comfortable, and provides a good general User Experience (UX)?"

While this question was later re-phrased, this first question served as the start off point for this project. See section 6.3 to read about the new research question and the reasons for changing it.

1.6 Ethical Aspects

This thesis project involves vehicles and drivers, and the final concept is meant to apply to vehicles in traffic. As a result, ethical concerns regarding the safety of both the driver and others, needs to be taken into consideration. The concept and its design need to adhere to established safety guidelines of the motor industry to reduce the probability that the concept contributes to any traffic accidents.

User tests will be conducted to evaluate and improve the concept, which brings forth other ethical issues. Proper protection and respect for the users' personal information, as well as keeping the users well-being a priority, is very important. It is hard to foresee if any user tests performed would cause the users' in any problems to their health, but if that is the case, communicating this clearly to the users, so the risk is understood, is important.

As this thesis project is conducted on behalf of Semcon, making sure to respect their image, values, integrity, and clients is another important ethical aspect. Finally, there are environmental aspects to this thesis project as well, such as making sure our design does not contribute in a significant way to any environmental hazards or emissions.

Chapter 2

Theory

This chapter presents the different theories chosen based on their relation to the aim and research question of this thesis project. These theories are presented below and explained more in-depth.

2.1 Driving Automation Taxonomy

The SAE is a global association developing standards for the aerospace, automotive and commercial-vehicle industry. In 2016, they issued a set of revised recommended practices surrounding the taxonomy and classification of motor vehicle driving automation systems [2]. This classification describes six levels of automated driving, from zero through five, ranging from no driving automation to full driving automation.

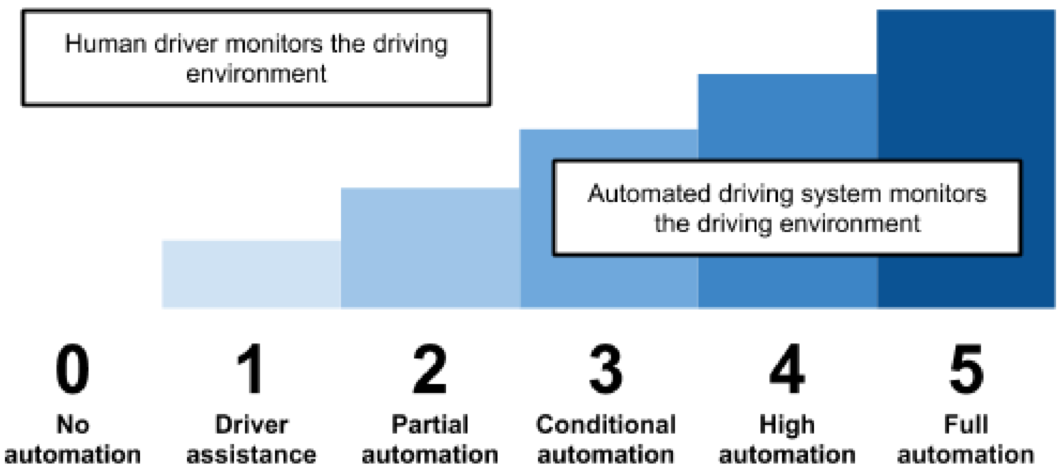

Figure 2.1: A visual representation of the SAE levels of driving automation

This thesis project will focus on vehicles placed in levels two and below, where level two is named partial automation. In a partially automated vehicle, the system executes the steering and acceleration/deceleration. However, the driver is still required to monitor the driving environment and act as a fallback if the automation fails.

2.1.1 Dynamic Driving Task or Primary Task

A "driving task" is a term describing a requirement for driving a motor vehicle [3]. This term can be broken down into three aspects:

- Operational, i.e., lateral steering, longitudinal acceleration and deceleration.
- Tactical, i.e., monitoring the driving environment, recognizing and responding to events and objects, maneuver planning, and signaling/gesturing to enhance conspicuousness.
- Strategic, i.e., determine destinations and way-points.

A Dynamic Driving Task, hereafter referred to as a Primary Task (PT), includes the operational and tactical aspects of the driving process, but not the strategic [4].

2.2 Advanced Driver-Assistance Systems

Systems developed to automate or help the driver during the driving process are increasingly more common in motor vehicles today. These systems are generally referred to under the broader term ADAS. In a partially automated vehicle, the longitudinal and lateral control of the vehicle is handled by certain driver assistance systems, mentioned below.

Adaptive Cruise Control

As an enhanced version of conventional cruise control, adaptive cruise control determines a set speed and following distance based on another vehicle ahead called a lead vehicle. The adaptive cruise control can automatically increase or decrease the speed to match the speed of the lead vehicle. It can also provide some limited breaking or completely stopping the vehicle if the OEM has implemented this functionality. As a lateral control system, adaptive cruise control can reduce the drivers cognitive, visual, and physical work load.

Lane Centering

Lane centering steers the vehicle and keeps it in the center of the lane, relieving the task of steering from the driver to a certain extent. Compared to lane keeping assist, the car does not swerve inside the lane, as lane keeping assist does not keep the vehicle centered in the lane. Some lane centering systems provided by OEMs require the driver to keep their hands on the wheel in order for the system to function. If the lane lines are faint or covered, the lane centering might not work properly. As a result, the driver must still maintain focus on the road.

2.3 In-Vehicle Infotainment System

An IVIS is an embedded information and entertainment system, which provides both vehicle-specific and traditional portable smart device services. Certain IVIS may utilize wireless connectivity, enabling the IVIS to provide the driver and passengers with content related to information, entertainment, and communication, e.g., phone calls or direct text messaging. The rise of portable smart devices, e.g., smartphones, and increasing expectation on IVIS from consumers has further pushed the advancement and implementation of IVIS in motor vehicles. As a result, new STs (see subsection 2.4.1) have emerged in motor vehicles, e.g., social networking, instant text messaging, and web browsing. For this thesis project, only STs possible through a IVIS will be relevant.

2.4 Driver distraction

Driver distraction is a serious problem with real-life consequences. Human error, e.g., misjudging the driving environment, was considered the probable contributing factor in 92% of accidents, where lack of attention was a major cause [5]. Research shows that a shift in attention away from PTs could increase the risk of an accident [6]. Glancing away from the road for longer than two seconds increase this risk by a factor of two [7]. Different solutions have been implemented by OEMs to reduce driver distraction, e.g., by utilizing voice-commands instead of touch based input. However, this might not solve the problem, as University of Utah psychology professor David Strayer puts it:

"... putting another source of distraction at the fingertips of drivers is not a good idea." [8]

Furthermore, a bad design approach to these solutions might also lead to driver distraction, due to the underlying nature of the design. Strayer again says that:

"Many of these systems have been put into cars with a voice-recognition system to control entertainment: Facebook, Twitter, Instagram, Snapchat, Facetime, etc. We now are trying to entertain the driver rather than keep the driver's attention on the road."

Using this information, we can determine that driver distraction is not only caused by human error, but also poor design of current solutions.

2.4.1 Secondary tasks

In a study conducted by Klauer et al., they define driver distraction as:

"... a driver has chosen to engage in a secondary task that is not necessary to perform the primary driving task" [7].

Using this quote and the previous definition of a PT, a ST can then be defined as the opposite of an PT, e.i., a task not connected to the operational or tactical aspects of driving a vehicle. Research suggest that drivers engaging in STs increase the risk of an accident, e.g., a slower reaction time to sudden events. An increase in attention towards STs leaves less cognitive resources towards PTs and the driving process. Too demanding or too much prioritization on STs could overload the driver and impact the driving performance.

2.4.2 Situational Awareness

Drivers must use the current feedback gained from the vehicle and the dynamic driving environment, but also how these variables could or will change in the future, to properly adapt their driving behavior. Mica Endsley defines Situational Awareness (SA) as:

"the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future." [9]

Endsley has proposed other definitions as well but the one provided above is more broad and suitable for different domains. However, they all have the common basis of an individual "knowing what is going on". SA is an important safety aspect in driving and a lack of it increases the risk of an accident [10]. Making sure a driver has a high sense of SA is therefore very important, especially in partially automated vehicles where the driver needs to be able to take over when the ADAS fail.

2.5 Driver Characteristics

How effective and safe a HMI is depends not only on the individual technology of the car, but also the psychology of the driver. The HMI needs to consider the different types of drivers and their varying tendencies towards driving and ADAS. Creating a HMI concept which keeps driver behavior in mind and does not promote an unsafe driving process is required. In order to better understand the psychology of the driver, the psychology concept presented in this section are used.

2.5.1 Mental Workload

Mental Work Load (MWL) is the quantity or quality of the work required to perform a task. The concept has many direct implications on driving, as a drivers MWL often determines how well they are able to respond to dynamic traffic conditions. Research shows that MWL is decreased when automation is enabled [11]. It is important to understand the drivers MWL to understand if certain systems are overwhelming, which can lead to mental overload, or if the systems are underwhelming, which could lead to mental underload.

Mental Overload

Mental overload can occur when performing tasks requires too much attention and energy, leading to a loss of focus and control in regards to the primary driving task. This can lead to dangerous situations in traffic as the driver can be too focused on performing either STs or driving tasks, and will not be able to respond to dangerous traffic situations.

Mental Underload

A lack of tasks and inattentiveness may lead to mental underload, which is seen as just as bad as mental overload [12]. With ADAS enabled, the driver is able to focus on STs such as text messaging, which likely requires less mental effort than driving does. When a driver is experiencing mental underload, and their attention is on STs, reclaiming control of the vehicle in cases where adaptive cruise control fails can become difficult. Mental underload can also lead to skill degradation over time as the driver is no longer required to focus on the main driving tasks and will not have to practice their driving as frequently [13]. Skill degradation also contributes to problem of the driver not knowing how to reclaim control when required.

2.6 Research Through Design

Research through design is an approach to research where knowledge is acquired through the design process. For this thesis project, research through design will be used with the intent to gain knowledge and insight through the design of different concepts, and the evaluation of those concepts. Looking at related work and research, as well as look into areas besides the automotive industry, and draw knowledge from this is another important aspect to this approach.

One issue with research through design is that it might lack validity in certain scientific communities, as the approach currently lacks definitions and standards. However, William Gaver suggests that too many protocols can be counterproductive [14]. He claims standards can lead to research through design becoming too restrictive, when it's currently a more creative approach to research. Gaver finally makes the claim that this type of research might be accepted as a science if it has more guidelines and protocols, but that a lack of this should not stop designers from pursuing research through design.

2.7 Guidelines for Safe In-Vehicle Systems

To establish a foundation of what is considered essential in safe driving, a list of guidelines provided by National Highway Traffic Safety Administration, Japan Automobile Manufacturers Association,
Alliance of Automotive Manufacturers, and the Commission of the European Communities has been created [15–18]. The guidelines are meant to be used as design input for internal use by OEMs. The list also does not contain all guidelines found, as guidelines outside the scope of this project have been removed, as well as guidelines that are very similar to each other. Examples of guidelines and what types of guidelines there are, see the table on the next page.

Type of Guideline	**Description**	**Example**
Overall guidelines	General guidelines that do not belong in any particular category.	The system supports the driver and does not give rise to potentially hazardous behavior by the driver or other road users.
Installation guidelines	Guidelines that discuss how systems should be installed into the vehicle.	The system should be located and securely fitted in accordance with relevant regulations, standards and manufacturer's instructions for installing the system in vehicles.
Information presentation guidelines	These guidelines deal with how the system should display information.	Information with higher safety relevance should be given higher priority.
Interface with displays and controls guidelines	Guidelines regarding user operation of the system.	The driver should always be able to keep at least one hand on the steering wheel while interacting with the system.
System behaviour guidelines	Describes how the system should behave.	While the vehicle is in motion, visual information not related to driving that is likely to distract the driver significantly should be automatically disabled, or presented in such a way that the driver cannot see it.

For full list of guidelines, see section A.1 in Appendix A.

Chapter 3

Methodology

The theory presented in chapter 2 served as a basis for the decisions made regarding the chosen design process, methods and measures presented in this chapter. This chapter goes through what was used to ideate, design, and evaluate the concept of this thesis project.

3.1 Interaction Design

Interaction design is the practice of shaping the users' interactions with products, with a focus on user behaviour. For this project, interaction design is used as a design principle that falls under the term Human-Computer Interaction which specifically focuses on the interfaces that facilitate interactions between users and computers. When discussing interaction design, it is important to also acknowledge the term UX, with both terms being involved in the overall experience of products. However, the interaction designer is focused solely on the interactions, flow and behaviour of that product, while UX is focused on the overall experience between the user and the product. E.g., conducting user research is an important aspect in creating a good UX and to determine if user goals are supported in interaction design. As a result, interaction design could be seen as a subset of UX. Within interaction design, there are established methods and measures approaches which are described in section 3.2.

Four general and basic activities, which can be found in other design disciplines as well, can be established:

- **Establishing requirements**
  Understanding who is the target group, what their needs and goals are, and how those can be achieved, is very important in interaction design. Different data gathering methods, e.g., surveys or interviews, can provide data to be analyzed for initial user requirements. In order to better understand the data gathered, task description methods, e.g., scenarios and use cases, could help in documenting and establishing more refined and detailed requirements. Performing task analysis techniques help in investigating existing systems and practices.
- **Designing alternatives**
  This could be considered the core activity of interaction design, suggesting ideas for products that meets the established requirements. The activity can be broken down into two sub activities: creating a conceptual design and a physical design. The conceptual design involves the creation of a conceptual model. This explains what a product should do and how users interact with it. The physical design determines the details of the product, e.g., colors or sounds. Brainstorming is a tried and valid method to establish early concepts to explore and evaluate. Sketching and storyboards are other means to create conceptual designs. For the physical design, different prototyping methods are used to create a more interactive design.
- **Prototyping**
  To properly evaluate a conceptual design, a physical and interactive prototype is necessary. A prototype does not necessarily need a piece of software to be effective. A low-fidelity prototype is often a paper-based build with a low cost in time and effort. The objective is to identify both obvious and unforeseen problems with the design, and if the design satisfies the established requirements.
- **Evaluating**
  The validation of the concepts usability, user experience and support of established requirements is an important aspect of interaction design. By evaluating the concepts with users, a higher chance of the concept being accepted is achieved. Other more technical evaluations, e.g., quality assurance and safety inspection, is another part of the evaluation process. The methods used during the data gathering can be used as well, but they will be structured and conducted differently, in order to validate and understand if the concept fulfills the user's goals, the requirements, and provides a satisfying UX. Other more specific methods are case studies in controlled or open environments, e.g., in simulators. Gathering and comparing data related to the usage of the concept and data collected before is another way to measure improvement.

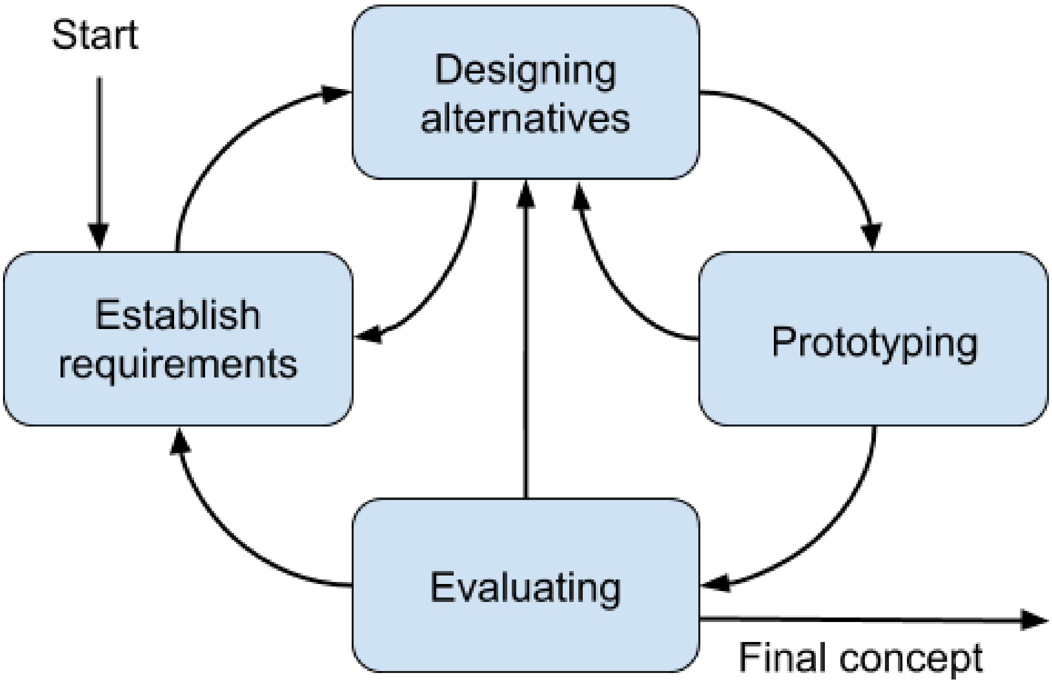

Figure 3.1: A visual representation of the design process

These four activities are initially conducted sequentially, but are nonetheless intertwined and performed repetitively. The feedback gained from each step can be used and influence other steps. New requirements could be established by evaluation, new alternative designs could be needed by creating a prototype, and so on. This iterative process is a key aspect of the user-centered design approach of interaction design.

3.1.1 User-Centered Design

As an approach to interaction design, user-centered design involves the user in every step of the design process. The benefits of having the user as the centre of focus during the design process is that the resulting product fills all the user requirement and needs. In order to exercise user-centered design, gathering data about users is essential. Some data gathering methods are outlined below (see subsection 3.2.1) and are used to help the designer establish requirements. Other ways of including users in the design process is through evaluations, which is also detailed in the following section. In conclusion, the aim of user-centered design is to, by involving users in the design process, deliver products that are intuitive, easy to use, and that accommodate all the users' needs.

3.2 Methods and Measures

The methods and measures presented in this chapter are commonly found in interaction design and will serve as the basis for the design process used in this project. Some methods are more suited for certain steps, while others can be used across multiple steps of the design process, although modified to serve a different purpose.

3.2.1 Data Gathering

During any part of the design process, collecting qualitative and quantitative data is an important aspect, as it provides a foundation for requirements, decisions and proof of concept. These data gathering methods serve different purposes and are suited for different contexts and situations. They each have their own pros and cons, but they also complement each other in different ways.

Observation

Observation is a broad but useful tool in any stage of the design process. It can be used in the early stages of the project to determine user goals, tasks, or context. During the evaluation phase, observation can help determine whether the concept supports those user tasks and goals. The method can be conducted in a controlled setting, e.g., in a simulator, or in the field. Users can be observed directly as they perform an activity or indirectly through different types of records, e.g., photos or video. Observations is a useful complement to other data gathering methods, as it provides real world data and could help bridging any gaps in data or knowledge not found with interviews or surveys.

Survey

Surveys are used to collect quantitative user opinion of a concept and establishing their background through carefully constructed and contextually aware questions. A great benefit of utilizing surveys is distribution. By providing surveys electronically, e.g., by a web page, many users can be given a survey to answer. It also has a low time cost, since surveys can be answered by users separately and concurrently. Also, since a survey is the same for every users, collecting, sorting, and categorizing data from answered surveys can be a short process. However, a problem with surveys is user motivation to answer. There is no guarantee that every recipient of a survey will answer it. A solution is to try and conduct a survey directly with individuals in person, but this requires more time and effort on behalf of the project team in order to reach and question these potential participants. The data gained through a survey is also limited to the given answers, so any attempt to gain further insight or clarification in a subject would require further data gathering.

Follow-up questions

As a complement to surveys, asking follow-up questions has the potential to give more qualitative data due to its one-on-one nature. Follow-up questions can be unstructured, through an open conversation about the subject, or structured, where the user is asked predefined questions. By asking users follow-up questions, one may gain a better understanding of the users and their needs, their likes and dislikes, and their opinions and thoughts. Also, these questions can be altered based on the response of the user, in order to gain more insight in relation to a given answer. On the other hand, this one-on-one nature also means that follow-up questions are time consuming.

3.2.2 Task Description

Different task description methods can be used to better convey the knowledge gained from the collected data to stakeholders and the project team. Properly understanding the needs of the users is very important in order to assure they are addressed properly.

Personas

Data gathering methods tend to create a lot of similar data, both subjective and objective. This data can be used to create summarized representations of larger user groups called personas. A benefit with personas is that their are easier to develop for, as they cover a wide set of users with similar goals. They are also easier to target during development and provide an overview of the different users. They are usually created in the beginning of a project when sufficient analyzed data has been established and can be used.

Use Cases

Unlike user goals, use cases focus on the interaction between a user and a system. A use case can for example describe a desired goal that is desirable by using the system. By analyzing these use cases, it is possible to understand the different functionality that a system needs to have in order to reach these goals. By breaking down use cases, one can determine the necessary steps needed to complete a task, what deviations a user might take, and how to handle the different cases that might appear. To create a use case, one first determines the actors interacting with the concept. You then examine the actors, what their goals are when interacting with a concept. Finally, you note down the necessary or theoretical steps the actor has to complete in order to reach their goal.

3.2.3 Task Analysis

Investigating existing systems and practices can help understand the underlying motivation of users, as to why they use them in the first place. The goal is not to consider alternative products or solutions, but to analyze these systems and practices in order to establish new requirements based on the knowledge gained.

Hierarchical Task Analysis

Hierarchical Task Analysis (HTA) is used to break down the necessary steps required to reach a user goal [19]. By doing so, one can compare the steps to other solutions, understand the necessary interaction and levels of abstraction, and see in what ways design can be reused.

3.2.4 Ideation

Once requirements, scenarios and use cases are established, coming up with concepts with the potential to address and support this is the next step of the design process. Different methods can be used, but using the common methods brainstorming and affinity diagram help in the creation and categorization of ideas to prototype and evaluate.

Brainstorming

Brainstorming is used to generate ideas. There are many ways to conduct a brainstorming session, but two key factors should be considered: that users' goals should be known and understood by the participants, and that no idea is to be criticized or debated. Other more general tips are to present the problem to solve clearly, to document all suggestions, allow expansions on already documented ideas, and to not conduct the session for too long as to not loose focus or interest.

Affinity Diagram

After a brainstorm session, a lot of different ideas has generally been gathered, many of which are similar, deal with different areas, and so on. This tends to create the need for organization. A good way to categorize and organize all these ideas is to create an affinity diagram [20]. To create an affinity diagram, one begins by putting similar ideas based on their natural relationship into groups. These groups are then analyzed and discussed. Groups can be split up into additional subgroups or combined. Similar ideas might also be discarded or combined. Each group is then given a name, based on its content. In the end, a large cluster of analyzed, reviewed, and named groups which contains related ideas is achieved.

3.2.5 Prototyping

Creating prototypes is an effective way of getting an early perception of the viability of a product. A prototype is simple model that represents a product or an idea where the complexity and quality of the prototype can be different depending on what project the prototype is for, and what resources are available. Prototypes are often divided into two categories, low-fidelity and high-fidelity prototype.

Low-Fidelity Prototype

This version of a prototype is used to explore conceptual designs. They do not provide all of the final functionality, or only represent the functionality without actually performing it. It is often made rapidly with paper, or other cheap materials, to provide a quick way to check the feasibility of certain concepts. This also means a low-fidelity prototype is fast, cheap, and easy to update or modify, based on knowledge gained through evaluating the prototype.

Sitemap

Sitemapping is a technique used mainly during the creation of websites, but it works with software as well. It is basically a way to structure the Information Architecture (IA) hierarchically and establish how different views of the software relate to each other. IA refers to the structure of information on the Graphical User Interface (GUI). This is displayed using a tree structure. Starting with a "home view", one determines which views a user can navigate to. E.g., a view called "Messages" brings the user to a messages view, and from there, they might be able to navigate to "Message", "New Message", and "Contacts". For each identified view, this process is repeated until a final view is reached and the user can not navigate further down the tree structure. Sitemaps provides a way to gain oversight of a software's structure and help determine which views are needed.

Flow chart

While sitemaps are beneficial in establishing a structure and provide a general overview, flow charts helps determine when and how a user may navigate between views, e.g., which buttons starts a new view or are certain conditions meet to allow a user to navigate to a new view.

Wireframes

Creating a low-fidelity representation of the IA of a project has a number of benefits. It is a fast way to determine paths between different stages, the layout of elements, information to display, functionality, and which templates can be used. Wireframing is a great tool to achieve these things. A wireframe is a two dimensional illustration of an interface. Its focus is on layout, space allocation, content, behavior, and functionality. A wireframe does not include any styling, color, or graphics.

High-Fidelity Prototype

High-fidelity prototypes often require more time and resources to create. They achieve more of the "look and feel" of the final product and provides more functionality than the low-fidelity prototype. The main objective of this version of a prototype is to convince the stakeholders and users of the viability of the design, and to find any technical issues.

3.2.6 User Testing

To learn what users think about your design, it is often vital to conduct user tests. Depending on the purpose of the test, whether it be to find critical issues with your design, or to test out the usability of a system, user tests can look very different. One common example of a user test is simply to observe the user while they use your product, or if the testing is done early, the users can interact with your prototypes, and record anything of note. Another example of a more time consuming user test could be to use eye-tracking software to learn where the users attention is directed. Regardless of what type of test you are conducting, any test can provide vital information and insights to the designer that they might not have thought of themselves.

3.2.7 Evaluation

The evaluation could be one of the more complicated parts of the design process. Satisfaction and efficiency are hard aspects to get conclusive data on. Furthermore, what to evaluate, where to do the evaluation, and when to do it are additional factors that needs to be considered. There are two distinct settings where an evaluation differs in its conduction, focus, and result: a controlled or natural setting.

Performing an evaluation in a controlled settings could be considered an easier way to determine if a concept allows a user to accomplish their goals, the use cases and scenarios, and requirements. A directed and controlled evaluation allows for more in-depth observation and evaluation of usability, where issues or divergence can be more easily detected. However, the context of use will not be as easy to establish or control, meaning the result of the evaluation might not represent the realistic use cases.

Field studies in more open and natural settings are a lot more relaxed and open ended, and has a better potential to show how the concept is received by users in its' intended setting. Furthermore, unforeseen or unintended issues could more easily be discovered, due to the unstructured nature of the evaluation. However, external factors have more impact on it as well. A natural setting for the evaluation could also cost more in time and resources.

Common for both approaches is the collection of data through different data gathering methods, some of which are mentioned below. This is easier in a controlled setting. It is also valid for for more open settings, but the data gathering method has to adapt to the unstructured nature and lack of framing.

Besides the setting and environment during evaluation, a use of objective and subjective evaluation methods also needs to be considered. A product can be objectively good, but lacking subjectively, meaning the users are not happy with the product. This also works the other way around. A product can be ineffective but users enjoy the product so much, they are willing to overlook this flaw. A proper balance of both subjective and objective measures helps in getting a better evaluation of a product.

Lastly, the evaluation will be formative in its nature, as its results will be used to monitor our progress towards our goals. This means the data and feedback received will be used to determine how to best revise of modify our concept for improvement, and not to compare to any other standards or benchmarks, e.g., other studies of a similar nature, which is more of a summative assessment.

Effectiveness

To determine whether or not a product is effective, two measures can be used: Completion Rate (CR) and number of errors.

Measuring the CR is straightforward; You take the number of tasks a participant completed successfully, divide this number by the total amount of tasks for the test session, and finally multiply it with 100 to gain a percentage. As a result, a CR is gained which represent how effective the solution is. The full equation to calculate the CR is shown below:

$$CompletionRate = \frac{Number\ of\ tasks\ completed\ successfully}{Total\ number\ of\ tasks\ undertaken} \times 100$$

Error Rate

The amount of errors a participant encounters has an effect not only on the effectiveness of a product, but also the participants perception of the product. Getting a good grasp on a product's error rate and what kinds of errors a participant encounters is therefore important. During a test session, noting down the number of errors a participant encounters in each task is helpful in keeping track of error prone tasks. To further understand these errors, a categorical system can be used to break down each error into a subcategory:

- Unintended actions, e.g., missclicks
- Slipups, e.g., an obvious navigational error.
- Mistakes, e.g., selecting a wrong element
- Omissions, e.g., not noticing presented information.

Keeping track of what kind of errors a participant encounter and during which tasks they occur helps in understanding which tasks are error prone and what is the cause.

Efficiency

Two methods can be used to determine the efficiency of a product: Total Task Duration (TTD) and Time Based Efficiency (TBE). Much like measuring a products CR, it is just as straightforward to measure TTD. For each task, after the participant has begun with the current task, start a timer. Once the participant has completed the task, successfully or not, stop the timer.

The TTD is achieved by subtracting the end time with the start time, much like the equation below:

$$Total\ Task\ Duration = End\ Time - Start\ Time$$

Using TTD, one can quickly establish which task requires a significant amount of time for the participants to complete. However, one must also keep in mind the nature of each task. E.g., a task which requires a participant to enter text would naturally take more time to complete than selecting an element.

The second method, TBE, is primarily used to see how many tasks the participants completes on average per second. TBE takes the resulting time and success for each task, for each participant, and provides a final value which represent the overall efficiency of the product. The equation below is used to achieve this result:

$$Time\ Based\ Efficiency = \frac{\sum_{j=1}^{R}\sum_{i=1}^{N}\frac{n_{ij}}{t_{ij}}}{NR}$$

where N is the total number of tasks, R is the total number of users, n_{ij} is the result of task i by the participant j; if successful, then $n_{ij} = 1$, else $n_{ij} = 0$. t_{ij} is the amount of time spent by the participant j to complete the task; if not successful, then t_{ij} = the time until the participant gives up. Important to remember is that if the time is measured in seconds, the result will give tasks per second. Multiplying by 60 will give tasks per minute, and so on.

Single Ease Question

The Single Ease Question (SEQ) is a simple but effective way to quickly gain a subjective measurement of a product on a task level. At the end of each tasks a participant completes, they are asked a single question:

"Overall, this task was?"

Using a Likert scale[1], the participant then selects the alternative they feel represents their answer to the questions above. The scale can look something similar to what is given below:

Very Difficult				Very Easy
○	○	○	○	○

[1] https://en.wikipedia.org/wiki/Likert_scale

In this case, *"Very Easy"* represents the value 5, and *"Very Difficult"* represents the value 1. These are later converted to a 0 to 100 scale for easier scoring. Since this data is gained after each task, one can quickly get an oversight of which tasks participants find difficult and easy to complete. The SEQ is short, easy to understand from a participant perspective, and easy to score and administer during a test session.

System Usability Scale

In order to get a quick but still broad and test specific subjective measure, the System Usability Scale (SUS) [21] can be used. SUS provides a quick but reliable way to measure the subjective usability of a product. At the end of a test session, the participant responds to 10 statements. Each statement deals with a different area of usability. An example of a statement is *"I found the system easy to use"*. Each statement has 5 options of responses the participant can choose from. These responses, much like the SEQ, use a Likert scale and the responses range from *"Strongly agree"* to *"Strongly disagree"*.

When interpreting the responses from a participant, it can be somewhat complex. Each response has a single designated value. These values range from 0 to 4. For an even numbered statement, the response value is kept, while for an uneven numbered statement, the number 4 is subtracted with the value of the chosen response. The new value is then multiplied by 2.5, in order to convert the value into a 0 to 10 range. In the end, all response values for all the 10 statements are added together, providing a percentage which represent the participant's usability score for the product.

What makes the SUS good is that it is easy to administer to the participants, still provides a reliable results even when a small size of participants are questioned, and can quite effectively tell if a product is usable or not. Another benefit is that each statement has its own category of usability, so you can easily determine in what area a product is lacking. E.g., the product can achieve a high score in categories such as low technical complexity and is easy to start using, but a low score in reliability, meaning focus has to be put into making the product more reliable.

However, as mentioned before, the scoring system can be quite complex. Also, the SUS gives a general picture of a products usability, but does not go into any specifics as to what makes or breaks the product. Therefore, it should not be used as a final evaluation tool to determine usability, but rather as guidance.

Retrospective Probing

In order to combat some of the shortcomings of the objective and subjective measures mentioned above, Retrospective Probing (RP) is a good method to utilize. RP is a technique where after a test session, questions regarding a participants thoughts and action during the session is asked.

This is helpful as it provides a richer and deeper insight into what the participant thinks about the product. Another benefit of RP is that it does not interfere with the test session, e.i., interrupts the participant, or disturbs other evaluation methods, e.g., TTD. However, depending on how long a test session is, it can be hard for a participant to remember. This can be countered by taking down notes during the test session, in order to later remind the participant of what happened.

Subjective Workload Assessment Technique

Since the MWL of a driver of a vehicle is an important aspect of how usable and safe a product is, a relevant technique has to be used to establish the over or under-load a participant experience. The Subjective Workload Assessment Technique (SWAT) [22] is subjective measure where the participant rates the time, mental effort, and psychological stress load the product requires.

The SWAT can be done on a task to task basis, or at the end of the test session. The participant has to chose one of three statements, whichever one represent their opinion the most, provided for each category: time, mental effort, and psychological stress. Once the participant has provided an answer for each category, a final MWL score is achieved. This is done by giving each statement for each category a value from 0 to 2. These values of the chosen statements are then converted to a 0 to 100 scale. The average score of the three statements are then calculated, which represent the MWL required. A high score represent an experience that creates overload, while a low score represent an experience that creates underload.

The benefits of SWAT is that it is unobtrusive, as you do not need any hardware such as heart beat monitors or eye tracking headsets to measure stress. Also, it does not require much time and is easy to administrate. It also provides an easy measure of the MWL required from the participant.

However, a disadvantage is that it can be quite time consuming if it is administered on a task to task basis. Also, the phrasing of the statements can be confusing, as it uses quite technical and advanced sentencing. Rewriting these sentences to make them more understandable might be required.

Situation Awareness Probing

There are a lot of methods which can be used to determine the SA of a participant, e.g., eye-tracking. However, asking simple questions about a participants environment can be a simple and effective tool to gauge how situationally aware a participant is. During a test session, e.g., during a driving simulation session, a participant is asked at certain times or during certain events, questions about their surroundings. If the participant answers correctly, they were situationally aware of their surroundings.

However, a potential problem is if the participant lies and gives a positive answer to a question, even if the participant was not situationally aware and did not know the correct answer. To combat this, one can have a number of decoy questions. e.g., *Did you see a warning sign?* when there was no warning sign present. This sort of question both shows if the participant was situationally aware, i.e., they did not see a sign, or guess/lies when giving answer.

Chapter 4

Process

Ultimately, the project consisted of five different phases: a initial research phase, a establishment of initial requirements phase, and three sequential iteration phases. Each phase had a different set of goals, measures, and methods to reach the goals of each iteration, utilizing what was presented in chapter 3. This chapter will describe in-depth what the goals for each phase was, the problems encountered, the solutions discovered or used, and present the process to reach the goal of each iteration.

4.1 Research

The research phase was an important first step of the project process. The research provided a important and solid basis on which our concept was based and built upon, but also evaluated and judged by. There were a few different goals for this phase, and because of it, different areas the research had to be focused on. The first goal was to gain a better grasp on what is currently used and what is being researched and developed in terms of interaction and presentation of information in the automotive industry. The second goal was to understand current guidelines and taxonomy used in the automotive industry in regards to the project domain. The third goal was to look into the characteristics and behavior of drivers, in order to better understand how they think and act. The results of this research was used to establish what was presented in the chapter 2, but also carried over into the next phase, the establishment of requirements.

4.1.1 Literature study

The first step in the research phase was the study of appropriate and relevant literature. A majority of the literature was provided by Semcon and included studies curated by other people involved in different parts of the SEER project. The study of this literature was crucial for us to be able to quickly attain knowledge in different areas relevant to the SEER project. Further access to literature was gained by using the Chalmers online library. A large part of the research topics dealt with automotive industry guidelines, taxonomy, technology, and driver characteristics, and contained terms and concepts which was significant when designing tools for interaction in vehicles. The literature read during this part served as the basis for the topics presented in chapter 2.

4.1.2 Research of Similar Products

In order to understand how users currently interact with IVIS, much of the early research was spent on researching the types of interaction tools other vehicle manufacturers were currently implementing. Some of this research was done online, by looking at different car manufacturers web pages, expert and customer reviews, and tech-shows, e.g., CES[1]. By reading articles and watching footage of various future concepts from various auto shows, we also got a good grasp on where future interaction technologies in vehicles are heading. As a result, it was easy to get an overview of current IVIS and the means of interaction, both the cutting-edge as well as current standards.

A number of different requirements could be established using the knowledge gained from this research. However, this part was mainly done for the benefit of the team itself, in order to get inspiration and understanding about what users considers positive and negative in regards to current IVIS.

Field Research

While parts of the research was done online, field research was also conducted in order to get hands-on experience with different IVIS and their means of interaction. The research consisted of traveling to different car retailers and testing out the IVIS. This provided insight into what types of interaction worked well, and what did not work as well. Some issues that were encountered were the fact that most system required either the car to be turned on and started, or to have a mobile phone connected via bluetooth. While these issues could be resolved in most instances there were still some cases were this issue made us unable to properly investigate the system, as the car retailers did not allow us to start the cars or the cars IVIS

[1] https://www.ces.tech/

were locked in a presentation mode. Pictures from the field research can be found in section A.4 in the appendix.

During this step in the research phase, a HTA was conducted by recording the steps necessary in order to reach a final goal. A number of different tasks were used, e.g., call a number or send a text message. Only tasks which adhered to the limitations of this project were tested and mapped out via HTA. Also, because of the limitations mentioned in the previous paragraph, certain tasks could not be analyzed using HTA, e.g., connecting a phone to the car was not possible in certain models, and having a phone connected was necessary in order to do certain tasks. The different HTAs was used as a reference during later phases of the process, as it provided guidance during the creation of our concept, but also something to compare to during internal evaluations.

4.1.3 Driving Habit Survey

A survey was conducted in the early stages of the project with the goal of understanding the driving habits of different drivers, as well as how and which STs they do or do not perform while driving. In order to achieve this, and to get as many responses we could, from a wide range of demographics, we implemented a survey using Google Forms[2]. The survey was distributed through various online channels, e.g., Facebook groups, forums, friends and family, and so on, with the goal to target as many different types of drivers as possible, i.e., truckers, people who own vehicles with ADAS, and so on. The questions the participants had to answer were about subjects as their personal and driving backgrounds, if they have ever driven using ADAS, what kind of tasks they perform while driving, and so on. Additional questions regarding the participants experience with touch screens and other forms of input were also asked in order to understand which technologies the participants were the most comfortable with.

The survey was conducted in collaboration with the other student group who focused on city driving. This was done as both groups wanted to learn the same type of information, just regarding different driving environments. It also prevented the groups from having to send out two very similar surveys to the same users. In the survey, the users also had to answer what environments they primarily drive in. Based on the answer to that question, the survey branched into different paths where the questions were focused on either city driving, highway driving, or both. Using different queries on the finished data, the results could be easily divided to only show relevant data to each group.

[2]https://www.google.com/forms/

Pilot

Before the survey was distributed, a pilot session was conducted with various people at Semcon, including our supervisor. This was done as a means to find any mistakes or to see if we had overlooked any important aspect of the survey before we send it out. After receiving feedback from Semcon and proper updates had been made to the survey, it was distributed to a small number of people for further feedback. The feedback gained was that the survey was quite long and with a very technical language. Also, small mistakes such as spelling errors, were also found. As a result, the survey was condensed further and questions were rewritten in order to make it more understandable by participants who are not as knowledgeable in the subject matter.

Follow-up Questioning

While the survey provided quantitative data, a more qualitative method was required in order to get more detailed feedback and knowledge. As one of the final questions in the survey, the users were asked if they could be contacted with follow-up questions. Out of all responses, a few agreed to answer some more questions, and left their e-mail as contact information. These users were then asked more detailed questions, and were asked to clarify some of the comments and answers they gave in the survey.

To get as qualitative replies as possible, each e-mail sent was customized to each individual, asking questions based on their answers in the survey. On the next page is one of the e-mails that we sent out:

"Hi,
About two-three weeks ago you were kind enough to answer our survey regarding driving habits in motor vehicles with advanced driver assistance. We really appreciate you for taking the time to answer it. The reason why we are contacting you is because we have some follow-up questions. If you don't want to answer, please tell us and we will not contact you further.
***NOTE**: For all questions below, assume you are driving a car on a highway/rural road without any driver assistance enabled.*

You answered that you either rarely perform voice calls:
1.) To perform voice calls, do you use your phone or your car (by connecting the phone to it)? If neither, how do you perform voice calls?
2.) What problems do you experiencing when you perform voice calls?
3.) If you have any problems, how do you currently handle them?

You answered that you feel a little comfortable when performing voice calls:
4.) What would have to change in order for you to feel more comfortable with voice calls?

You answered that you mainly use "Touch" when performing voice calls:
5.) Do you think touch works well? Why/why not?
6.) Would you like an alternative to touch? If so, what could that be and why?

You answered never when asked if you use direct messaging, social media or email:
7.) Would you like to be able to engage with the activities above through an in-car system (as in, not using your phone directly)? If yes, which ones?
8.) What are the main reasons you're not currently engaging with the activities above?
9.) What would have to change in order for you to engage with the activities above?

Final question:
10.) Do you have any other comments about improving the use of communication activities?
If you have any questions, do not hesitate to ask us and we will answer. Otherwise, please reply to this email with your answers. Your reply only needs the number of each question above followed by your answer.
Thank you for your time!"

The relevant responses from the follow-up questions were then compiled into different personas, some being related to driving without ADAS and some with ADAS. By analyzing the data from the survey, as well as the answers from the follow-up questions, some user needs and requirements were identified and could be used as a foundation when thinking of our own design solutions.

4.2 Requirements

Using the literature study, the research of similar products, and the user research, a thorough set of requirements could be established. These requirements were divided into three categories;

- Functional Requirements - These requirements describes what the system should do.
- Non-Functional Requirements - Describes constraints around the system [23].
- User Requirements - Requirements gathered from the user research.

While the majority of requirements are compiled from the guidelines mentioned in section 2.7, the full set of all requirement also contain those acquired from the user research. To read all requirements, see section A.2 in the appendix.

4.3 First Design Iteration

The first iteration began as soon as the initial literature study was completed. For the first iteration, the aim was to, through various methods, establish initial concepts that could be viable solutions to our research problem.

4.3.1 Conceptualization

After the initial requirements were established, categorized and framed, the conceptualization phase of the project was carried out. The main goal was to establish as many diverse ideas and concepts as possible which deal with the interaction with STs, discuss and transform those which were deemed interesting or showed promise, and finally narrow down and combine the options into a full solution.

Brainstorm

In order to generate early ideas and concept to later explore and discuss, a brainstorming session was conducted. A small conference room was used as the location for the sessions, so that the session could be conducted without outside disturbance or interruptions. Small notes and markers were brought so we could write down our ideas. This makes sure the ideas are recorded for later reference. To begin the brainstorming session, the goal of the session was clearly written down on a whiteboard in the room, along with some bullet points related to the scope of the project. This was done so we would remember and understand the underlying goal of the session.

Once everything was setup, we were ready to proceed with the sessions. Approximately one hour was spent on generating ideas. The session was conducted in silence. The reason behind this was to reduce the probability of getting sidetracked and to give each of us room to think. Once an idea was generated, it was written down on a note and laid out on a table in the room for easy overview. This was so that inspiration could be drawn from each others' ideas.

Affinity Diagram

Once the brainstorming session was over, all the notes were looked over and any duplicates were removed. The notes were then put up on a whiteboard in order to create an affinity diagram. The notes were sorted into groups based on their similarity, as seen in Figure 4.1. Once all notes were sorted, each group was given a category name. We then proceeded to discuss each category, where ideas were either dropped due to scope limitations, a lack of engagement from us, or due to technical, economical or logistical concerns. Other ideas where further discussed and depending on our judgment, were then kept and moved to the next step of the process. The categories we came up with were:

- System Behavior
- Tangible
- Steering Wheel
- Gestures
- Design

In the end, a list of diverse ideas had been established through the brainstorming session. These ideas where then sorted and discussed. Those ideas that remained had been further transformed and explored. Finally, we narrowed down ideas into a few of concepts to further explore and discuss.

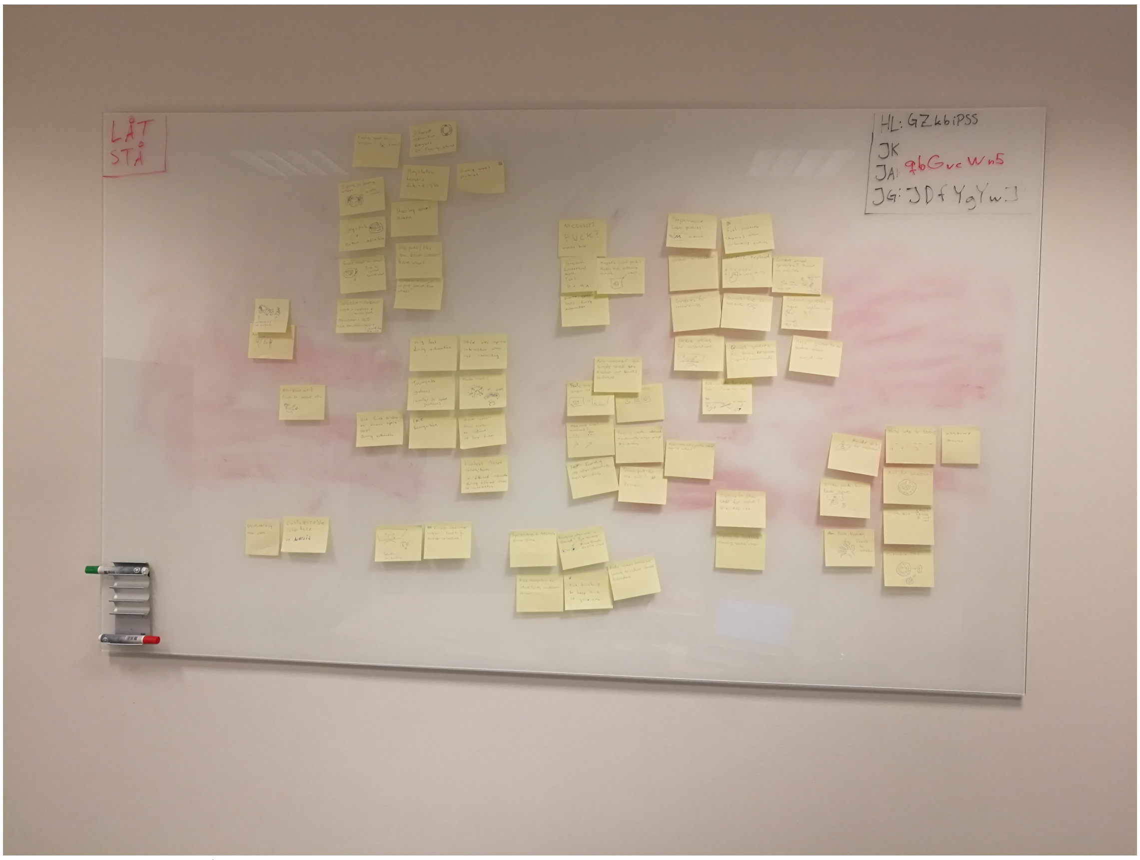

Figure 4.1: Affinity diagram created from the result of the brainstorming session.

4.3.2 Initial Ideas

The concepts produced through the brainstorming session where often unclear at this point, and needed to be transformed into easy-to-understand ideas. The HTA done in an earlier stage provided a lot of insight into which steps are required and in which order they need to be completed to allow the interaction with different STs in an infotainment system. By utilizing the HTA, three different interaction subcategories could be established, which had to be addressed in any of the concepts we came up with. These categories were:

- The selection of elements
- The navigation between different elements
- How the textual and numeral input is achieved

Narrowing Down Ideas

First, focus was directed towards how textual and numeral input could be implemented. Early on, we found the idea of handwritten text input, sometimes called scribble, which means physically writing the input with a finger on a touch surface, to be interesting. Different ideas for how the driver could scribble the text was established during the brainstorming phase, but they all shared the same base idea: a semi-flat or flat surface which takes touch input from the driver and presents the result on a some sort of screen or via a projection.

Using the idea of a touch surface for scribble text input, focus was now diverted towards the first two points mentioned earlier, i.e the selection of elements, and navigation between elements. A great source of inspiration was the Microsoft's Surface Dial, a tactile "puck" which is placed on a screen and provides contextually aware controls and options[3]. Using this tactile and movable puck as inspiration, a early concept of a similar product which could be used to control different settings or menus in the vehicle was initially explored. However, this concept was later dropped as we felt that a detachable solution could get lost or the driver could experience mental overload trying to locate the puck when trying to use it.

Still, the idea of a fixed tactile puck with different means of controls, such as being able to rotate, shift, click, and lift, was established and what these means of controls would achieve. However, as the idea was discussed further, concerns regarding navigation between elements was raised. The scope of the project entails social media and other similar applications. The diversity in content placement and number of elements could mean that the driver would have to rotate the dial many times in order to scroll though a large amount of options to reach what they desire. This could potentially require a lot of mental workload from the driver, as they would have to provide a large amount of inputs and check visually to confirm they have arrived at the correct option.

Drawing inspiration from smartphones, the idea of using gestures with the touch area placed on top of the puck was explored. Different gestures could be used to scroll through content while rotating the dial would provide a more precise selection of elements. To provide even further precise selection of elements, the puck could be shifted in different directions, mimicking that of a computer mouse to move around a pointer. Very precise selection of elements could now be achieved and allow for the usage of different diverse applications, while traditional touch gestures in combination with the dials rotational and vertical controls would allow for more natural and tactile navigation and selection.

However, the questions as to why use a dial at all was raised. The track area is used to provide text input and navigate in the system, while the puck itself is used mainly for moving a cursor. Instead, we explored using a trackpad as a single solution, where the output display which contains the GUI that the user would look at, would mirror the trackpad 1:1. Meaning that if the user places their finger in the top-right corner of the trackpad, the element in the top-right corner of the GUI would be selected. The user would select elements based on the general position of the finger on the trackpad rather than a mouse pointer. The touch area would allow for scribble input and using different finger gestures would allow for scrolling,

[3]https://www.microsoft.com/sv-se/surface/accessories/surface-dial

swiping and other actions. The concept of a trackpad seemed a lot more simple, intuitive and interesting than the idea of using a puck, which is what we aimed to investigate by building prototypes.

4.3.3 Rapid Prototyping

While exploring both the puck idea, as well as the trackpad, we wanted to build simple prototypes for both concepts, to get an idea of their viability. Rapid prototyping, which is quickly creating very simple representations of a product, or concept, allowed us to get hands-on with our ideas and to get a feel of how they could work.

The first prototype we built was for the puck, and was as simple as cutting out thick circular piece of extruded polystyrene foam, and placing a strap of paper around it, which could be rotated around the puck. A small piece of soft padding was then glued to the underside of the puck, which created a space between the surface the puck is placed on, and the puck itself. This allowed the puck to be pressed in different directions, and provided the final functionality that we had in mind for the puck. Being able to rotate, press in multiple directions, and use the top of the puck as a touch surface, we could now test how it felt to use these different interaction tools. What we found was that too many different means of interaction in one single unit, i.e the puck, could be confusing for the user. We also noted that the scribble area on top of the puck was quite small, and would make it difficult for the user to easily write entire words, and would most likely end up writing one character at a time. This would increase mental workload, and force the user to focus their attention on text input. Another flaw that was discovered was when pressing the puck in multiple directions, compared to simply using the trackpad where the user moves their finger in any direction, the puck seemed overly-cumbersome and in-precise. Figure 4.2 shows the prototypes together with a large paper containing some of the sketches we did.

The second prototype was of the trackpad. Using a hard paper cutout was sufficient as a simple prototype, as it provided enough resistance and structure needed to get a feel for the concept. Another part that we included in the prototype, was a stand, which could angle the trackpad in various different degrees and positions. By testing different gestures and positions, and comparing that with our experience with the puck, we concluded that the trackpad would be a more viable solution to our research problem, than the puck would.

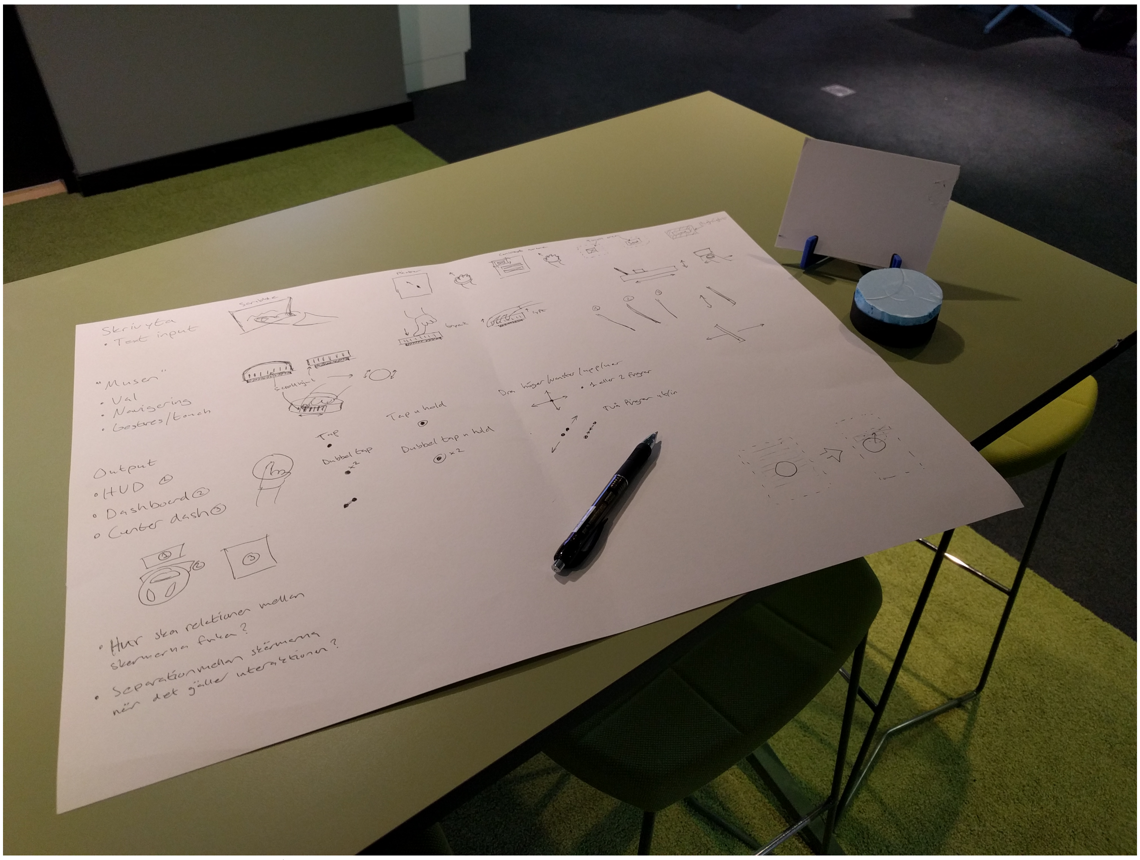

Figure 4.2: A collection of sketches together with the early prototypes

4.3.4 Trackpad

After the rapid prototyping sessions, and having evaluated the concepts based on the prototypes we created, we decided to pursue the trackpad idea. Part of the reasoning for this is the familiarity with trackpads, as it would work like a combination of a computer touchpad and a smartphone screen, meaning that people using the trackpad would already have experience using similar products. Other reasons are the larger input area, as well as the simplicity of having touch based input.

The main points of interaction with the trackpad is the user using their finger to select elements, and using gestures to complete other tasks, such as scrolling, zooming, text editing, and so one. To avoid accidental presses while driving, the trackpad also makes use of a physical click to select elements or perform certain actions, similar to that of certain laptop touchpads. While testing the trackpad we did however discover the need for simple, easy to understand shortcuts to commonly used actions. At this point we added buttons to the trackpad, which would have permanent actions connected to them. Three buttons were added to the top of the trackpad, a "Back" button that we would take the user back one step to the previous screen, a "Home" button which takes the user all the way back to the systems landing screen, and finally a "Options" button, which is meant to bring up additional, contextual options depending on where in the system the user currently is. Unlike a traditional computer touchpad, this concept tracks the relative position of the users finger, and maps that position to the output display. This eliminates the need for precise control by the user, as they would not need to find the exact position of their target element, but instead only need to be in proximity of the target.

As we decided to move forward with the trackpad concept, we decided that in the next design iteration, the concept would be tested by users, and evaluated to get an objective view of how the trackpad could work in a driving environment.

4.3.5 Head-up Display

The system GUI also has an effect on how viable the trackpad, as well as the entire system, is. Having too many elements on one single screen would make it difficult to select the right element, but dividing major elements between different screens would force the user to explore the system in order to find what they are looking for. This means that an effective information architecture, i.e the logic order and layout of the elements in GUI, needs to be established. This was however not the focus of this iteration, but something that we planned to do in the next iteration.

An alternative to using a traditional screens is using a Head-Up Display (HUD), which is a screen being projected on a transparent display. In a automotive context, the screen is often projected onto the front windshield, but some cheaper commercial HUDs use a separate screen which mirrors the users smartphone. Some commonly used information to display in a HUD is the speed limit, the speed of the vehicle, and some basic navigation. As HUDs are becoming more prevalent in cars, we wanted to explore the advantages of using our system in combination with this technology. Testing and evaluation of the HUD is however planned for the next iteration as well.

4.3.6 The Concept

We decided to move forward with using a trackpad as the main input method. Using this tool, the user will navigate through the system, make selections, and enter text. We also decided to use a HUD as output for the system. As of this iteration, the screen will be projected onto the front windshield, and will display the entire system. The HUD is also where the user will direct most of their attention while interacting with the system. The concept can be seen in Figure 4.3.

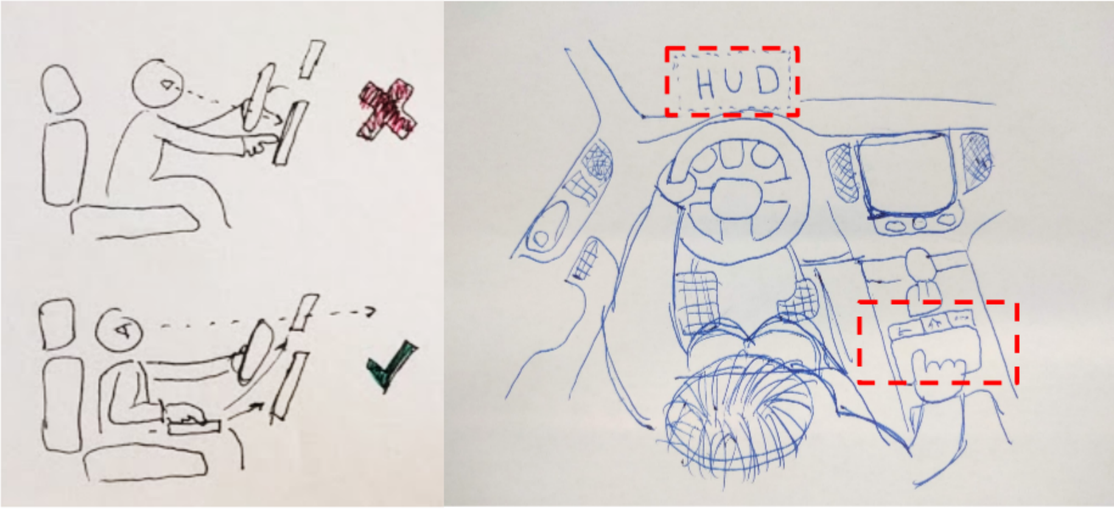

Figure 4.3: A drawing of the concept.

The user will highlight elements in the HUD by placing a finger on the trackpad. The element which is highlighted depends on the placement of the finger relative to the trackpad. If the user moves their finger to another location, the highlighted element change, as seen in Figure 4.4.

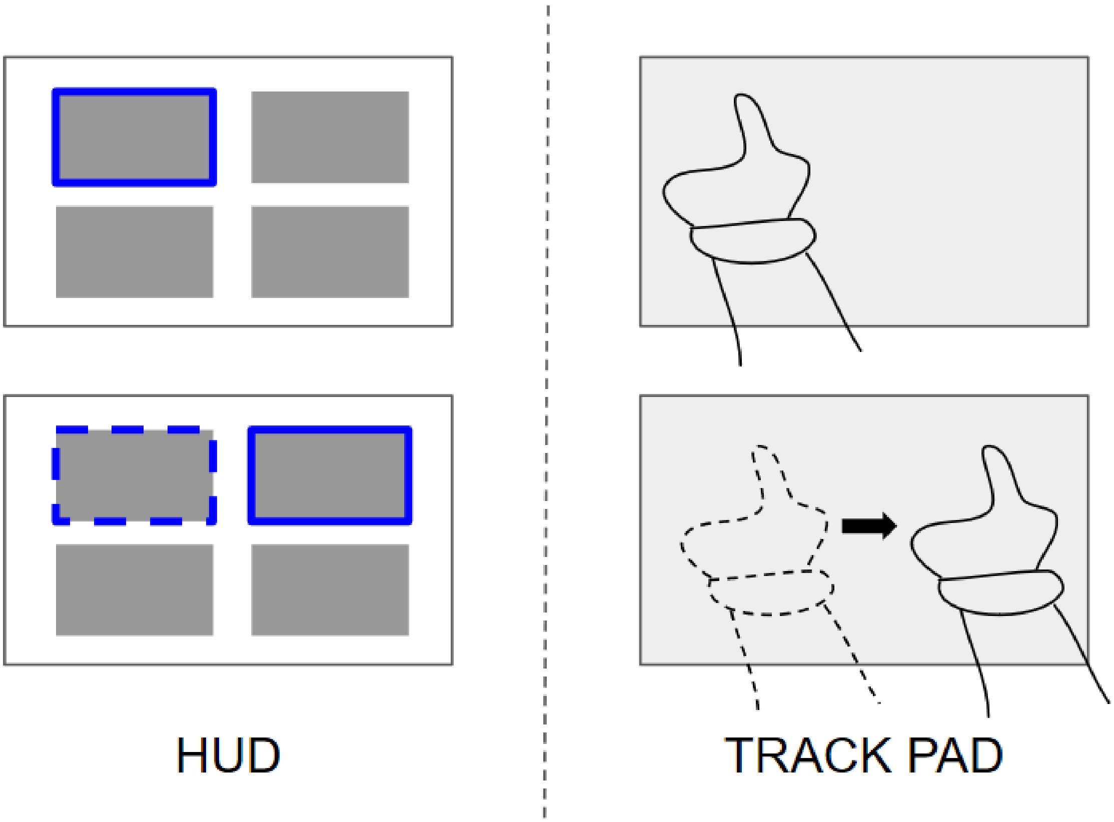

Figure 4.4: The user highlights elements by touching the trackpad. The highlighted element is chosen based on the finger's location.

In order to actually select an element, the user has to click the trackpad, much like how a typical trackpad on a laptop works. To scroll content, e.g., lists, two fingers has to be used, since one finger is used to highlight. This can be seen in Figure 4.5.

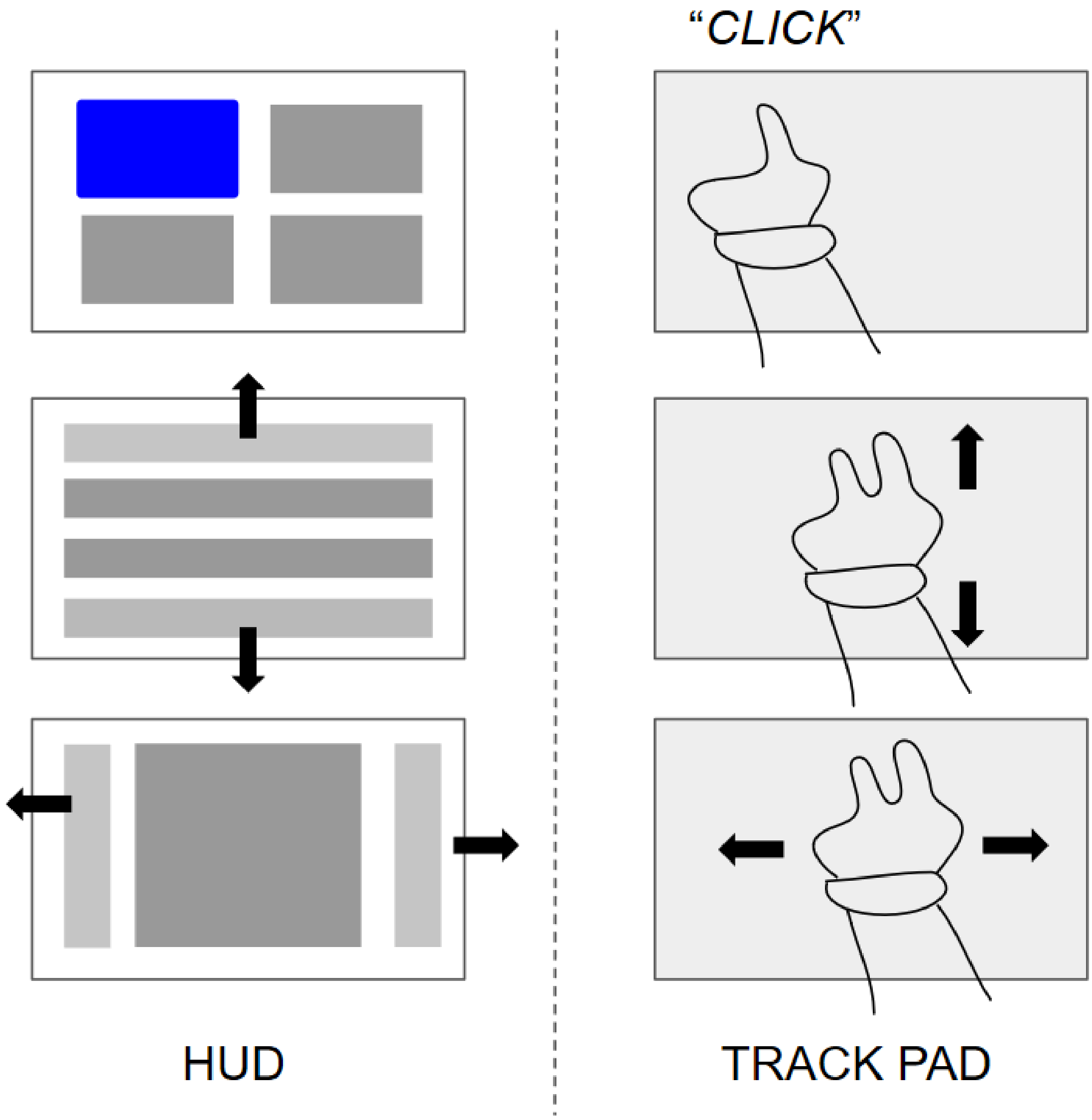

Figure 4.5: Selecting elements is done by clicking the trackpad. Scrolling is done with two fingers

Text input use the trackpad as well, as seen in Figure 4.6. The user will scribble the character or word to input on the trackpad.

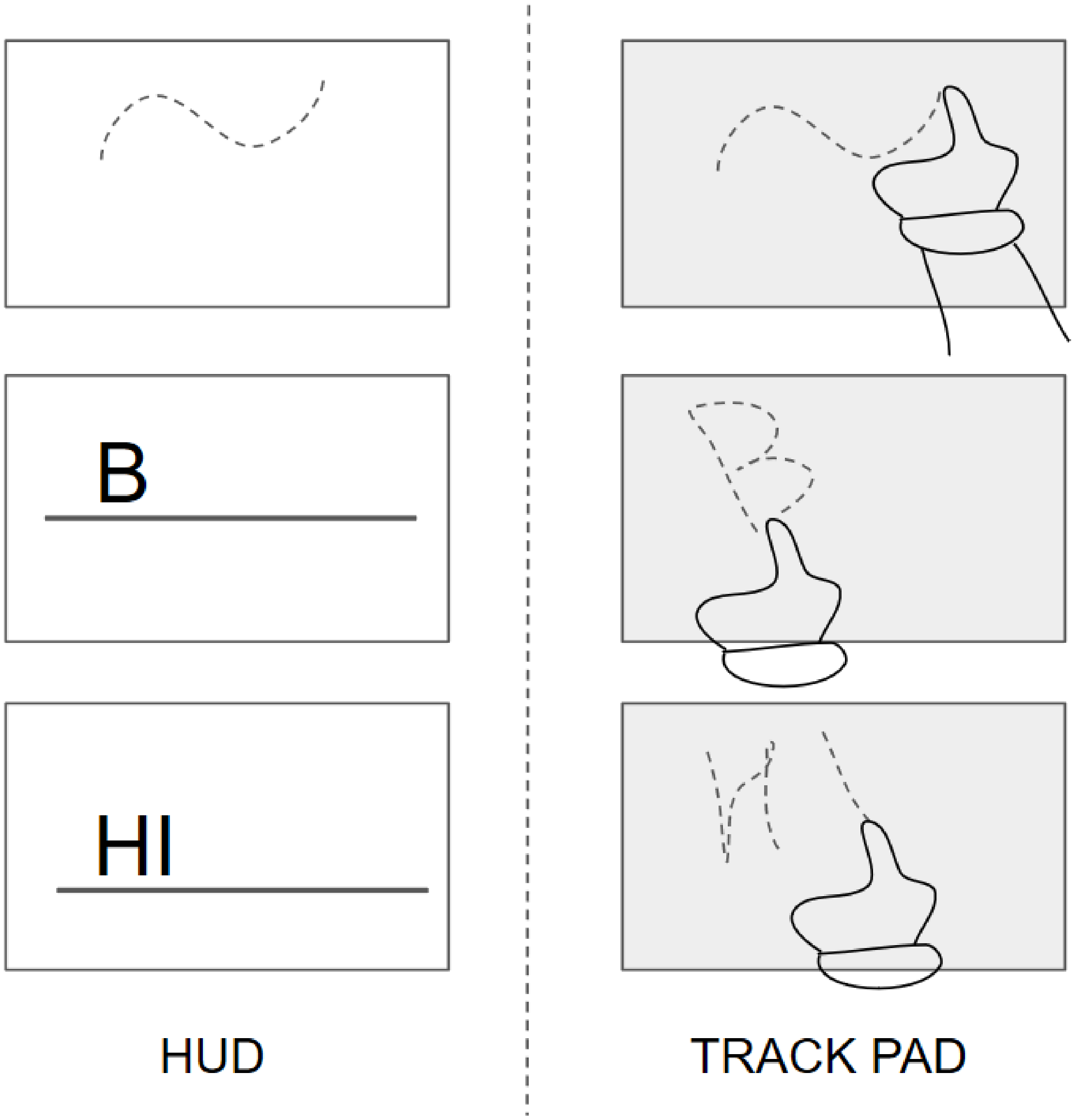

Figure 4.6: The user use handwriting to input characters or words.

Some physical buttons are also part of the setup. This is to provide some easy to reach alternatives to options that are typically used often, e.g., *"Back"*, as seen in Figure 4.7. However, there is another reason for this as well. Since the trackpad is used for highlight elements, the user needs to press the physical back button to leave the handwriting mode.

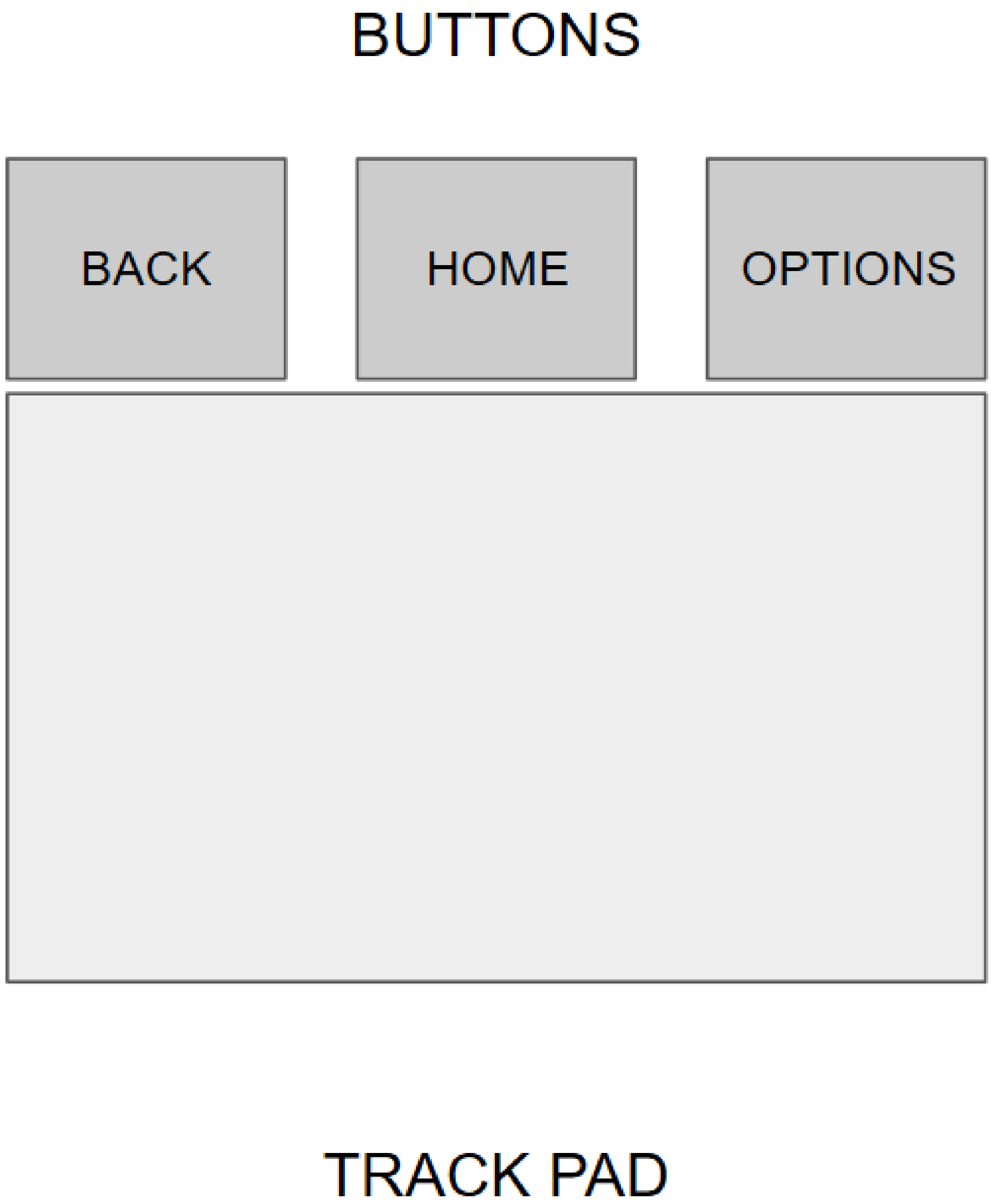

Figure 4.7: The three physical buttons placed above the trackpad.

4.4 Second Design Iteration

For our second iteration, we wanted to take what we got from the first iteration, and develop it further. One of the main goals and focuses of this iteration was to further visualize our concept, as well as decide on how important aspects such text input would work.

Another goal with this iteration was to get actual user feedback of the concepts, which will be achieved by creating high-fidelity prototypes, and testing those with a diverse group of users. By collecting both their opinion and feedback, as well as data collected via observations, we get a collection of subjective and objective data that we can use to further develop our concepts.

4.4.1 Use cases

Using our research as a base, we started this iteration by creating different use cases which served as the basis for the upcoming wireframes, prototypes, and flow charts. By having these use cases established early, we knew which areas to concentrate on, and which ones we should not focus on. These use cases all have to do with communicative tasks, as that is the focus of our research. Other tasks, such as car status, climate control, and so on, is left for future work. The use cases are found below.

- Answer a phone call.
- Decline a phone call.
- Make a phone call to a random number.
- Make a phone call to a contact.
- Read a text message.
- Send a text message.
- Decline a text message.
- Read an email.
- Send an email.
- Read a social media time line.
- Comment on a social media post.

4.4.2 Information Architecture

When first designing the information architecture, the requirements established earlier were used to guide the process, e.g., only 30 characters should be displayed at a given time. A simple layout where only the most pressing options and information was presented was chosen, as to not overburden the driver with information, and because the small display area of the HUD would only allow a small amount of elements. Furthermore, since the information is not displayed on a physical screen but rather projected on the front windshield, extra attention to font size and color scheme of the elements was important. Otherwise, content could blend in with the environment, making it harder for the driver to see. We kept this problem in mind, but since we did not have access to an actual vehicle HUD projector, we instead used a background picture of a driving environment, as seen in Figure 4.8.

4.4.3 Text Input

During the first design iteration, we decided that handwritten input would be a suitable option when it comes to text input. This is an area we discussed extensively, as according to National Highway Traffic Safety Administration, distracted drivers caused over 3000 deaths in 2015 [24]. We wanted to find a method that would decrease the amount of time the driver has to look away from the road, while still being a fast and effective way of typing. The result of a study by Kern et al [25], which is based on the research done by Burnett et al [26], shows that handwritten input is generally better than standard on-screen keyboard input. For this reason, the solution presented in this thesis uses handwriting as the main text input method. We also tested this method in a driving simulator, where the input surface was mounted on the steering wheel and the input was displayed on a HUD. Based on this experience and the research presented in this section, handwriting input was deemed as the most appropriate, and safe method.

There are many cases where the user would enter a text input mode. For example when writing an email, replying to a message, or searching for a specific person in their contact list. As mentioned previously, text is entered by using their finger to write characters, but there are also a some options that the user can utilize to make text input, as well as editing that input easier.

4.4.4 Wireframes

In order to visualize our concept, wireframes were created using Figma[4]. This web tool allows for collaborative design, with up to two users at the same time using their free model. Collaboration makes for faster creation of wireframes, as the work could be divided while still working on the same space. These wireframes were based of the initial sketches and whiteboard drawings, and took them further by making them higher fidelity. We also focused the wireframes around the use cases mentioned in subsection 4.4.1, meaning that we ignored including options such as navigation, car status, and other alternatives that are not related to communication. Figure 4.8 shows the first iteration of wireframes. When creating these wireframes, we used images of real traffic as the backdrop, although we dropped this approach for later

[4]https://www.figma.com/

designs. To view more wireframes, see section A.3 in the appendix.

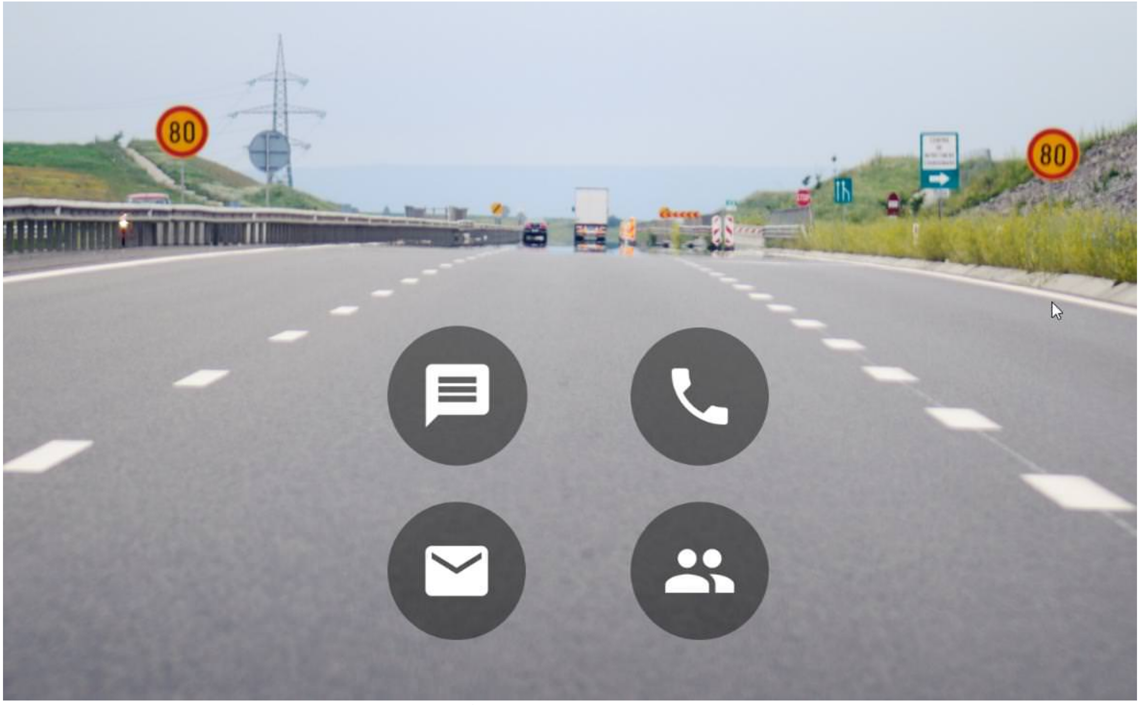

Figure 4.8: An early design of the HUD.

4.4.5 Flowchart

Creating flowcharts played an important role in figuring out the logical steps the user has to take in order to complete certain tasks. The charts which were primarily drawn on whiteboards gave a simple overview that allowed us to catch any superfluous steps that could be eliminated. After reaching a flow of steps that was satisfactory for each task, we could compare those tasks to the steps compiled in the HTA to see which if our system provided fewer or simpler steps for completing a task.

4.4.6 Prototyping

Two different kinds of prototypes were creating and then evaluated based on how they could be used for testing with users. The first prototype make use of the wireframes created in the previous step. The first prototype is an interactive prototype made using Invision[5], which allows for the user to see and experience interactive elements in the wireframes. This prototype also enables the user to test the information architecture by navigating through the wireframes. The second prototype was made in Android, as Semcon requested an Android prototype to later evaluate

[5]https://www.invisionapp.com/

and discuss internally, and was meant to be used in a driving simulator in order to test the navigation while driving.

The prototypes had different intended uses which were meant to provide insight into. The data collected from testing each prototype could then be compiled and analyzed to see which parts of our solution needs to be changed, and which parts works well.

4.4.7 Android Prototype

To properly test the interaction with the system, a functional high-fidelity prototype had to be created. The high-fidelity prototype also serve as a proof-of-concept. Initially, InVision was supposed to be used to create the functional prototype, as this service can be used to quickly create a high-fidelity, interactive prototype using the content created in Figma. However, a number of limitations, e.g., not being able to specify or use different touch input gestures, the need to create a path for every single possible combination of navigational or selective inputs, and so on, put a stop to these plans. Instead, the decision to create an Android application was decided on.

The first major challenge was the fact that Android does not have support for a hover state for touch input which is a major part of the concept. The concept use the idea that the user can explore and confirms where their point of contact is through the highlighting of elements. A hover state is supported when mouse input is used but this sacrifices another important aspect of the concept, namely having multiple points of touch input. As a result of these shortcomings with Android, a new solution had to be implemented. The solution was the use of hitboxes. A hitbox is a bounding box which stores four groups of x and y values, each group represent the corner of the box. For each element displayed, a hitbox was created by keeping a reference to each element and using its' positional data to create a hitbox. The application could then retrieve the x and y value of the touch input and compare it to a list of hitboxes. If the touch input was within the bounds of a hitbox, the same reference used to retrieve an elements positional data could be used to change its properties, allowing it to be highlighted. The solution was effective, allow the user to put their finger on the screen and highlight different elements by simply swiping their finger around the screen.

However, the hitbox solution created a new problem. Android uses a hierarchical system to decide what the user has touched on the screen. So a parent element with any number of child elements within it would first register the touch event. If the parent element does not use the touch event, it would be passed down to its' children and so on. In order to get the hitbox solution to work, the application uses the top parent view in order to get the position of a touch event and compare to the list of hitboxes. This would consume the touch event and not allow it to be transferred down the tree of child elements. Because of this, any child element which has some functionality which is performed on a touch event could not be performed, e.g., a button which opens up a new activity. The solution to this problem was to intercept the implemented methods used by android and re-write what should happen, in this case, highlight or select. The same solution to intercept and re-write the executed code was used for scrolling in lists, which is implemented as a single finger touch event but was changed to two fingers, as one finger is used in the concept to select and explore.

A third problem, which could not efficiently be fixed is the selection of an element. The concept utilizes the idea of a tactile click, much like a mouse button, to select an element. However, this is not possible on a touchscreen. Some initial effort was used to create a solution for this, e.g., connecting a Bluetooth mousepad which the phone could then be placed on and pushed down to register a click, but the phone was too heavy which meant the mousepad could not return to a clickable state. Due to time constraints and the fact that the rest of the application had to be programmed, the decision was made to not implement a solution to this problem at this point.

Lastly, the final problem was how to implement handwriting into the prototype. Some research into how a self-made solution could be created was conducted, but ultimately, this was considered to time consuming to do. As a solution, a third party alternative was used, namely Google Handwriting Input. Although the alternative was not optimal, e.g., the handwriting input area only covered half the screen, it was deemed good enough since the goal of the prototype was the overall interaction with the system and to test this interaction.

In the end, a functional Android application was created, utilizing the gesture based system of interaction developed in previous parts of this iteration and previous iterations. The application only implements the messaging activity. The reason behind this was that the the actual means of interaction, navigation, selection, and so on, does not change between different activities. Another reason for this was that the goal of the application was not to test out the information architecture but rather how a user interacts with it. Figure 4.9 shows the prototype being used while also being mirrored from one tablet to another.

Figure 4.9: The Android prototype being mirror between two tablets.

4.4.8 User Testing

The user tests were divided into two different areas. One test aiming to give insights about the information architecture using the prototype made in Figma. The other test was more focused on the interactions with the system, and made use of the Android prototype and a driving simulator.

Information Architecture Test

The goal with this test, labeled "Test number 1", was to test the usability of our solution and its effectiveness and efficiency. We wanted to see if the users could efficiently navigate and understand the different parts of the system. In order to do this, we used the SUS method, as well as observations, SEQ, measured the CR, TTD and TBE.

Before starting the tests, we aimed to gather 10 users to test with. In order to find testers, we mostly asked people working at Semcon if they wanted to participate in our test. Finding just 10 people was quite easy as the required time commitment was low for each user, as we found from our internal pilot testing the actual test would take around 15 minutes to complete. The test setup consisted of one laptop, with the interactive wireframes that we created earlier being opened, an Apple Magic Trackpad connected to the laptop via bluetooth, and paper cutouts of the physical buttons meant to represent the buttons that are included with our touchpad.

As the test begins, the user is given a brief explanation of the objective of our project, and an explanation of what the test will entail. The user then filled out a demographic survey where the objective is for us to be able to see how different demographics might respond to our system. After filling out the survey, the user had a few minutes to get familiar with the system before we began any actual testing. After the user had tried the system by navigating through the different parts and menus, we asked the user to return to the home screen, so that we could begin giving the tasks and writing down any observations we made, as well as carefully recording the time for each task. The tasks we asked them to perform were:

1. Open and read the text message history with your mother.
2. Write and send a text message to your mother.
3. Open and read the text message history with Kalle Eriksson.
4. Open and read the text message history with Adam Adamsson.
5. Call the number 0733456789.
6. Open the email conversation with Mattias Isaksson.
7. Open the latest email from Mattias Isaksson.
8. Send a reply to Mattias Isaksson.
9. Send an email to email@company.com.
10. Read a social media time line.
11. Open and read the latest post in your social feed.
12. Give the same post a like.
13. Open and read the latest comment to the same post.
14. Write a reply to the comment.

The user would start by reading the task out loud. Once they've done this, they would begin with the task. At this point, we started a timer, so we could determine the amount of time required by the user to complete the task. As the user completed each task, they were asked to think out loud, as to make their thoughts more easily understood, and to make it clearer to us which tasks they struggles with, and why. Each observation was written down to make it easy for us to analyze later. After each tasks, we would note down how long it took the user to complete the task and if they completed it successfully. The user would answer the SEQ and then proceed with the next task. Once they had completed all tasks, the did the SUS. Finally, the user would be asked for any final comments.

Driving Simulator Test

During this iteration, a simulator test was performed with the goal of testing and evaluating the system interaction in a driving environment. This test was labeled

"Test number 2". A open source driving simulation program called OpenDS[6] was used for this test. The program provides simulated driving environments, scenarios, and vehicles. The simulation ran on a laptop and the simulation was displayed on a TV monitor to which the laptop mirrored the simulation. A steering wheel and pedals were connected to the laptop so the driver could control the car in the simulation and to provide a more immersive experience. The actual concept system and prototype consisted of the Android application running on an android smartphone which mirrored its display onto an android tablet. The tablet was attached to the bottom of the monitor. The smartphone was placed to the right side of the chair in which the participants sat during the test sessions. Figure 4.10 illustrates how the user was situated during the test.

Figure 4.10: The setup for the driving simulator test using a steering wheel, pedals, and a phone as trackpad.

The test was split into two groups: one where the participants would be in full con-

[6]https://www.opends.eu/

trol of the vehicle, and one were the vehicle was partially automated. The partial automation was represented by displaying a pre-recorded film of the driving scenario instead of the actual simulation. The driving environment was the same for both tests, a highway environment without any traffic which created a very non-challenging driving scenario. A total of 10 participants with mixed backgrounds, expertise in the project subject, and previous experience with the system, took part in the test.

Before each tests, the participants received an introduction to the subject, the system, the driving simulation or the film, and how the test would be conducted. They would then fill out a demographic form and were then given time to familiarize themselves with the system and the simulation. Participants were told to drive as safely as possible, to respect common road safety rules and behavior, and complete the tasks at a comfortable pace. Once the participants felt comfortable and ready, the test would begin.

One project member would sit to the left of the participant, with a clear view of the participant and the simulation. This member would note down any observations, e.g., the actions of the participants, mistakes, comments, and so on. The second project member would sit to the right of the participant, in order to assist the participant and provide tasks and instructions. This member would at various points during the test ask the participant questions about their surrounding in the simulation, e.g., the color of road signs, in order to gauge their SA. Once all tasks had been completed, the simulation would end. Below are the tasks that the participants were given:

1. Read your most recently received message.
2. Read the most recent message from your mother.
3. Send a reply to your mother with the text: "I am almost there".
4. Read the most recent message from Anna Andersson.

After the test, the members would ask the participant to gauge their own mental workload. This questioning was based on the SWAT, a subjective and scaling measurement technique used to assess a participants mental workload levels. Finally, the participant would fill out a SUS form and be asked for any final comments.

4.5 Third Design Iteration

As the final iteration, the goal was to take the data gathered from the previous iteration, and make changes to our concept according to the findings we made, as well as test those changes one final time. This way, the final product would be tested and evaluated, providing answers to our research questions, and serve as a solid basis for the SEER project to expand on.

4.5.1 Re-designing

The first step in the final iteration was to re-design the initial screens created in Figma. Using the feedback we got from the previous iteration, we decided not to use current wireframes as a starting point when re-designing. This way, we could apply all the information we had learned and create a higher fidelity design, and not be limited in what we could add or remove by our old design. Before starting the actual design work, we decided to not include any screens of social media. This was done as we felt that creating design for social media would likely be a unnecessary step to take, as each social media company would create their own application to use within the system. Figure 4.11 shows one of the re-designed screens. Additional screens are included in the appendix under subsection A.3.2

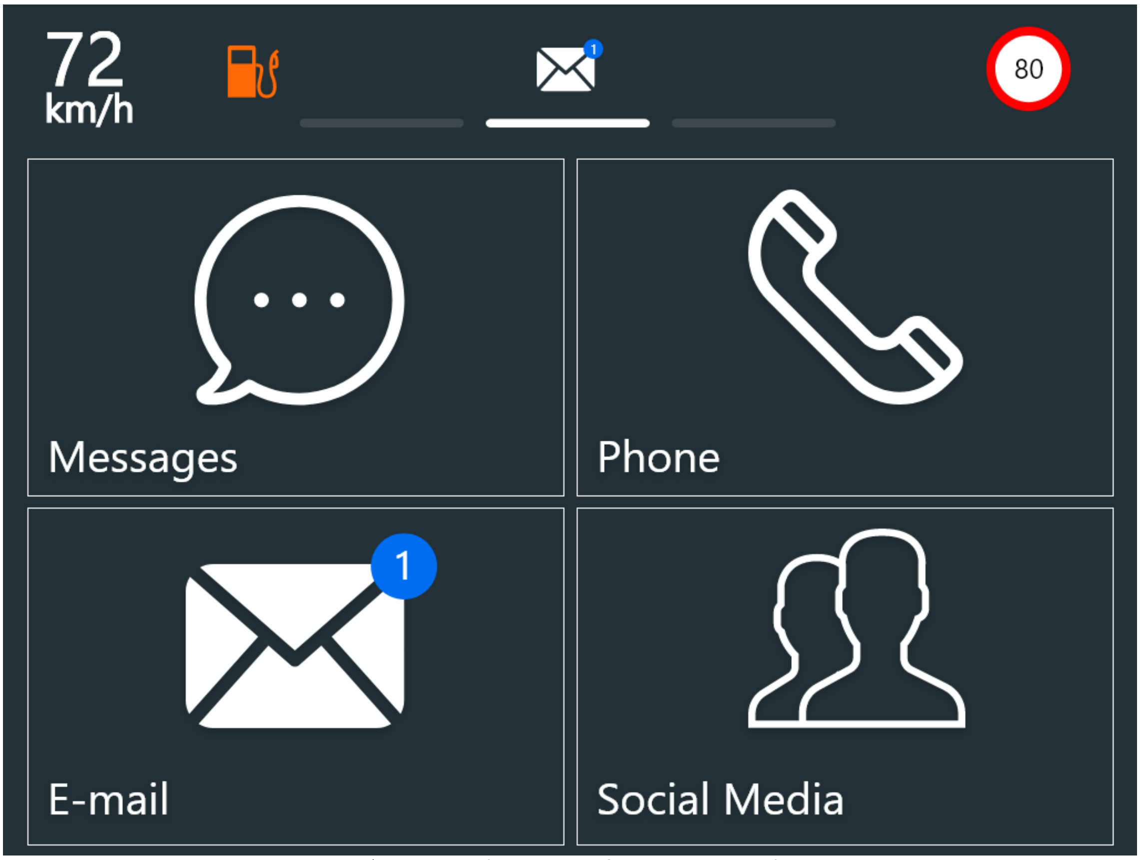

Figure 4.11: A screen from the final design of the concept.

Small updates such as changing text labels could be applied to increase the user's understanding of where they are in the system, what they can or should do, and where they should navigate. Other updates to increase the user's efficiency was also implemented, such as reducing the number of steps to complete tasks, views, and options.

Additional Features

As we tested the usability of both the interaction system, as well as the information architecture, we then used this iteration to implement some of the additional ideas and features we got from our original brainstorming session into our new design. These features include:

- A primary screen on the HUD which displays information such as current speed, speed limit, car system alerts, to the driver.
  This is similar to how current HUDs are used today [27]. It allows for vital information that drivers are accustomed to, right in the driver field of view.
- The system tracks the users eyes, and can dim the HUD if the user is focusing too much attention to it.
  This features is meant to discourage the user from spending too much time just using the system, and not enough time and attention on the road.
- Disable certain tasks when ADAS is not enabled.
  Some tasks require too much attention from the user, and to ensure the safety of the driver using the system, as well as everyone else in traffic, the system disables certain tasks when driver assistance is not enabled. If the user has ADAS enabled and is currently performing a task, and the situation requires the driver to take control, the system will not allow the driver to continue the task at that time, but will save the current state, i.e the driver can continue right where they left of, as soon as ADAS can be enabled again-

4.5.2 Final User Tests

As a final step in the design process, we wanted to evaluate the newly created designs. In order to do this we set up a third user test labeled "test number 3", which is set up the same way as the first test which also investigated the information architecture. We decided to also test with just 5 users, unlike the first test where we had 10 users. An article by Jacob Nielsen describes why testing with 5 users is sometimes enough [28], and as we learned from the early tests, after 5 users we can accurately predict what feedback we will get. Another reason for testing with 5 users, is that at this time of the project, we had to think about how to most efficiently allocate the time that is left. Therefore we decided that we should test using 5 users, and spend the time we save from that decision to proper analyze and the data we get.

For this test we used the newly designed screens, made interactive using Invision. As we knew precisely how to set up the test, we could quickly get started on testing with users. There were however a few differences from the first test, with one difference being that we decided not to use the Apple Magic Trackpad this time, as we felt it didn't provide anything of value that the laptop trackpad did not. We did also re-write some of the tasks that the user has to perform during the test. This was done because of changes to the design, as well as to make the tasks clearer to the user. As this design does not include any interactions with social media, the tasks related to that area were also discluded. However most the actions the user has to take were still the same as the first test. The tasks were:

1. Open and read your latest text message.
2. Reply "Hello" to that message.
3. Write a new message, "Hello", to your mother.
4. Before you send the message, try to edit the message.
5. Call the number 0733456789.
6. Hang up and go back home.
7. Open the email conversation with Mark Cuttings.
8. Reply "Sounds good" to that email.
9. Write an entirely new mail to Mark Cuttings with subject "Hello" and message "It was nice to meet you"

One key point we took from the first test was that in order for the user to more easily understand the tasks and what they are doing, it's important that what they are told to do, also matches what happens on the screen. For example, as they are told to write an email with a certain text, when they are performing that task, as well as when they are finished, the completed email should be presented as the exact same mail that they just wrote. In the first test, we used a template for the emails and text-messages, which were always the same regardless of the users actual input. The template was used to save time for us, but caused a lot of confusion among some of the testers.

To gather data, we recorded task completion time, how difficult they thought the tasks were, and asked for general thoughts and feedback. To conclude the test the users also filled out the same form as from the first user test, which is then used to compile a SUS score.

Chapter 5

Result

In this section, the results of the design process are presented. This includes the result from the brainstorming session, survey regarding driver habits, the field research, as well as the data gathered from the user tests. The results of the tests are divided into three sections, where each section belongs to one of the three tests that were conducted. The implications of these results are brought up later in the Discussions chapter.

5.1 Survey

The data we got from the survey conducted during the research phase of the design process was used to understand driver habits and needs. The survey was open to responses for an entire work week. When the survey was closed, a total of 153 persons had answered it. Out of those, 120 were relevant to us, i.e., they were driving in primarily highway environments or both highway and city environments equally. The full survey we sent out can be found under section A.5 in the appendix.

Demographically, around 85% were male and the majority of responds lived in either Sweden or the USA. However, the results were more diverse in other areas, such as age distribution and driving experience, i.e., how long the participant has had a driving license.

To get an overview of the data, the answers that we considered relevant to our project were compiled into the following categories:

1. Drives in both city and highway environments without ADAS.
2. Drives in both city and highway environments and owns a vehicle with ADAS.
3. Drives primarily in highway environments without ADAS.
4. Drives primarily in highway environments and owns a car with ADAS.

For each one of these categories, two types of graphs were created. The first graph show how often the drivers included in the category performs certain activities. The second graphs shows how comfortable they feel performing those activities. The above mentioned categories and their respective graphs are presented on the next page. One thing to note is that the amount of respondents between the first and second graph may differ. This is because the first graph's question was mandatory to answer while the second graph's question was not. The reason behind this is because if a respondent never performs an activity, they most likely could not answer how comfortable they are with that activity because they never performed it.

Drives in both city and highway environments without ADAS

This category combines those who do not use ADAS and does not drive in any specific environment. This combination was the most common one, i.e., this combination contained the most respondents, meaning that the data gathered here represent the largest group of drivers. By looking at Figure 5.1, we can see four activities, e.i., social media, email, web browsing, and news, blogs or forums, which a clear majority of drivers do not perform at all. Direct messaging sees a slight increase in occurrence, but voice calls was the only activity performed regularly by some drivers.

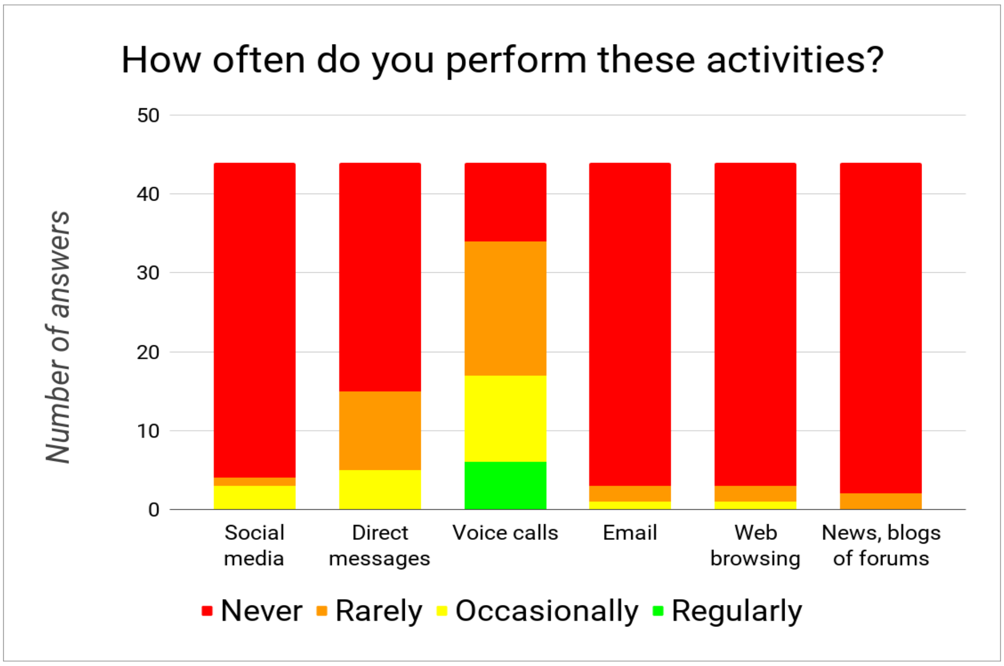

Figure 5.1: Graph showing how often drivers of the first category perform certain STs.

Figure 5.2 shows how comfortable the drivers of this category are performing the different activities. The results show that a majority of drivers are not comfortable performing STs in general, except for voice calls. For this activity, voice calls, about a third of responding drivers were a little comfortable or very comfortable with performing it. No driver felt completely comfortable with any of the activities.

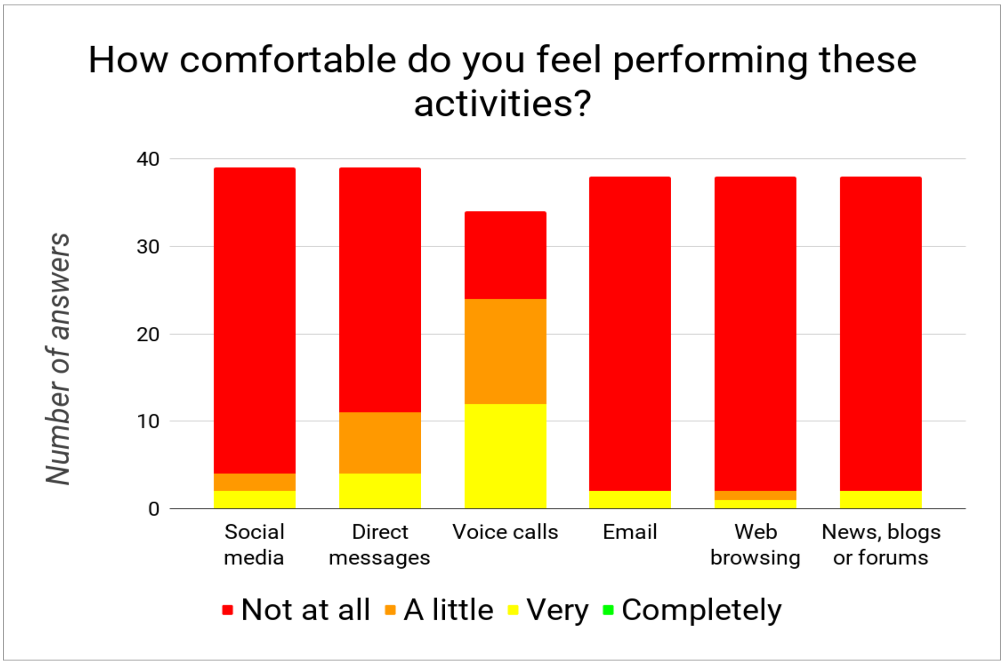

Figure 5.2: Graph showing how comfortable drivers of the first category feel performing STs.

Drives in both city and highway environments and owns a car with ADAS

This category has a small sample size compared to the previous category, but the results show that a higher share of drivers of this category seem to perform STs more frequently. As can be seen in Figure 5.3, all activities, except for news, forums or blogs, sees an increase in frequency of how often they are performed, especially direct messaging and voice calls with a slight shift for social media as well. However, a majority of those who answered still do not engage with certain STs too frequently.

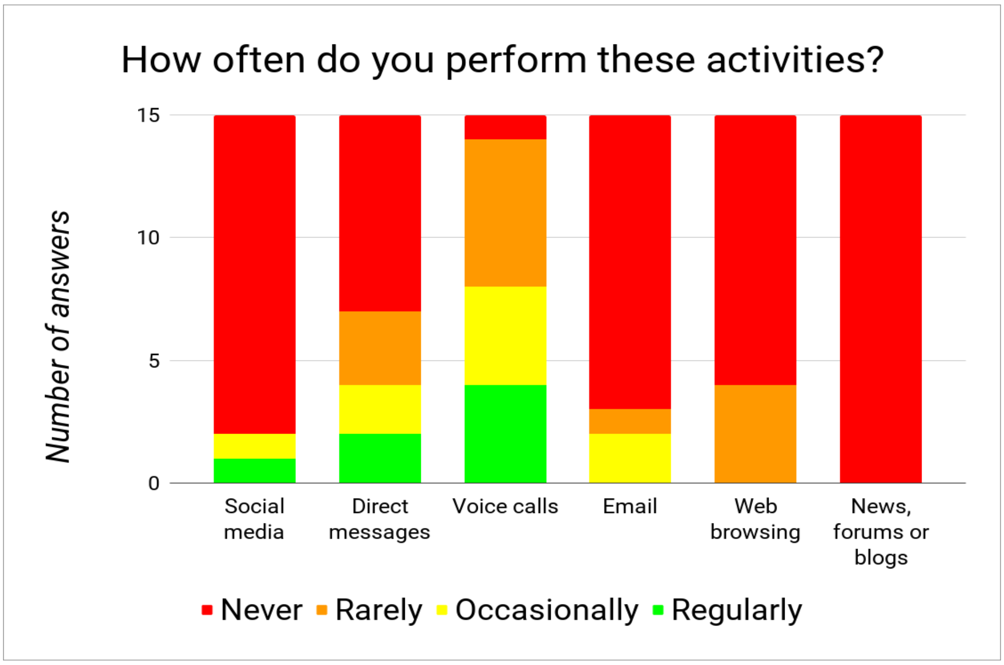

Figure 5.3: Graph showing how often drivers of the second category perform certain STs.

A much larger difference compared to the previous category can be seen when looking at how comfortable drivers are with performing STs. From Figure 5.4, we can see that every type of activity receives an increase in level of comfort, especially voice calls were only one driver was not at all comfortable, and has at least one driver claiming to be completely comfortable performing that activity.

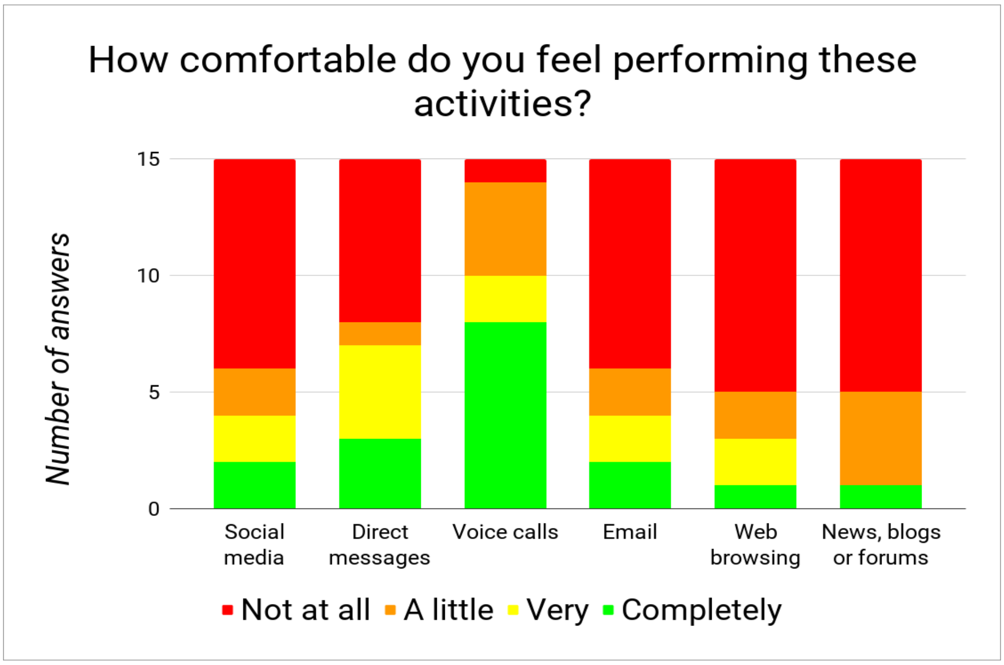

Figure 5.4: Graph showing how comfortable drivers of the second category feel performing STs.

Drives primarily in highway environments without ADAS

The results for this category are quite similar to those of the first category, with a slight difference in the frequency of how often certain activities are performed, i.e., social media and direct messaging, as seen in Figure 5.5. A larger difference can be found in comfort levels, as seen in Figure 5.6. The most notable difference is an increase in number of drivers who responded "Completely" for social media, direct messages, and voice calls.

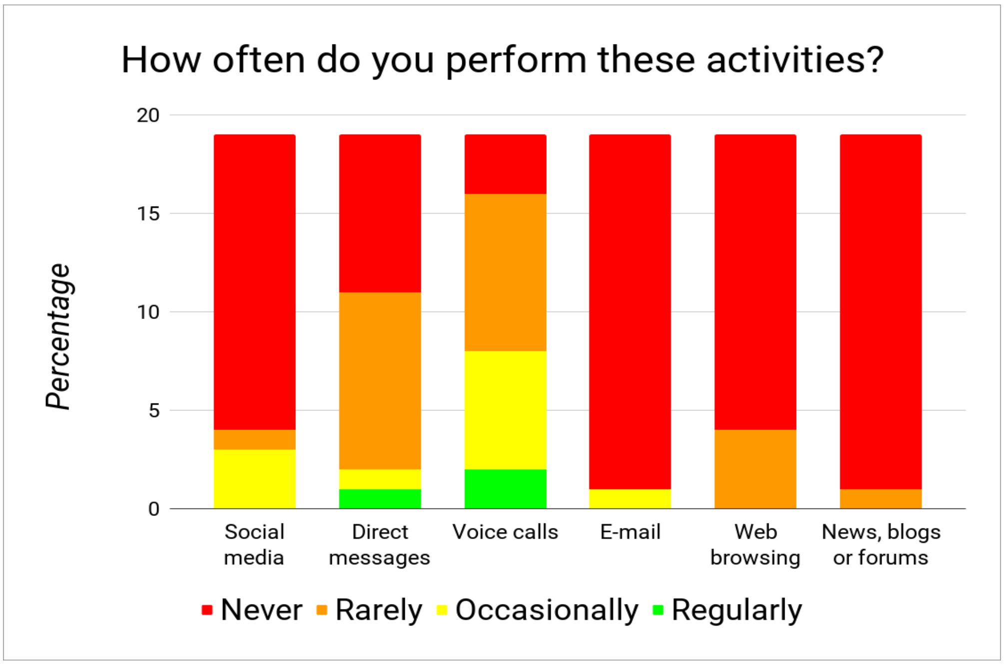

Figure 5.5: Graph showing how often drivers of the third category perform certain STs.

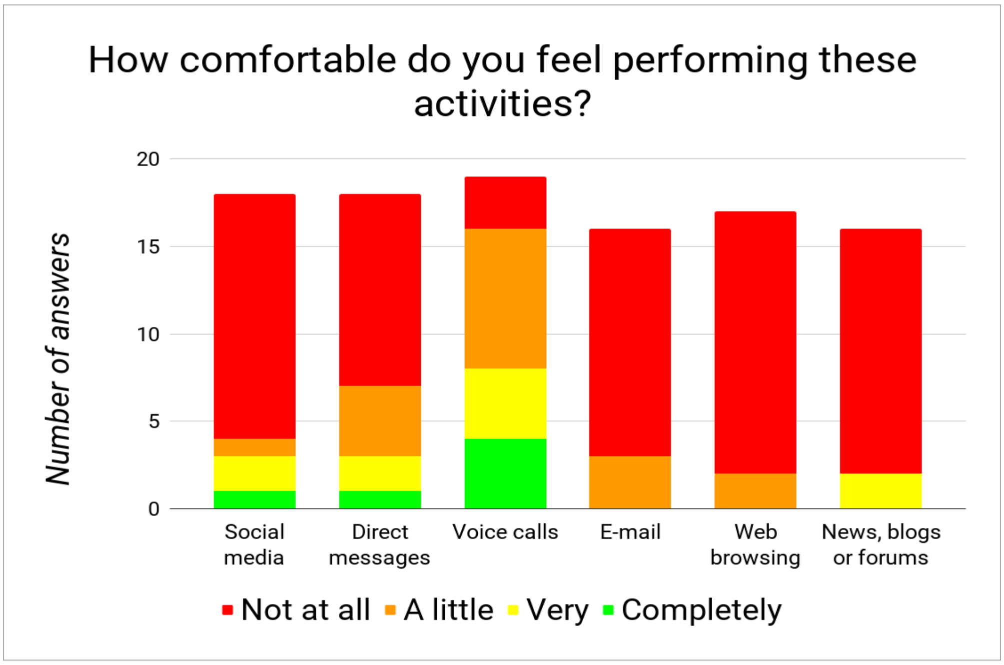

Figure 5.6: Graph showing how comfortable drivers of the third category feel performing STs.

Drives primarily in highway environments and owns a car with ADAS

As seen in Figure 5.7, this category received a similar amount of respondents as the second category and shows similar answers, with some major differences. The most significant is the number of drivers that "Occasionally" perform voice calls. There are also some differences for the other activities, e.g., some drivers interacting with news, blogs, or forums. Each task shows at least one driver being completely comfortable with each task.

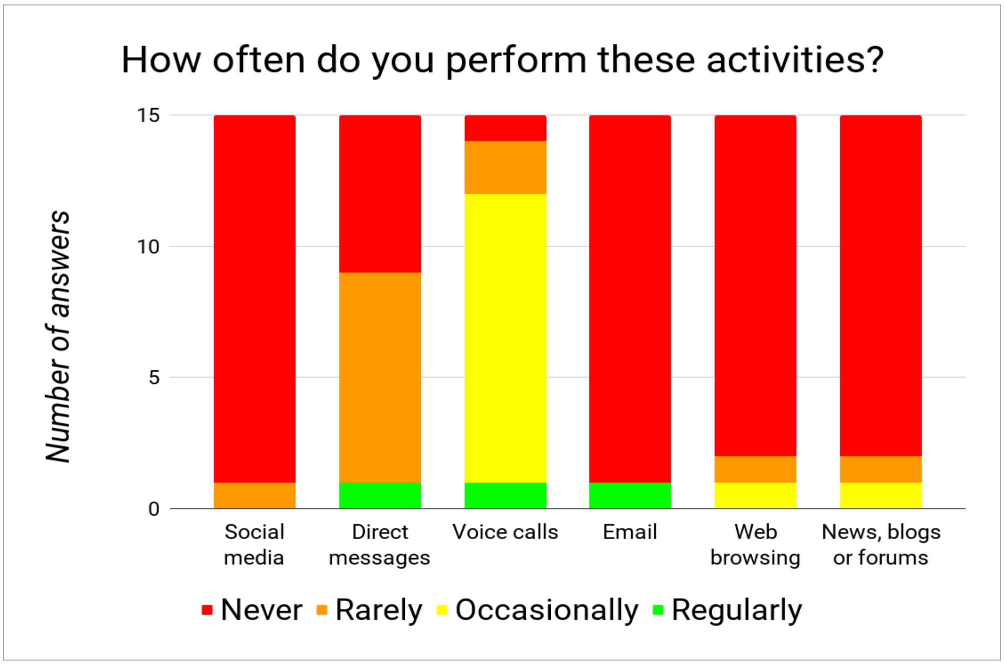

Figure 5.7: Graph showing how often drivers of the fourth category perform certain STs.

Figure 5.8 also shows similar results as category two. However, social media, email, and web browsing lack any drivers that responded "Very" and a lower amount of drivers that responded "Completely" for voice calls.

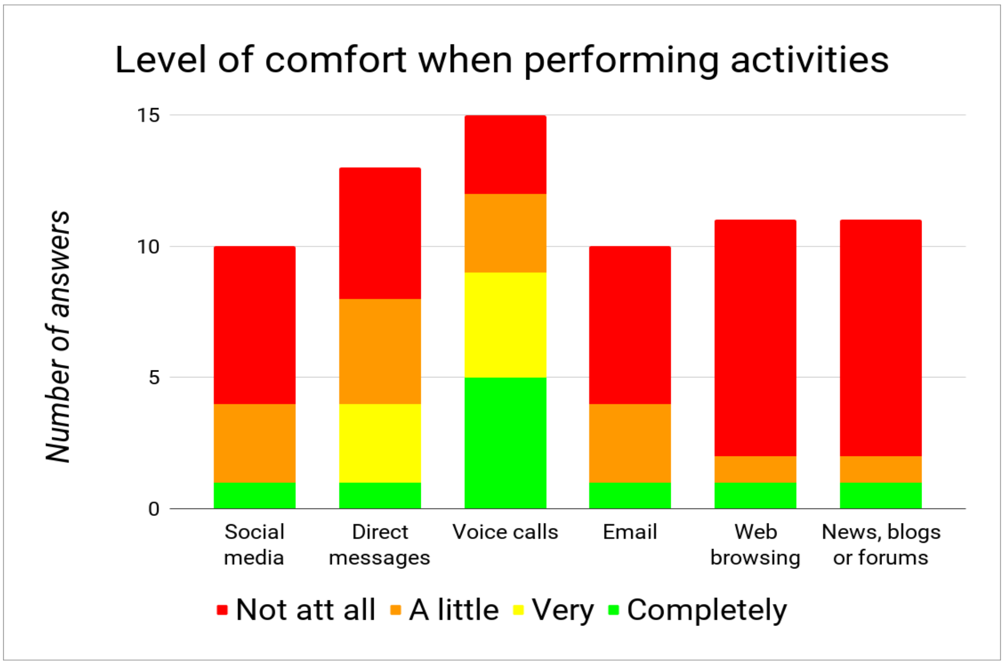

Figure 5.8: Graph showing how comfortable drivers of the fourth category feel performing STs.

For all categories, we also looked at the primary means of interactions, i.e., are they using voice, buttons or touch input in order to perform STs. Our data found that touch input was the most popular for all types of tasks, except for voice calls, where voice input was the most popular.

5.1.1 Follow-up Questions and Personas

For the follow-up questioning, a total of 15 e-mails were sent. Only 7 responded and only 5 of those responses were deemed usable, as the others provided only "Yes" and "No" answers. The recipients were chosen from those who provided their e-mail when they answered our survey, and were willing to answer follow-up questions.

The personas we created from the relevant data gave us insight into drivers needs and wants, and was used to help establish requirements. Below is one of 5 personas that were created:

Person 1
Driving Habits
Gender: Male
Experience: 2 - 5 years
Age: 18 - 24 years
Avg. nr. of driving sessions: One or more times a week
Country: UK
Avg. driving session length: < 30 minutes
Main reasons: To perform errands, more convenient

Interaction
"I would like to be able to perform voice calls or dictate messages using an in-car system."

"I don't feel the need to [interact with social media or email]."

"I don't think that I would ever feel emails or social media urgent enough to warrant using while driving."

Information
"I can see incoming texts..."

"A HUD system that displayed messages on the windscreen of the car could be useful. . . "

Comfort
"... I would only feel comfortable actually using my phone while driving if the car had [ADAS]..."

Safety
"[The HUD] should probably only activate while on a motorway. . . "

5.2 Field Research

The information gathered from the field research was organized into different categories, where each category represent a car brand whose infotainment system and interaction tools we tested. We choose not to use specific car models as categories, and instead simply choose the brand name. Below are the notes presented for each of the different car brands.

BMW

- Uses a rotary dial with a touch surface on the top.
- Can use voice commands.
- Some gestures are possible, such as answering and dismissing calls, raising and lowering the volume.

Notes:

Gesture controls worked well occasionally, but did not feel reliable enough to be used as something more than a gimmick. The placement of the gesture sensor was unclear and made it difficult to understand where you could perform gestures. Only a few gestures were available, with one being programmable by the user.

Mercedes-Benz

- Has a small touchpad on the steering wheel.
- Rotary dial.
- Touchpad with three buttons.
- Voice controls.

Notes:

A lot of redundancy in the system. There are multiple ways to navigate through the menus.

Volvo

- Touchscreen.
- Lots of apps.
- Has a HUD which features current speed, and speed limit among other things.

Notes:

Has a good user interface that was easy to navigate. You can write on the screen to input characters, but the placement of the touch screen made this very exhausting for your hand. In comparison, the touchpad on the Mercedes and BMW was placed in an arm rest position.

Tesla

- One big center display
- Screen in the dashboard

Notes:

Touch and voice input was used for all interactions. The big screen has a good, although sometimes unclear user interface. Some information, such as navigation was shown in the dashboard as well.

Nissan

- Uses mostly buttons and dials for interaction.

Notes:

Somewhat poor UX, as there were few shortcuts and help alternatives.

Volkswagen

- Touchscreen
- Mostly buttons and some rotary dials

Notes:

Makes use of a mix of tradition buttons, touch based buttons, and touchscreen. Some information is hidden while not interacting with the system, when moving your hands closer to the touchscreen, information expands into view.

5.3 Conceptualization

This section will go through the results from the conceptualization phase that occurred at the start of the first design iteration. This includes the result of the brainstorming session, and as well as the results from narrowing down ideas, and prototyping.

The ideas we came up with during the brainstorming were very diverse and touched on a lot of different areas. In order to create to organize these ideas, an affinity diagram was made where the ideas were put into different categories. When the ideas had been places in their respective categories, we discussed each idea and decided to eliminate the ideas that we felt should not be pursued further. In the end, we had gone from a lot of varied ideas, to a smaller selection of ideas that we could develop further. The categories with a selection of ideas can be seen below (note that this does not include every single idea, just a small selection).

- System Behavior
  - Fade out certain tasks when ADAS is disabled.
  - Hide information when not interacting with the system.
  - Use front window as screen space.
  - Enable different tasks depending on level of automation.
- Tangible
  - Joystick.
  - Touch screen.
  - Touch pad.
  - Detachable device.
  - Computer mouse.
- Steering Wheel
  - Different input areas on the steering wheel.
  - Tap steering wheel to make selections.
  - Touch sensors behind the steering wheel.
- Gestures
  - Touchpad gestures, similar to gestures on a laptop touchpad.
  - Smartphone gestures, i.e. pinch to zoom, rotate, and so on.
- Design
  - Simple interface.
  - Customizable interface.

Using the ideas that came from the brainstorming session, with key ideas we wanted to pursue, prototypes were developed to enable us to quickly test these ideas. As we tested the prototypes for ourselves, we realized that the idea of a trackpad as a single point of input would be the most interesting for us to pursue, as we found it to have the most potential out of all the ideas we had. As a final outcome of the brainstorming session, we also decided to further pursue the idea of using the front windows as screen space, i.e., using a HUD as the systems output device.

5.4 User Tests

A total of three test sessions were completed for this thesis project. Two of the sessions focused on the IA while the third focused on the system interaction. The results of the three sessions conducted are presented below.

5.4.1 Test Number 1

The feedback gathered from this test was written down and summarized in a table, which can be seen below. The task number represents the task that the user was instructed to perform. These tasks can be found in section 4.4.8. The second column, titled "Observations & feedback" contains any observations we made during the test, as well as the any feedback that the user provided regarding a particular task. Observations and feedback that were very similar to previous ones were removed, or combined.

Task number	Observations & feedback
1	The task appears to be completed before you press a conversation. Everything looks like a single feed, and not multiple messages from different people. After having entered a conversation with "Mom", there is no indication that you are in a conversation with "Mom", i.e no title at the top of the screen. The mail icon looks like it could also be for text-messages.
2	It is unclear how to send the message. There is no "Send"-button. Nothing tells the user how to send. It is unclear how to exit scribble mode. Pressing the "Back"-button is unintuitive, and feels more like a cancelling action. Both the "Back"-icon and "Send"-icon are arrows pointing to the left.
3	It is unclear that the "New message"-button leads to more contact options. Unclear that the first feed is sorted by new conversations. It is hard to find Kalle as he does not appear in the conversation history.

4	Users want to press the contact-suggestion right away, without first leaving scribble-mode. It is unclear how to proceed after contact-suggestions appear. There is some confusion as to why the scribble area is only half of its previous size.
5	Nice to confirm before placing a call. At this point it is becoming more of a habit for users to press the "Back"-button to exit scribble mode. The phone icon makes it look like the call will be places as soon as you press it. The icon to make a call is the same as the icon for entering scribble mode.
6	All lists look the same, even if they belong to different things. Unclear when you've reached the end of the task as "everything" looks the same. Difficult to understand where you are after you have pressed an e-mail.
7	Simple task with no confusion.
8	It is unclear what the "X"-button does. You can not see the mail you are replying to.
9	There are a lot of steps involved in sending an email. It is difficult to know which part of the e-mail you are filling in, as nothing indicates whether it is subject, or actual e-mail content. Would likely feel better if some steps could be combined. The icon for writing a new e-mail is not entirely clear. Once you have written something, for example the subject in an e-mail, there is no way to see the subject line later.
10	Sometimes some guesswork is required to know if you are at the right place. Posts and comments look the same. The icon for social media looks like it could be for a contact book.

11	Simple task, although no confirmation that you have liked a post.
12	It is unclear which post is the most recent one. There are a lot of nested posts and comments which makes it very difficult to know where you are.
13	It is unclear that you are writing a reply. Difficult to see if you are doing things correctly as there is no feedback from the system.
14	Again no feedback when you have completed the task. It is difficult to know where you are in the system hierarchy.

Aside from feedback and observations, objective measures along with subjective measures was recorded as well. The results are provided below. Figure 5.9 shows how many times a task was completed successfully by a user. E.g., task 1 has 7 successful completions, meaning that 2 out of the 9 test users failed with that task. The CR calculated was 92%, meaning 8% of all tasks conducted by users resulted in a failure.

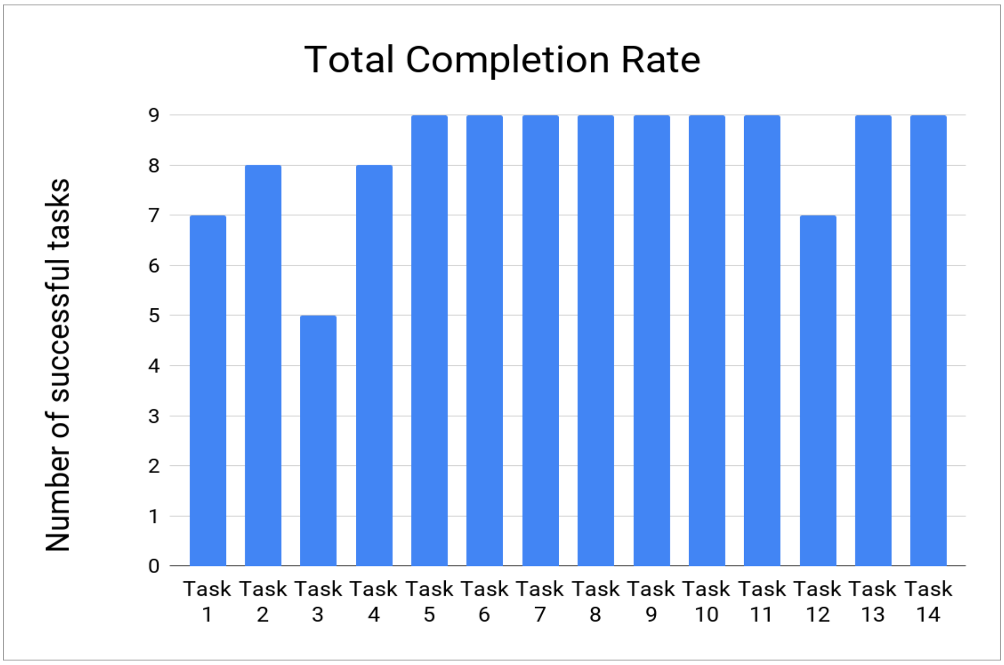

Figure 5.9: Graph showing the total number of successful users for each task.

Figure 5.10 shows the average TTD for each task, recorded in seconds, meaning the average amount of time required to complete a task from start to finish. Using these values, the TBE was calculated. A final value of 3.1 tasks per minute was achieved using this data.

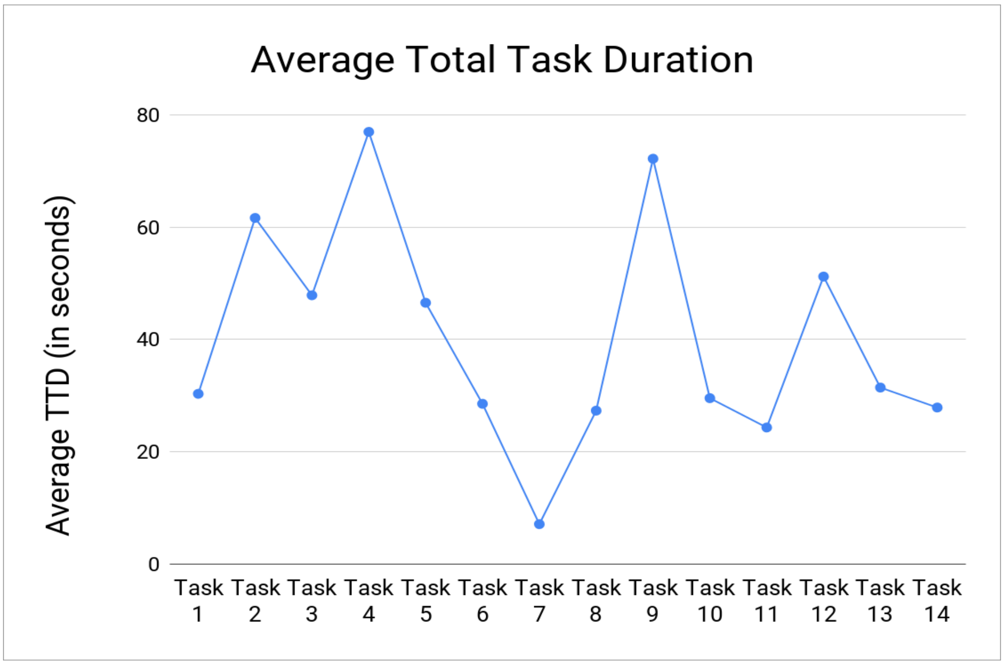

Figure 5.10: Graph showing the average amount of time, in seconds, it takes to complete each task.

Figure 5.11 shows the average result of the SEQ for each task. A high value is desired, but dips in ease is noticeable in certain areas, e.g., task 1 to task 4, task 7 to task 9, and task 11 to task 12.

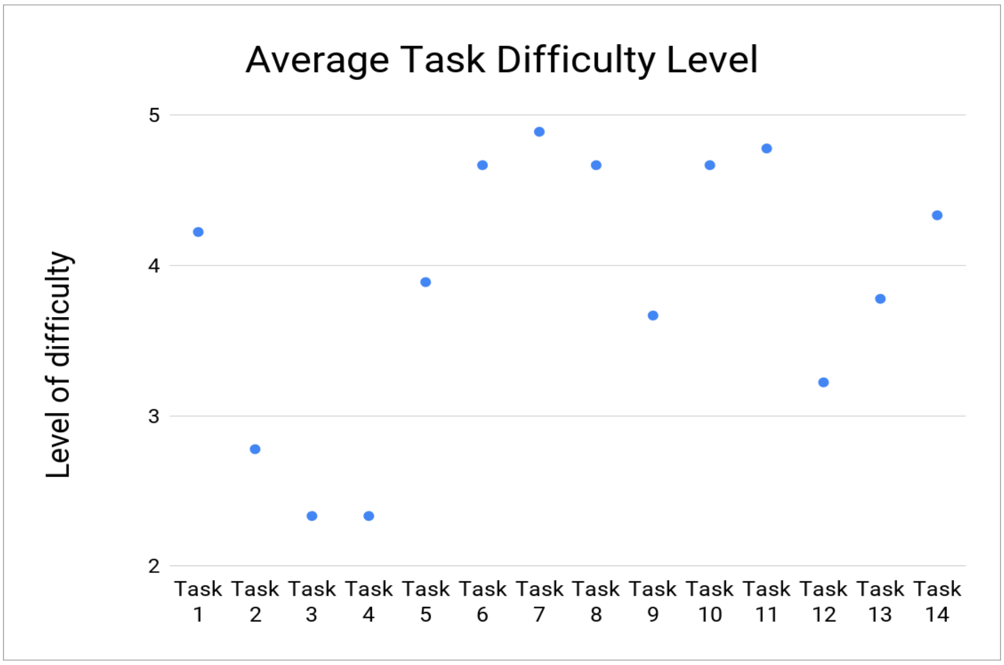

Figure 5.11: Graph showing user difficulty level for each task. A high number means the tasks was easy, while a low number means the task was hard.

The final graphs for this test contains the average value for each of the 10 categories of the SUS survey. A high number for each category is desirable. Figure 5.12 shows these values. A high value is achieved in the "Support" and "Pre-Knowledge" categories. The values of the other categories rest between 5 to 6,1.

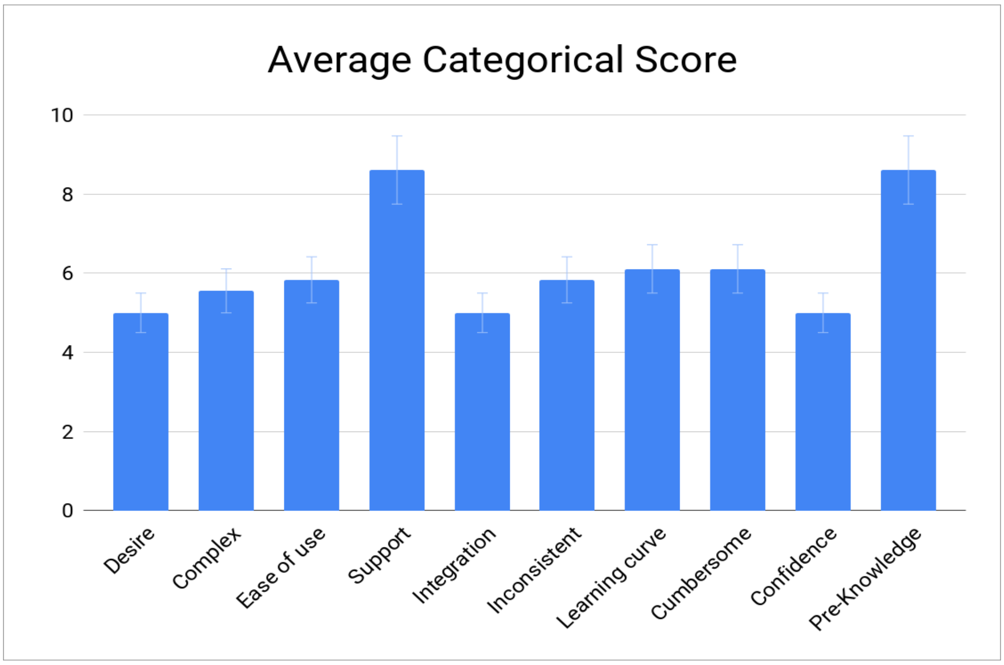

Figure 5.12: Graph showing the average score for each category in the SUS survey.

By adding together the values of each category, a final SUS score is achieved. The SUS score we got for this test was 61,7, which could be considered barely ok.

5.4.2 Test Number 2

The second test session, where we tested how the system interaction works in a simulated driving environment, different key points could be extracted from our observations, the different users' comments during the test session, and the retrospective probing.

- The users liked the highlighting system overall.
- It became clear with the initial users that more time with the system and the driving simulation was required, in order to both understand how they work but also control. Once this time was given to later users in the test session, the users responded more positively to the system.

- There was a small disconnect between how the users thought the system worked and how it actually worked. This was mainly displayed by the fact that a lot of users did not touch the touch screen until they wanted to make a selection or scroll. When later asked about this, the common reason was that they have grown accustomed to how a touch screen usually works, e.i., keeping a finger on a touch screen is the equivalent of a long press and not the highlighting of elements. However, once this became more clear to the users, they would put their finger on the touch screen and move it around in order to gauge where their point of impact was and what element their finger were currently over.
- Many users from the manual group displayed a dangerous driving behavior in situations which required full attention towards the driving environment and control of the vehicle. Instead, users would continue to focus on interacting with the system to complete the task they were currently on. When later asked why they behaved this way, a common explanation was that they did not feel as if they were in any danger due to the nature of the simulation.
- The users in the manual group felt they had to learn two things, to both control the vehicle and interacting with the system.
- users who have some previous experience with the system displayed a better control of the vehicle when interacting with the system. These users made it clear that this was because they had cleared the initial learning curve of the system, but also the driving simulation.
- users liked the gesture shortcuts, as it reduced their need to locate the back alternative visually and then selecting it.
- users disliked the need to tap on the screen to select an option. The users felt that a clickable button, much like how a traditional mouse pad would work, is a better solution.
- Some users felt that a lack of feedback, e.g., due to not having their finger on an element, was difficult. They would much rather always get some feedback in order to understand where on the track pad their finger is.
- users felt there was a lot of information displayed on a small area, especially text.
- Using the system and driving the vehicle at the same time was difficult for some. However, during the retrospective probing, most users felt that the main reason for this was the fact that they were unaccustomed to the driving simulator and its controls. Further time with the simulation before the actual testing begins is important in order to gain a better representation of the user experience with the system.
- A majority of users liked the placement of the input but would prefer an option to adjust its position to better suit their preference.
- The handwriting part was one the most difficult part of the test session, beside the lack of a tactile click. The reasons for this was the small input area, small buttons, and the system misinterpreting input.

Measures of SA, MWL and a SUS score was also compiled from the test data. That data is presented below, divided into the two categories: *manual* and *autonomous* driving. It is important to note that user 1 to 5 refers to test users who drove manually, and users 6 to 10 drove in autonomous mode.

Manual driving

Figure 5.13 shows the average score each category in the SUS survey. From those scores, the final SUS score given to the system for use in manual driving is 51,5, which could be considered a failing score.

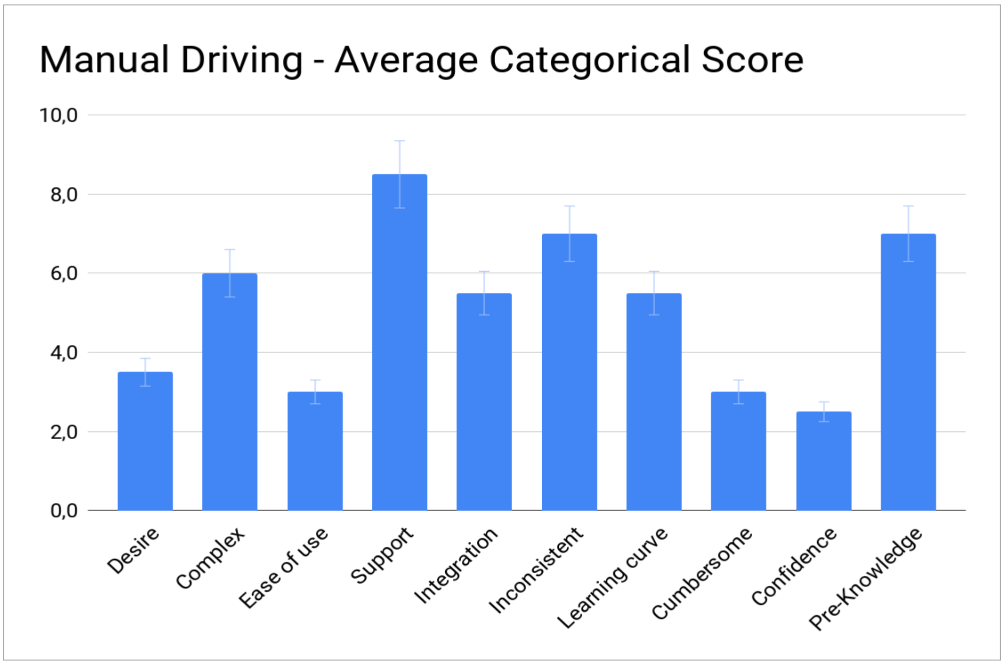

Figure 5.13: Graph showing the average score for each category in the SUS survey when the user is driving manually.

Figure 5.14 shows the MWL required of each individual user while using the system. As can be seen, the users tend feel either a high or average amount of MWL when using the system.

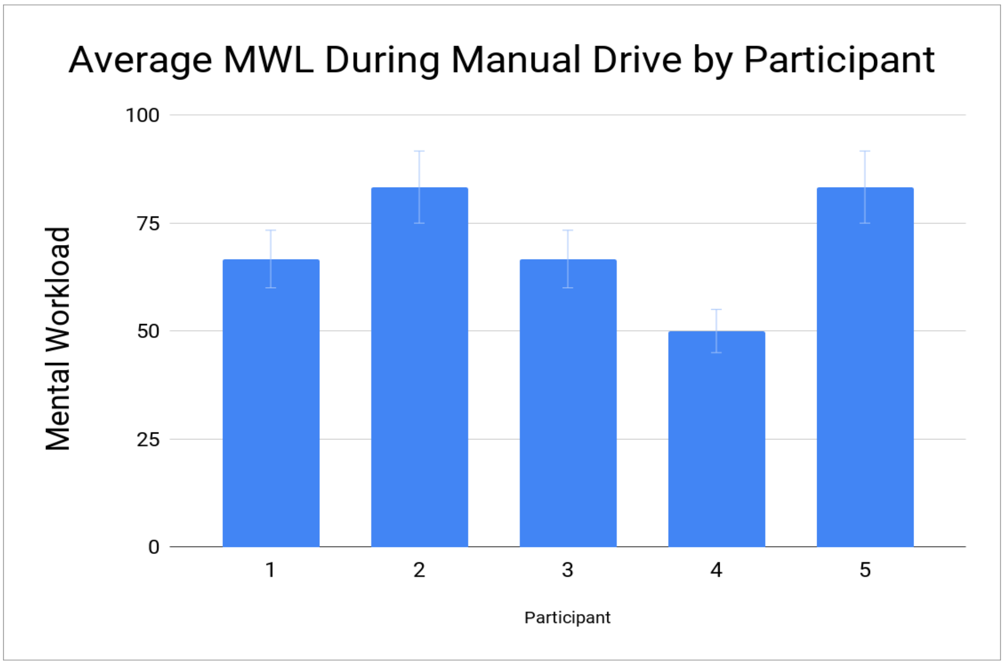

Figure 5.14: Graph showing MWL score while driving manually and using the system.

During the test session, each user were asked 5 SA questions and their answers were noted. On average, the test participants correctly answered 44% of these questions, with the lowest participants score at 20%, and the highest at 80%.

Autonomous driving

Figure 5.15 shows the average score for each category in the SUS survey for the autonomous drivers. An increase in score can be seen in some categories, e.g., ease of use, but a majority of the categories rest around the 6,0 mark. The final SUS score calculated from the autonomous driving data is 61,5, which could be considered barely ok.

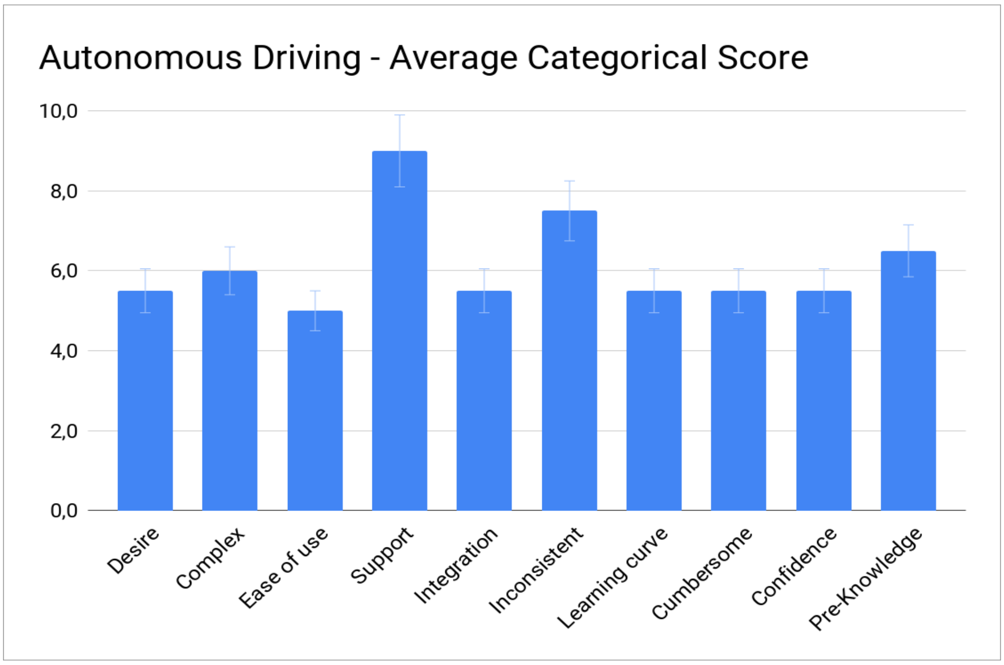

Figure 5.15: Graph showing the average score for each category in the SUS survey when the user is in autonomous driving mode.

Figure 5.16 shows the MWL required for each individual user. Compared to the manual group of drivers, three users gave a score which represent a sense of underload. However, two users gave a score which represent a sense overload.

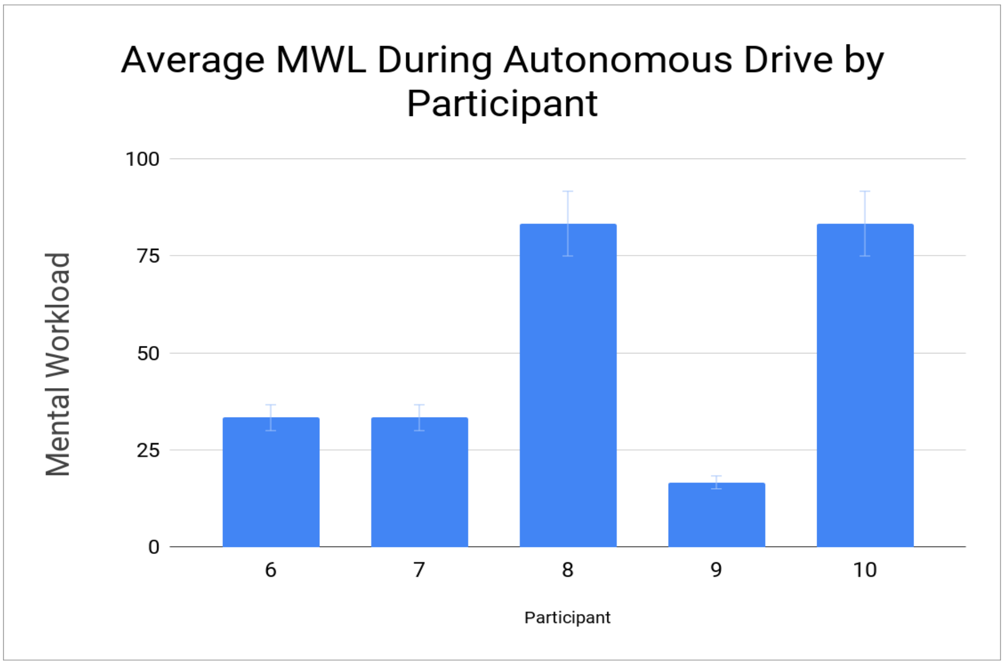

Figure 5.16: Graph showing MWL score while in autonomous driving mode and using the system.

The final figure in this category, Figure 5.17, shows a comparison of the average MWL for each category between manual driving, and autonomous driving. The autonomous drivers gave, on average, a lower score for each category. The category with the highest score was time for both groups, meaning the system creates a sense that it requires a lot of time from the driver.

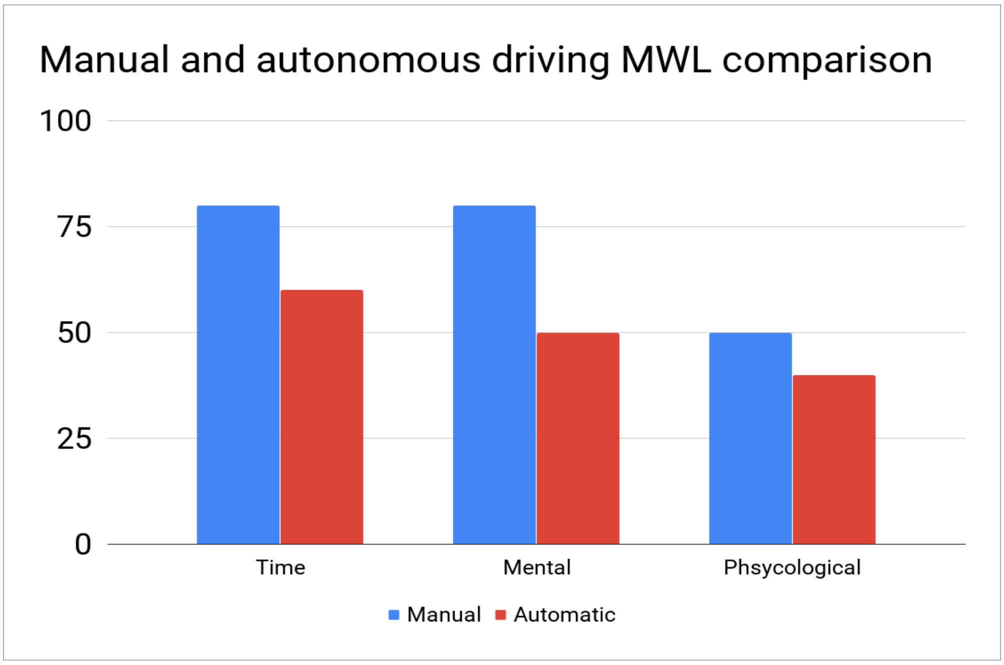

Figure 5.17: Graph showing a comparison between MWL required during manual driving and autonomous driving.

Just as the manual drivers were asked SA questions, so were the autonomous driving users. Each user was also asked 5 questions. The autonomous drivers answered, on average, 64% of the questions correctly. The lowest score achieved by one user was 40%, and the highest was 80%.

5.4.3 Test Number 3

Test number 3 was similar to test number 1, with the same goal and structure. However, a few key differences can be noted: the total users tested was 5 instead of 9, and the amount of tasks differed, going from 14 to 9. As this test was set up to be the same as test number 1, we decided to record the data the same way as well. The feedback gathered and summarized can be seen in the table below:

Task number	**Observations & feedback**
1	The user can easily find messages and see which message is the most recent.
2	The user understands how to exit scribble mode. This task is considered easy. Knowing that you have entered scribble mode for the first time can be a bit unclear.
3	User did not see Mom at first, but after a short while found her among favorite contacts. The "Reply"-button should be changed to something else when there is no previous message history with someone. It is obvious which contacts are favorites, as they have a big yellow star next to their name.
4	Most users understand how to edit messages, but there can be some confusion.
5	Task is completed quickly without much confusion. Pressing "New number" leads to finding more contacts, which some users found a bit confusing. Re-naming the button might be a good idea. You have to press "New number" twice, as the first time leads to more contacts, and the second time leads to a screen where you can input a number. It should perhaps be clearer that the first list of calls you see after pressing the "Phone"-button is a list of recent calls.
6	Very simple task, nothing particular to note.
7	One user notes that the system is very consistent. It is easy to see which e-mail is unread.

8	Task is easy. One user notes that they are comfortable pressing "Back" to exit scribble mode.
9	It is easy to what is the subject line, and what is the e-mail content. Going straight to writing the e-mail after writing the subject line can be a bit confusing. Should perhaps change to "Go back to confirm subject" from "Go back to confirm message". It can be unclear what "e-mail text" refers to. It is possible to miss the "Subject line" text.

As can be seen in Figure 5.18, a CR of 100% was achieved, meaning all participants completed all the tasks successfully. This is an increase from the previous 92% from test number 1.

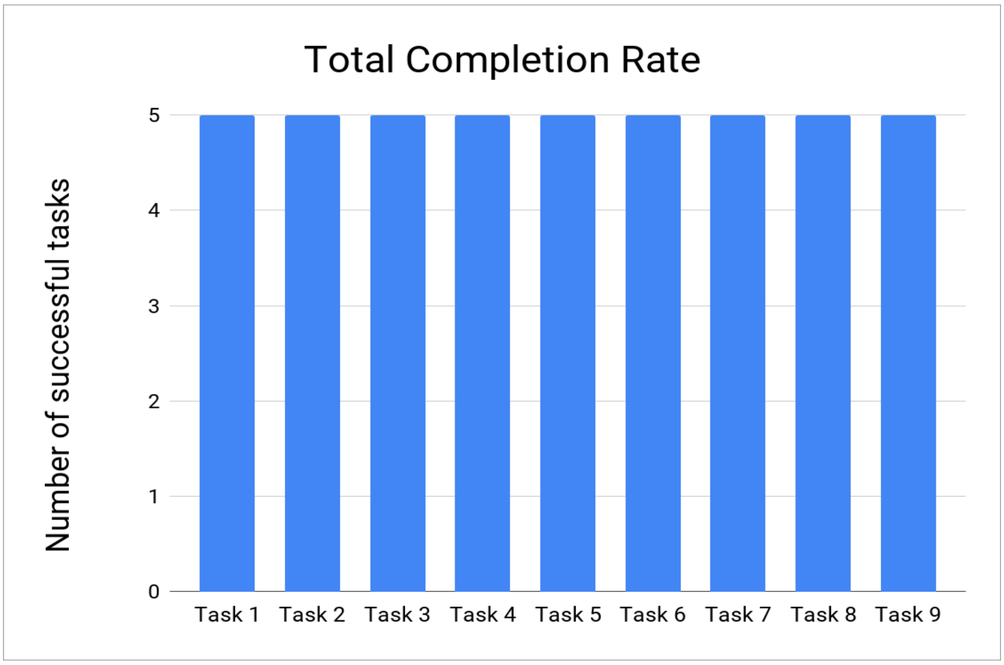

Figure 5.18: Graph showing number of completions of each task in test number 3

Figure 5.19 also show the average TTD for each task, and the final value for the TBE landed on 3.8 tasks per minute, an increase from the previous 3.1 tasks per minute from test number 1.

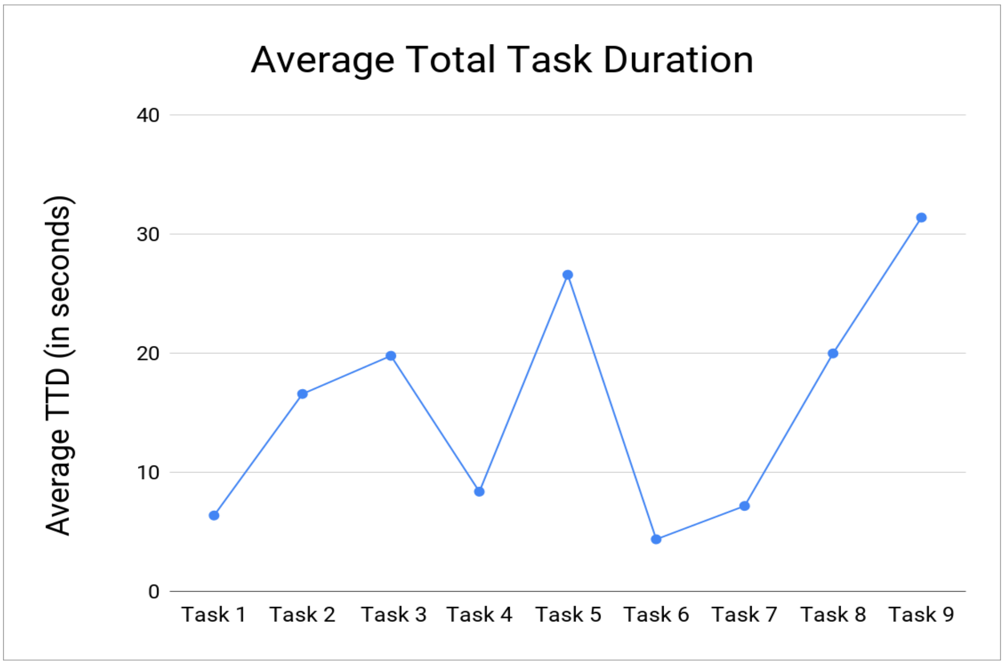

Figure 5.19: Graph showing average time to complete each task from test number 3, recorded in seconds.

The decrease in difficulty is also visible in Figure 5.20. The results from test number 1 showed a much more up and down result, with quite steep dips in ease for certain tasks. As the results for this test show, no task does goes below the level of 4.

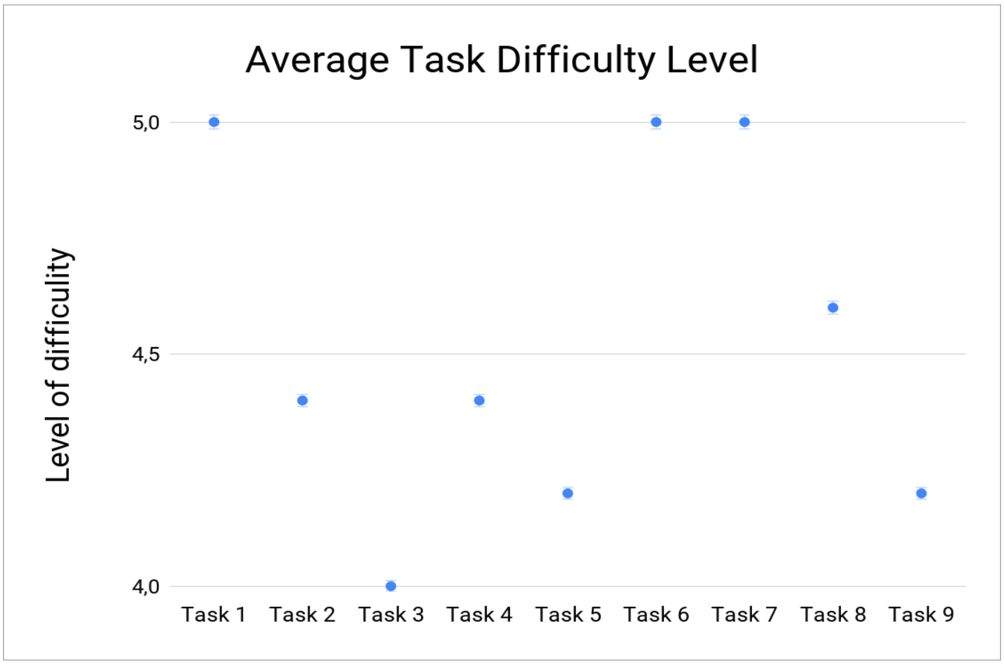

Figure 5.20: Graph showing the average difficulty of each task. A score of 5 means the task was very easy, while a score of 1 means the task was very difficult.

As can be seen in Figure 5.21, a sharp increase in score was achieved for a number of categories when compared to Figure 5.12. However, "Desire" and "Learning curve" still rest at a pretty similar score.

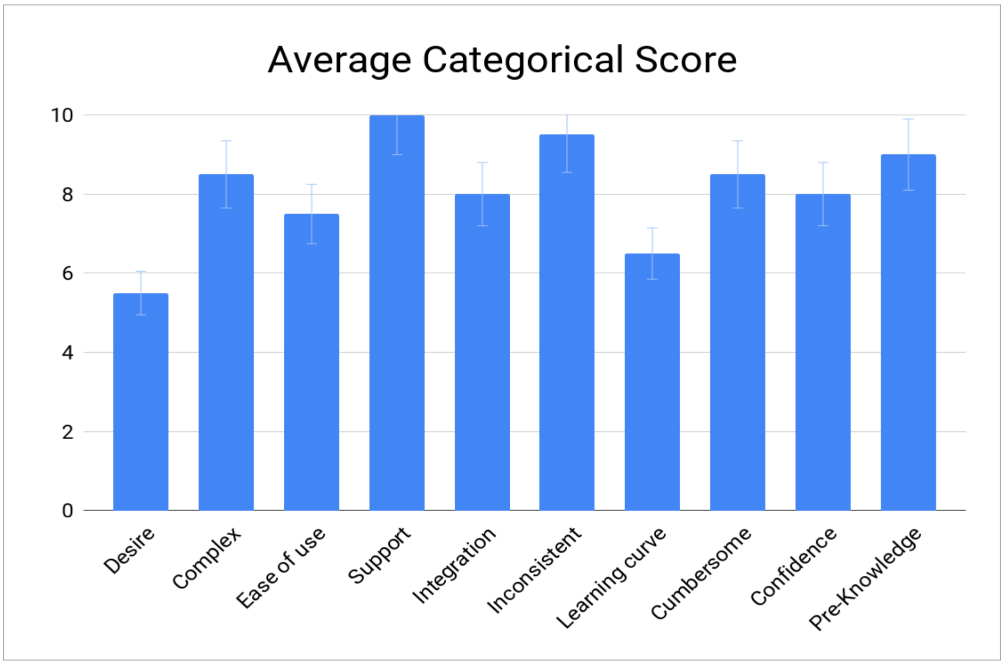

Figure 5.21: Graph showing the scores given to each category in the SUS scale for test number 3.

A new SUS score was calculated using the data received for this test. The score was achieved was 81,0, which is an increase from the SUS score of 61.7 gained from test number 1. This new score could be considered very good.

Chapter 6

Discussion

In this chapter, we discuss some of the methods and measures we used, what could have been done better, what worked and did not work, and what we would have done differently. The chapter has been split into three section, one were we discuss our process from chapter 4, our results from chapter 5, and our suggestions for future work.

6.1 Process

The process, including the methods and measures we chose for this project, allowed us to conduct a total of three iterations with a user centered focus. We were open to change and acted according to the feedback gained from our test participants and supervisor with more experience and expertise of the project domain. We gained a lot of feedback and data, which we used to update our concept and to back up our design decisions. We believe this gave us a good understanding of the domain, a solid basis to build and expand upon, and clear data and feedback to work with. However, our process was not spared from different problems, some of which we discuss below.

6.1.1 Understanding the domain and its users

The early stages of the project was the most time consuming, but also the most difficult. The first challenge was understanding and getting a good grasp on the domain, the automotive industry, its' taxonomy, guidelines, technologies, and driver behavior and characteristics. This was something we did not have any previous experience with, and we underestimated how much time it would take for us to get a good grasp of. This required a large amount of literature review, as seen in chapter 2.

Before work began on the concept, we assumed the project would allow for a lot of exploration and unorthodox solutions. The large amount of safety guidelines surrounding the implementation of systems in vehicles meant, however, that the concept became quite limited, which was further supported by the limitations set by Semcon. Furthermore, the large amount of psychological concepts surrounding driver behavior and safety added another ambiguous layer to the project which had to be considered during the process. In the beginning of the project, a lot of different driver characteristics were planned to be addressed. However, we quite early one determined there was to little time and resources to properly address all of them. With all this being said, we do believe all this knowledge was necessary and vital, especially considering the serious subject of on-road accidents and making sure the driver is not hindered or distracted from the driving task. Therefore, we definitively recommend anyone to do proper research of the automotive domain beforehand, in order to get a proper understanding of the domain. But setting limits, so the project does not involve to many factors to consider, is a good idea, especially considering the larger concept stage our project was part of.

Our field research was also quite time consuming. Traveling and testing out different car brands took a lot of time. Even though we traveled to a lot of different car dealerships, certain sacrifices had to be made, as we could not test all solutions from all the car brands. A good idea would have been to first look at what solutions different car brands were offering beforehand. Then, we could have sorted out any similar, or severely lacking systems, i.e., did not provide much in terms of functionality, and focus on car brands with unique or interesting systems. Because of this, the field research phase took longer than planned, mainly due to the reasons mentioned earlier. However, it did provide us with a better understanding of how interacting with IVIS works today. We do recommend some more in-depth research before hand in order to reduce the amount of unnecessary travel time and visits to car dealerships.

Conducting a survey and follow-up questioning gave, according to us, a balance of qualitative and quantitative data and feedback. It definitively helped in reducing speculation on our part, gave more in-depth insights, and a better understanding of our users needs and wants. However, it did create a lot data which had to be analyzed. This was something we were unprepared for, as we underestimated how many respondents we would get. Also, since we conducted the survey together with the other group, certain decisions and compromises had to be made, as questions not relevant to us but relevant to the other group, had to be included. This created a survey which could be considered to long and complex. We do feel these compromises were necessary, as we would have posted any independent surveys through the same channels and groups, which could have led to less respondents. Our extensive literature study and research did, eventually, provide us with a good understanding of the domain and its users.

6.1.2 The prototypes and technical difficulties

Early on, the decision to create two prototypes, one for the IA and a second one for the system interaction, created problems. The first problem was that too much time, effort, and resources were spent on creating the first iteration of the low fidelity IA prototype. While this extra effort made a good impression on the test participants, it changed the nature of the feedback and the participants frame of mind towards the test session. Too much focus went towards the information displayed and lack of functionality and transitions, instead of the navigation, structure, planned functionality, and layout. Creating a much more low-fidelity prototype, in order to test and evaluate faster and have more time to refine and update, would likely have been a better way to go. Also, a combination of the low-fidelity IA prototype with the interactive prototype at a much earlier stage could have been much more helpful, as it could have led to a more complete concept package to test with participants. However, this is speculation on our part, as it could just as well had lead to a much longer and complex first iteration.

The second problem was that the work on the interactive prototype began too late, which meant there was too little time to update the prototype. We also underestimated the technical difficulty, time and effort required to create the prototype. Since Semcon gave instructions to create an Android prototype, we just went along their instructions and did not consider any alternatives. In hindsight, looking into alternative solutions or what was required to create our solution, could have provided a better alternative to use for development, or at least a heads-up to the potential pitfalls of using Android. In the end, these reasons meant there was too little time left for updating and evaluating a second iteration of the prototype.

The third problem occurred when testing the interactive prototype. We noticed straight away some problems with the choice of handwriting input, i.e., Google Handwriting Input. We determined early on during the development of the prototype, that creating our own solution would most likely take quite a lot of time, time we did not have. So, using a third party solution was deemed a necessary solution. We did some internal testing with the solution and understood the flaws of using it. However, we underestimated how much this would affect our testing with users, as one of the major complaints with our prototype was the handwriting input. For one, the solution covered half the screen, severely reducing the amount of space available to use. Second, to exit the handwriting state, a very small back option had to be selected. This was true for inserting a space in the written text as well. If we had more time, we could have created a more optimal solution, or at least try to find a more suitable alternative. However, for the small time frame we had, this option was better than using nothing at all.

6.1.3 Extensive amount of evaluation measures

The large amount of methods and measures relative to the size of the project team, two people, was quite ambitious. This also led to a large amount of data and feedback to be analyzed. However, we felt that and the total number of chosen methods and measures were necessary, due to the project aim of creating a solution supposed to be safe, efficient, and comfortable, and to be able to answer our research question. Also, being able to clearly identify the problem areas of the concept, understand what those problems are, and how those problems can be resolved was vital. It also helped in guiding our iterations, in order to keep a user centered focus.

6.1.4 Using a controlled environment for testing

Using a real vehicle and driving on an actual highway would have the advantage of getting the test participants in a more life-like context. The decision to use a driving simulation instead of a real vehicle came down to a number of reasons. First, we thought it would be easier to administrate the test sessions. We could quickly set up, change, or move the setup according to our needs. We also believed it would allow the participants an easier way to explore the concept, and second, getting a hold of a test vehicle would require booking a vehicle ahead of a test session, which would hinder us from performing quick test sessions. Third, conducting a real driving test would require much more in terms of safety aspects, and we would have been limited to driving in a parking lot. This would not have represented our driving environment anyway. These factors led to the decision to use a driving simulation, which we felt saved time, resources, and was not as complex as using a real vehicle. However, we do believe that testing in a vehicle would be required to properly evaluate a final concept, and determine its safety aspects.

6.2 Result discussion

In this section, we discuss the results presented in chapter 5. These discussions are placed in section, structured similarly to the structure of the results chapter.

6.2.1 Survey

In order to reach a large and a diverse group of users, we posted the survey on different online forums and websites. Some of them were related to vehicles in general, e.g., car websites, some were related to very specific vehicles, e.g., Volvo enthusiast's groups, while some were not related to cars or driving at all specifically, e.g., student groups on Facebook. This lead to a very diverse set of respondents, e.g., in terms of age and driving experience. However, it also led to certain groups being over represented. As seen in section 5.1, the number of answers in each category of driver become quite low, ranging from around 45 answers at the highest, to around 15 at the lowest. This is too low of a number of respondents to make any statistically accurate conclusions. Furthermore, many places we posted our survey to either did not responds or removed it due to different reasons, e.g., website rules. This also led to certain groups being over-represented. E.g., a large majority of the drivers who own a vehicle with ADAS owns a Tesla. Therefore, basing any decisions on the feedback from this group would skew the results based on a very specific group with a very specific vehicle. This made it difficult to draw any conclusions that we can say accurately reflect reality. In the future, one should try to get enough responses from all different groups, in order make sure the data is statistically valid, and a solid basis can be achieved for any trends that emerge from the data. However, as the survey was conducted to provide us with guidance, we believe the answers and the data was informative enough for us to proceed with it.

Follow-up questions

The follow up questions were sent in an attempt to reduce speculations from our side, and gather more qualitative data. These answers provided further insights into the mindset of our user group, something the survey itself could not. However, we faced some of the same problems we did when conducting the survey, one being a low number of respondents willing to answer follow-up questions. We also encountered some additional problems we failed to foresee. The first being that not all of those we contacted sent back any reply. The second being that some of the responses we did get, did not provide much information. All in all, this led to a small set of responses we could gain any deeper insights or feedback from. However, the responses that did provide more in-depth answers, were very useful in letting us understand our users even further.

6.2.2 Field Research

We could determine from our research that buttons, dials, and touchscreens are the most popular input methods in cars today. This is something we, most likely, could have determined based on online research only, so the decision to go to different car dealerships could be considered unnecessary, due to the time and effort required of traveling to these dealerships. However, the hands-on experience we got from physically interacting with their means of interaction was very useful to us. Our opinion definitively changed when we sat down and tried out different IVIS in real life. Although the research could have been improved, if we had more time to explore more cars and IVIS, we strongly feel that the time spent on going out to car manufacturers and getting this hands-on experience, was an essential part of the process, and we would definitively do it again.

6.2.3 Conceptualization

We strongly believe the final concept was well-thought-out. However, we also believe that if we had spend more time in the conceptualization stage, we could have gone into the upcoming iterations with more details and structure surrounding our concept.

Brainstorming

The brainstorming session was an essential part of the entire project. During the session, most of the ideas that would come to be implemented were discussed, although at a very basic level, as the ideas were continuously evolving throughout the process. One of the downsides to how we conducted our session was how relatively little time we spent on it. The session lasted for about an hour and a lot of ideas were generated. However, we believe that if we had used the method more, even if they were shorter or structured differently, we could have discovered even more interesting ideas or solutions that could have been important additions or improvements to the concept.

Rapid Prototyping

The prototypes we created at this stage were of very low fidelity. This allowed us to quickly test our ideas, and make changes to them without investing a lot of time and resources. This ended up being very successful for us, as we quickly realized, by testing our prototypes internally, which concepts we liked the most. However, a case can be made that dismissing an idea based of very simple prototypes could be a mistake, as it is the nature of such a simple prototype which makes an idea *seem* worse than it is. Regardless of this, we believe this form of a prototyping session provided us with the insight and motivation to decide on one single concept idea.

6.2.4 User Tests

Information Architecture Tests

Both test number 1, and test number 3 were intended to only test the information architecture, and was not meant to test things such as visual, auditory or haptic feedback, scrolling through lists, text input, and so on. For test number 1, most of the test participants comments were regarding the IA, but some commented on the lack of interaction and the static nature of the prototype. For some participants, it was hard to imagine how the functionality would work without any visual representation of this functionality. E.g., when entering text, the users would be shown a view with no input, and once they scribbled in their input, they were shown a view with pre-written text. We could have given the users more time with the system, explain to them more clearly what the goal of the test session was and what they were shown/using was in no way the final design, and show some concept images of the planned functionality, to make the user better understand. Also, the test setup could have been improved, as a lot of irrelevant elements or objects surrounding the prototype caused confusion. E.g., some users would try to use they keyboard of the laptop the prototype was displayed on to input text, or click on elements not relevant to the the test displayed in the screen, such as the navigation menu of the program we used to displayed the IA. Covering the keyboard, and unimportant elements on the display, with paper could have fixed, or at least alleviate, this problem.

For test session 3, the second IA test session, we could see the benefits of our extensive evaluation methods and measures. We could clearly identify the problem areas, and could create direct improvements over the previous iteration, which could be seen in the resulting data and feedback. That being said, test number 1 was conducted with 9 users, while number 3 was conducted with only 5 users. Also, while the sessions were conducted nearly the exact same way, i.e., they shared the same structure, they were different in some ways, e.g., less tasks to complete. Therefore, it can be hard to justify the validity our resulting data. However, regarding the smaller amount of users, we justify this approach as we noticed early on during the first test session, that we could predict what feedback a user would provide. Testing with any more users would only reinforce what we already knew about the prototype. Regarding the number of tasks, they shrunk as a direct result of our updates of the concept, as certain tasks was removed or improved. Furthermore, since we conducted our evaluation in a formative nature, we never intended to use the data as a definitive proof, but instead use it as guidance, to determine if we were heading in the right path with our design decisions. To properly determine the validity of our concept, a much larger testing session with a much more diverse set of users has to be conducted. This is also true for the driving simulation test.

Driving Simulator Test

During the driving simulation test, we primarily looked at how easy or difficult it is to select elements on the HUD, and if the user understands the mapping of the trackpad and the HUD, i.e. that putting your finger in the top right corner of the trackpad will highlight an item in the top right corner of the HUD. During the development of the prototype, we knew that we had to make compromises with certain parts in order to get it ready to test at all. First, no physical buttons were included in the prototype. It would have required too much time for us to implement the three buttons that complemented our current prototype, and to implement a tactile, as in clickable, solution for the selection of elements. Thus, we decided to skip the buttons for this test as well. This was a major problem for most participants, as they had to rely on tapping an element to select it. This led to a lot of misclicks by the users, and even worse, a lot of attention towards tapping the correct element. Second, even though handwriting input was included in this test, we could not develop that functionality on our own in the time we had, and had to use a third party solution in our prototype. However, the solution only used half of the touchscreen. This was a major drawback, as this caused users to have to re-write their words and sentences multiple times due to the small input area, which was both frustrating for them, and caused them to pay less attention to the road. Also, no gestures or physical back buttons could be used to insert space or to exit the state of handwriting input. This meant the user had to divert a lot of attention towards locating the spacebar or digital back button, or that we had to do this for them. It was clear from just these observations that in order to properly test this system in a driving environment, and to increase the usability, a more customized and suitable handwriting solution has to be included in the system, one that properly uses the entire touchpad for input, a combination of gestures for common text commands, such as space, and a physical back button in order to stop using the touchpad for entering text. That being said, if we had given the users more time to test out the driving simulation and the prototype on their own, before the actual test starts, could have alleviated, at least to small degree, the problems with the handwriting. With more experience, it is possible that they could have been able to use the handwriting system with more success. These two compromises were the major cause of much of the negative feedback we received during the test, and the cause frustration for many of the test participants. Even though we were short on time, we could have reduced the problem though different means. Regarding the handwriting, we could have conducted more research on third party solutions test more of them out, in order to find a more suitable solution. Also, regarding the lack of tactile input, we could have used Wizard of Oz approach. We could tell the user to say out loud when they want to select whatever element they are currently highlighting, and then select that element using a computer mouse connected to the smartphone we used as a trackpad.

Some participants also displayed a reckless driving behavior, even when told to drive as safe as possible and to follow general driving laws and behavior. This affected our results, e.g., less attention to the road which led to less SA. Reasons for this behavior was that participants knew it was a simulation and they were not in direct danger, so they did not feel as enticed to drive safely. This is a major reason why we believe real-life testing is needed, if anything to get the users into the right frame of mind.

During the test participants were asked questions about their surroundings, for example they were asked for the color of a street sign they drove past. This was done to test their situational awareness, and to see if they are paying attention to traffic while using the system. Those who drove in autonomous mode answered more of these questions correctly, which was the result we expected, as these users did not have to focus on actually driving the car. However, as we did not compare these results to any other system, or even just driving the car without using our system, we could not draw any conclusions of the affects our system has on the users situational awareness. Also, due to problems with the prototype and the participants driving behavior, both mentioned above, we concluded that the data we got could not represent how our prototype affects SA fairly, but could be used as guidance or, at least, an estimation.

Mental workload was another areas that we wanted to measure. As the users filled in a survey where they rated their MWL. As with situational awareness, the results revealed that those driving in autonomous mode felt they had a lower mental workload than those driving manually. This was also expected even before starting the test, however just as with situation awareness, we did not test the participants mental workload when not using the system, which makes drawing conclusions around how our prototype affects MWL difficult. Also, for the same reasons regarding SA, the results is more suited for guidance and as an estimation of the MWL required by the prototype.

As we concluded the tests, we gained a lot of knowledge regarding what parts of the system users like and dislike, for example the highlighting system which highlights items on the HUD depending on your finger position on the trackpad was very well received. In contrast, selecting items in a list was one of the more difficult tasks, as it required more precision from the user, due to the lack of a tactile click. The key points we took from this test regarding our system and its design was the importance of feedback. The only feedback we had included in our prototype was visual and through vibrations, and to make it easier to use the system, other types of feedback such as visual or haptic feedback could be implemented. Another key point is the amount of information shown on the HUD. In its current state, we feel like there are occasions where too much information is shown to the user, and those instances would need to be changed as to not overload the user with information while they are driving. The points mentioned in this section, both the positive and negative, affected the testing in different ways, however we still feel that the test session was a success, as it gave us a lot of feedback and insights into how the system could work in a driving environment, and what is required to improve the prototype and the concept in whole.

6.3 Research Question

We started this project with the research question:

"What is an alternative way for interacting with the communicative functionality of an IVIS, e.g., text messaging, that is safe, efficient, comfortable, and provides a good general UX?"

The question is very broad, as it includes a lot of different aspects which have to be answered, such as safety, efficiency, comfort and general UX. Most of the decisions we made during the design process were done in order to answer this question, but as we started conducting user tests and evaluating the concept, we could see that the we could not answer most of the question conclusively. To determine safety, we would have to test in real life environments, in many different traffic situations, using a lot of diverse drivers. Comfort is also highly subjective, meaning that what is comfortable for one driver might not be comfortable for another. Therefore, we could not draw any conclusions regarding comfort either. In terms of efficiency, we can conclude that the concept does have potential to be quite efficient. However, the results of the evaluation shows that the major drawback is the handwriting input. As the concept used a third-party application for this, it is uncertain if implementing a more optimal solution would improve this area. Lastly, does the concept provide a good UX? In certain areas, yes, in others, no. The concept needs further iterations of refinements and evaluations to make sure it is improved in areas where the UX is lacking. Based on this, we decided to re-phrase the research question to:

"How can we design a trackpad that controls the communicative functionality of an IVIS, which use a HUD as the output, and what are some of the most important factors the concept has to address, in order to provide a good UX"?

The new research questions is less ambiguous than the original question. It also allows us to provide answers to the question. Using our results, as in the data, feedback, and our own thoughts and opinions, we got from our project, we can determine a set of pointers that could satisfy the above research question:

- Less is more - Rather than overburden the user with options, and choices, provide a more restricted, clear, and easy to digest experience. This is especially important for the IA, to reduce the MWL required by the user.
- Clarity is key - The user should be able to quickly find the information they want, and quickly understand it. This allows the driver to spend less time looking at the system, reducing the periodic glance time.
- Try to keep the number of steps to a minimum - Certain parts can be combined, or removed entirely, in order to keep the number of steps required to a minimum. Reducing the total time required to complete a task, and therefore reducing the amount of focus a user spends on a task instead of the driving task and driving environment, can reduce the total glance time a task requires.

- Always provide the user with feedback - Whether it is were in the IA the user currently is, what they can do or is expected from them, or so they understand where their finger currently is in regards to the trackpad.
- Physical over digital - Provide more tactile and haptic feedback, instead of only visual, in order to reduce misclicks and misunderstandings, especially in a driving situation where the user should not look away from the road to confirm where their finger is or what selection they will make.
- Text input is one of the most important factors - Not only does text input require a lot of focus and attention, but also time. Creating a proper handwriting solution is necessary to increase efficiency, reduce MWL, and provide a much more satisfying UX.

6.4 Future Work

Using the set of pointers established with our new research question, but also other points made in the chapter, we can determine future work which should be done to improve the prototypes and the concept. The safety aspect is one of the areas where more testing is required, as with the current tests using the driving simulator could not accurately imitate realistic traffic conditions. Testing the system using a real car, where the driver is required to focus on real traffic situations would be a step in the right direction to determine how safe the system actually is.

Another aspect that would need to be determined is the actual size of both the HUD and the trackpad. As of this project, a final decision about the size of both these objects has not been made, and instead a temporary size has been used while developing the wireframes and sketches. In order to fully understand how much content could be shown on the HUD, and how big the trackpad has to be to be comfortable to use, a final size for both items has to be decided on through user testing.

The physical buttons that are included with the trackpad also needs to be tested. The prototypes that were developed for this project could not include the functionality of these buttons, as it would have been very difficult and taken too much time to implement. The physical click would also need to be implemented for the trackpad, as it was the one of the major causes of a lot of errors and frustrations during the testing of the system. Finally, a more robust handwriting solutions would be a required implementation, as the current prototype uses a third-party solution that does not fit the needs of the system.

Chapter 7

Conclusion

This master thesis project delivered an evaluated HMI concept for interacting with communicative STs in a IVIS in both non and partially automated vehicles.

The projects domain was a huge challenge due to its complexity, broadness, and ambiguity regarding the automotive industry, driver mentality and characteristics. Furthermore, creating a concept that works for both non and partially automated vehicles was another major challenge.

In the end, we completed a total of three iterations during the design process, each one with its own set of goals. We used the requirements established during the early stages of the project during the ideation and conceptualization of our initial idea. This concept then evolved as a result of the data and feedback gained at the end of each iteration. Our goal was to keep the concept simple, to move they driver's eyes towards the road, and to provide an input method which did not require the driver to take their eyes away from the road. We believe the results show promise and the concept should be explored further, although it requires more work in certain areas and more in-depth testing to establish how safe it is.

Towards the end of the project, we determined we could not answer our initial research question properly. We decided to create a new one, based on the results of the project. We believe we could provide much more realistic, proper, and definitive answers to this new question.

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[35] Gregor Cresnar, “”Chat".” https://www.flaticon.com/authors/gregor-cresnar. [Image].

[36] Freepik, “”Telephone".” https://www.flaticon.com/authors/freepik. [Image].

[37] Smashicons, “”Plus".” https://www.flaticon.com/authors/smashicons. [Image].

[38] Freepik, “”Vintage phone receiver".” https://www.flaticon.com/authors/freepik. [Image].

[39] Google, “”Volume off indicator " (CC 3.0).” https://www.flaticon.com/free-icon/volume-off-indicator_60750#term=mute&page=1&position=12. [Image].

[40] Smashicons, “”Warning".” https://www.flaticon.com/authors/smashicons. [Image].

[41] Smashicons, “”Users".” https://www.flaticon.com/authors/smashicons. [Image].

[42] Google, “”Call Missed" (CC 3.0).” https://www.flaticon.com/free-icon/call-missed_566035#term=outgoing&page=1&position=14. [Image].

[43] Google, “”Arrow" (CC 3.0).” https://www.flaticon.com/free-icon/arrow_566032. [Image].

[44] Google, “”Arrow" (CC 3.0).” https://www.flaticon.com/free-icon/arrow_566036. [Image].

[45] Smashicons, “”Star".” https://www.flaticon.com/authors/smashicons. [Image].

[46] Google, “”Forward arrow" (CC 3.0).” https://www.flaticon.com/free-icon/forward-arrow_60546#term=send&page=1&position=4. [Image].

[47] Google, “”Black envelope email symbol" (CC 3.0).” https://www.flaticon.com/free-icon/black-envelope-email-symbol_61214#term=mail&page=1&position=3. [Image].

[48] Google, “”Phone call button" (CC 3.0).” https://www.flaticon.com/

free-icon/phone-call-button_60720#term=phone&page=1&position=2. [Image].

[49] Google, “”Bubble speech with three lines" (CC 3.0).” https://www.flaticon.com/free-icon/bubble-speech-with-three-lines_61085#term=chat&page=1&position=9. [Image].

[50] Google, “”Users, social symbol" (CC 3.0).” https://www.flaticon.com/free-icon/users-social-symbol_60541#term=social&page=1&position=11. [Image].

[51] Google, “”Thumb up button" (CC 3.0).” https://www.flaticon.com/free-icon/thumb-up-button_61012#term=like&page=1&position=1. [Image].

[52] Google, “’Add button inside black circle" (CC 3.0).” https://www.flaticon.com/free-icon/add-button-inside-black-circle_60740#term=add&page=1&position=1. [Image].

Appendix A

Appendix 1

Below is a full list of guidelines (see section A.1) and requirements (see section A.2). The list of guidelines are based on guidelines provided by the National Highway Traffic Safety Administration, Japan Automobile Manufacturers Association, Alliance of Automotive Manufacturers, and the Commission of the European Communities[15–18]. Some of the guidelines presented in section A.1 are directly taken from the organizations mentioned above, while some are a combination of similar guidelines or has been rewritten for our own understanding.

A.1 Guidelines

Overall guidelines

- The system supports the driver and does not give rise to potentially hazardous behavior by the driver or other road users.

- The allocation of the driver attention while interacting with systems and displays and controls remain compatible with the attentional demand of the driving situation.

- The system does not distract or visually entertain the driver.

- The system does not present information to the driver which result in potentially hazardous behavior by the driver or other road users.

- Interfaces and interface with systems intended to be used in combination by the driver while the vehicle is in motion are consistent and compatible.

- Design of system interaction such that under all reasonable circumstances the driver is able to maintain safe control of the vehicle, feels comfortable and confident with the system and is ready to respond safely to unexpected occurrences.

- Presence, operation, or use of a system specified in such a way that it does not adversely interfere with displays or controls required for the driving task and for road safety.

- Design and location of information and communication systems in such a way their use is compatible with the driving task under routine conditions.

Installation guidelines

- The system should be located and securely fitted in accordance with relevant regulations, standards and manufacturer's instructions for installing the system in vehicles.

- The screen of the display monitor shall be located within the 30 degree inclination.

- No part of the system should obstruct the driver's view of the road scene.

- The system should not obstruct the vehicle controls and displays required for the primary driving task.

- Visual displays should be positioned as close as practicable to the driver's normal line of sight.

  - 2D eye-movement should not exceed 30 degrees from the center in either direction.

- Visual displays should be designed and installed to avoid glare and reflections.

Information presentation guidelines

- Visually displayed information presented at any one time by the system should be designed in such a way that the driver is able to assimilate the relevant information with a few glances which are brief enough not to adversely affect driving.

- Internationally and/or nationally agreed standards relating to legibility, audibility, icons, symbols, words, acronyms, and/or abbreviations should be used.

- Information relevant to the driving task should be accurate and provided in a timely manner.

- Information with higher safety relevance should be given higher priority.
- System-generated sounds, with sound levels that cannot be controlled by the driver, should not mask audible warnings from within the vehicle or the outside.
- The System should not produce uncontrollable sound levels liable to mask warnings from within the vehicle or outside or to cause distractions or irritation.
- Presentation of information so as not to impair the driver's visual, cognitive, or auditory ability to safely perform the driving task under routine driving conditions.
- Systems with visual displays should be designed such that the driver can complete the desired task with sequential glances that are brief enough not to adversely affect the driving.
  - Single glance duration should not exceed 2 seconds.
  - Task completion should not require more than 20 seconds of total glance time.
- In the case of vehicles with the eye point measuring less than 1,700 mm from the ground, the upper end of the display monitor shall conform to the lower boundary requirements of the driver's 180° forward visual field stipulated in 90/630/EEC on the visual field of drivers.
- 30 is the maximum number of letters that drivers can read without feeling rushed.
  - A number such as "120" or a unit such as "km/h" is deemed to be a single letter irrespective of the number of digits.
- The display of addresses and telephone numbers as guiding information shall be prohibited while the vehicle is in motion. However, images that do not contain such addresses and telephone numbers and are to appear in the searching process may be displayed while the vehicle is in motion.
- The display of information describing restaurants, hotels and other similar facilities shall be prohibited while the vehicle is in motion. However, images that do not contain such information on restaurants, hotels, etc. and are to appear in the searching process may be displayed while the vehicle is in motion.
- Static images that are useful for driving and are quickly comprehensible may be displayed while the vehicle is in motion.

- The display of motion pictures including broadcasted television pictures andreplayed video and DVD pictures shall be prohibited. (However, traffic information and other similar motion pictures specially simplified for driving use may be displayed.

- Information relating to driving and arranged for existing equipment may be displayed. Such as Traffic Information, Emergency Information.

- The luminous intensity, contrast, colors and other display conditions of a display system shall be such that the driver is not dazzled by the display at night.

- Information, such as the reporting of system state and operation that is displayed in response to the data inputted by the driver shall be quickly and easily comprehensible.

Interface with displays and controls guidelines

- The driver should always be able to keep at least one hand on the steering wheel while interacting with the system.

- The system should not require long and uninterruptible sequences of manual-visual interface. If the sequence is short, it may be uninterruptible.

- The driver should be able to resume an interrupted sequence of interface with the system at the point of interruption or at another logical point.

- The driver should be able to control the pace of interface with the system. In particular the system should not require the driver to make time-critical responses when providing inputs to the system.

- System control should be designed in such a way that they can be operated without adverse impact on the primary driving controls.

- The driver should have control of the loudness of auditory information where there is likelihood of distraction.

- The system's response (feedback, confirmation) following driver input should be timely and clearly perceptible.

- Systems providing non-safety-related dynamic visual information should be capable of being switched to a mode where that information is not provided to the user.

- The total time of the driver's looking at the screen between the start and completion of operation task shall not exceed 8 seconds.

- When the above total time is measured by a bench test using the occlusion method, the total of shutter opening time shall not exceed 7.5 seconds.

- Preferably, a display system is so designed that its adverse effect on safe driving will be kept to a minimum.

- Preferably, a display system is installed in such an in-vehicle position that the driving operation and the visibility of forward field will not be obstructed..

- Preferably, the types of information to be provided by a display system are such that the driver's attention will not be distracted from driving; for example, entertainment types of information need to be avoided.

- Preferably, a display system can be operated by the driver without adversely affecting his or her driving work.

- Information to be presented by a display system shall not cause the driver to gaze at the screen continuously.

- Preferably, a display system is so designed that its display of information can be discontinued by the driver.

- Preferably, the visual information to be displayed is sufficiently small in volume or is presented in portions so that the display system can be operated in separate steps.

- A display system's functions that are not presumed to be used by the driver during driving operation shall be inoperative by the driver while the vehicle is in motion.

- When the driver is to input data into a display system, the display system shall not demand immediate responses from the driver.

System behaviour principles

- While the vehicle is in motion, visual information not related to driving that is likely to distract the driver significantly should be automatically disabled, or presented in such a way that the driver cannot see it.

- The behaviour of the system should not adversely interfere with displays or controls required for the primary driving task and for road safety.

- System functions not intended to be used by the driver while driving should be made impossible to interact with while the vehicle is in motion, or, as a less preferred option, clear warnings should be provided against the unintended use.

- Information should be presented to the driver about current status and any malfunction within the system that is likely to have an impact on safety.

- The system should clearly distinguish between those aspects of the system, which are intended for use by the driver while driving, and those aspects (e.g., specific functions, menus, etc) that are not intended to be used while driving.

- Information about current status, and any detected malfunctions, within the system that is likely to have an adverse impact on safety should be presented to the driver.

A.2 Requirements

Most of the requirements are based on the list of guidelines above, except for the user requirements, which are based on our research (see subsection 4.1.2 and section 4.1.3).

A.2.1 Functional requirements

1. The system supports the driver and does not give rise to potentially hazardous behavior by the driver or other road users.

2. The allocation of the driver's attention while interacting with the system remain compatible with the attentional demand of the driving situation.

3. The system does not distract or visually entertain the driver.

4. The interfaces of the system intended to be used by the driver while the vehicle is in motion are consistent and compatible.

5. The system should clearly distinguish between those aspects of the system, which are intended for use by the driver while driving, and those aspects (e.g., specific functions, menus, etc) that are not intended to be used while driving.

6. The system should lock-out any secondary task that draws a driver's attention from the primary driving task to the point where safety is reduced, unless the engine isn't running, the vehicle is in park, or the vehicle is neutral with the parking brake on.

7. The behaviour of the system should not adversely interfere with displays or controls required for the primary driving task and for road safety.

8. While the vehicle is in motion, the visual information displayed by the system not related to driving that is likely to distract the driver significantly should be automatically disabled, or presented in such a way that the driver cannot see it.

9. The interaction with the system is designed such that under all reasonable circumstances the driver is able to maintain safe control of the vehicle.

10. The interaction with the system is designed such that under all reasonable circumstances the driver feels comfortable.

11. The interaction with the system is designed such that under all reasonable circumstances the driver is ready to respond safely to unexpected occurrences.

12. The design and location of interaction/communication with the system shall be compatible with the driving task under routine conditions.

13. The system should not require long and uninterruptible sequences of manual-visual interaction. If the sequence is short, it may be uninterruptible.

14. The visual information displayed by the system should be able to be discontinued by the driver.

15. The driver should be able to resume an interrupted sequence of interaction with the system at the point of interruption or at another logical point, and be provided with an indication to aid a driver in finding where to resume the task. [edited].

16. The driver should be able to resume an interrupted sequence of interaction in four or less input actions.

17. The driver should be able to control the pace of interaction with the system. In particular the system should not require the driver to make time-critical responses when providing inputs to the system.

18. The driver should have control of the loudness of auditory information where there is likelihood of distraction.

19. Non-safety-related dynamic visual information should be capable of being switched to a mode where that information is not provided to the driver.

20. The visual information displayed by the system is sufficiently small in volume or is presented in portions so that the system can be operated in separate steps.

21. The visual information shall be quickly and easily comprehensible.

22. Visual information about current status and any malfunction within the system that is likely to have an impact on safety should be presented to the driver.

23. Information presented by the system relevant to the driving task should be accurate and provided in a timely manner.

24. Information with higher safety relevance should be given higher priority

25. The visual information displayed by the system shall not cause the driver to gaze at the screen continuously.

26. The visual information displayed by the system shall be designed in such a

way that the driver is able to assimilate the relevant information with a few glances which are brief enough not to adversely affect driving.

27. The presentation of information by the system should not impair the driver's visual, cognitive, or auditory ability to safely perform the driving task under routine driving conditions.

28. Static images displayed by the system that are useful for driving and are quickly comprehensible may be displayed while the vehicle is in motion.

29. The luminous intensity, contrast, colors and other display conditions of a display system shall be such that the driver is not dazzled by the display at night.

30. The system should not produce uncontrollable sound levels liable to mask warnings from within the vehicle or outside or to cause distraction or irritation.

31. The visual information displayed by the system should provide means for that information to not be seen by the driver, for example by dimming the information, turning of or blanking the information, changing the state for which the information can be displayed, or moving/repositioning the display.

32. The following tasks should be disabled if the vehicle is in motion, i.e not parked:

    - Video-based communications including video phone calls and other forms of video communication.

    - Displaying static photographic or graphical images not related to driving. However, displaying driving-related images including icons, line drawings, and either static or quasi-static maps is acceptable.

    - Automatically scrolling text. The display of continuously moving text is not recommended. The visual presentation of limited amounts of static or quasi-static text is acceptable

    - Manual text entry. A driver should not enter more than six button or key presses during a single task. This would include drafting text messages and keyboard-based text entry. The list above is intended to specifically prohibit a driver from performing the following while driving:

        – Watching video footage,

        – Visual-manual text messaging,

        – Visual-manual internet browsing

- Visual-manual social media browsing.

33. The system should provide an easy to understand layout, so I can get my head around the content.

34. The system should provide shortcuts/fast-functions options, so I can easily and quickly reach the function I want.

35. The system should provide programmable shortcuts, so I can decide what should do what.

36. The system should not put functions in odd locations, so I don't get confused or can't find what I'm looking for.

37. The system should not provide a redundant amount of input/choice, as to not confuse me.

38. The system should have a large input area, to make it easier to give input

A.2.2 Non-functional requirements

39. The display of information of the system should be designed so that its adverse effect on safe driving will be kept to a minimum

40. No part of the system should obstruct the driver's view of the road scene.

41. Visual displays should be positioned as close as practicable to the driver's normal line of sight.

    - 2D eye-movement should not exceed 30 degrees from the center in either direction

42. Visual displays should be designed and installed to avoid glare and reflections

43. **No Obstruction of View.**

    - No part of the physical device should, when mounted in the manner intended by the manufacturer, obstruct a driver's field of view.

    - No part of the physical device should, when mounted in the manner intended by the manufacturer, obstruct a driver's view of any vehicle controls or displays required for the driving task.

44. Visual displays that present information highly relevant to the driving task and/or visually intensive information should have downward viewing angles

that are as close as practicable to a driver's forward line of sight.

- Visual displays that present information less relevant to the driving task should have lower priority, when it comes to locating them to minimize their downward viewing angles, than displays that present information highly relevant to the driving task.

45. Visual displays that present information relevant to the driving task and/or visually-intensive information should be laterally positioned as close as practicable to a driver's forward line of sight

46. 30 is the maximum number of letters that drivers can read without feeling rushed.

    - A number such as "120" or a unit such as "km/h" is deemed to be a single letter irrespective of the number of digits.

47. Visual displays should be designed such that the driver can complete task with sequential glances that are brief enough not to adversely affect the driving.

    - Single glance duration should not exceed 2 seconds.

    - Task completion should not require more than 20 seconds of total glance time.

48. **Single-Handed Operation.** Devices should allow a driver to leave at least one hand on the vehicle's steering control. All tasks that require manual control inputs (and can be done with the device while the vehicle is in motion) should be executable by a driver in a way that meets all of the following criteria:

    - When manual device controls are placed in locations other than on the steering control, no more than one hand should be required for manual input to the device at any given time during driving

    - When device controls are located on the steering wheel and both hands are on the steering wheel, no device tasks should require simultaneous manual inputs from both hands.

    - A driver's reach to the device's controls should allow one hand to remain on the steering control at all times.

    - Reach of the whole hand through steering wheel openings should not be required for operation of any device controls.

A.2.3 User requirements

49. The system should allow me to make and receive voice calls and conduct basic text messages, so I can choose the communication option that is comfortable for me.

50. The system should display incoming text messages on a HUD, so I don't have to take my eyes off the road.

51. The system should provide the option to automatically send a message to a caller if a call is declined, so they may know I am driving and unavailable.

52. The system should not force me to interact with it in an unnatural way, so I don't feel uncomfortable or confused.

53. The system should tell me who is calling, so I can determine if I want to accept or decline the call.

54. The system should provide me with the option to accept an incoming call.

55. The system should provide pre-written responses, so I can easily send a reply.

56. Social media and email is not as urgent as voice calls and direct messages.

57. The system should not be too small or I can't see the information.

58. The system should be easy to reach or I don't feel safe using it.

59. The system should be easy to interact with, as I don't want to pick anything up.

60. The system needs to be reliable, so I can trust it.

61. The user should be able to interact without taking their eyes of the road

62. The user should be able to use the system without using their mobile phone

63. It needs to be clear how the system works, and under what conditions

64. The system should not be overly complex, so I can easily locate relevant information.

65. The HUD should only activate and display information while on a highway, as I feel safer with this information in this driving environment.

66. The system should allow for seamless interaction, so I am not confused.

67. The system should allow for hands-free interaction, so I can keep my hands on the wheel.

68. The system's mechanics for interaction should be intuitive enough, so I don't have to think twice before doing anything.

69. The system should not require to much of my mental workload when interacting with it, so I can focus on the driving task.

70. The system should not require to much eye attention away from the road, as it makes me feel unsafe.

71. The system should not take too much focus away from the driving task, as it makes me feel unsafe.

A.3 Wireframes

A.3.1 Low-fidelity Wireframes

These low-fidelity wireframes were created during the second iteration of the design process and was used for the first user test.

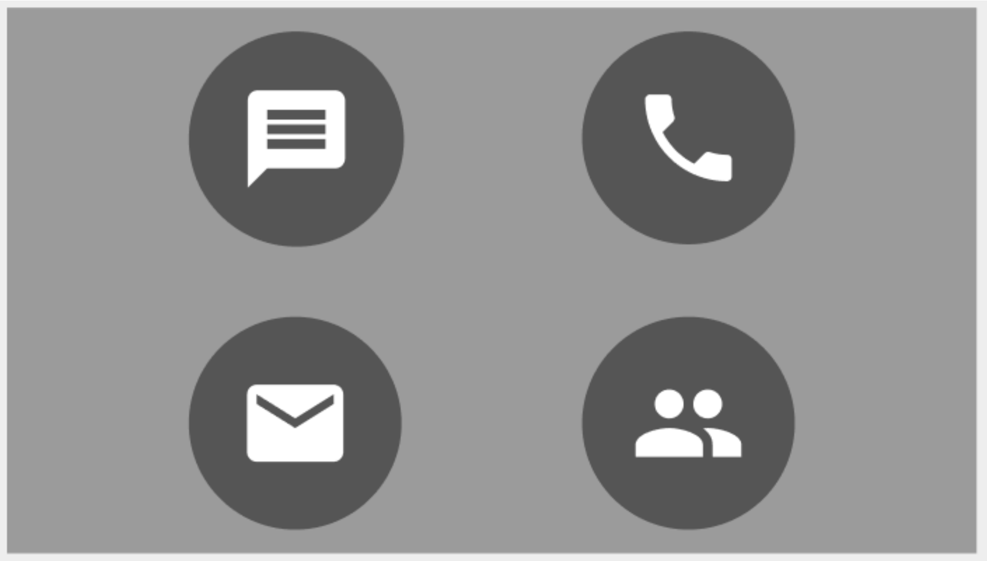

Figure A.1: Home screen.

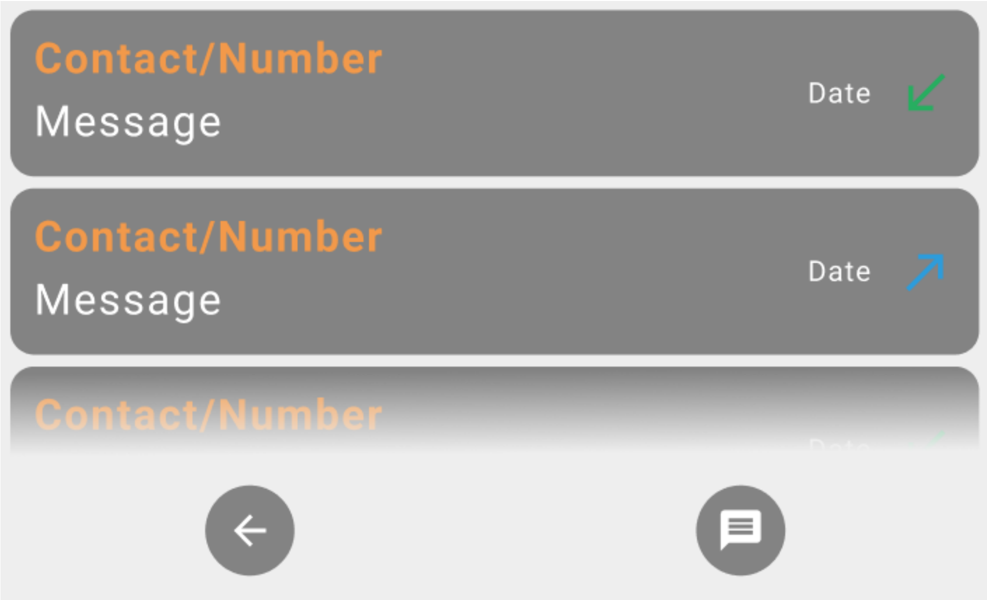

Figure A.2: List of contacts.

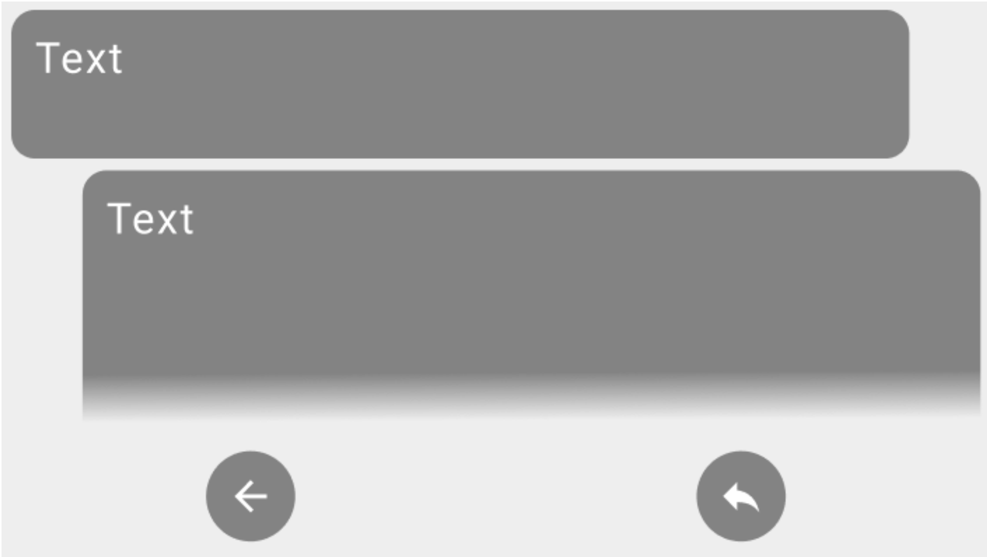

Figure A.3: Inside a conversation.

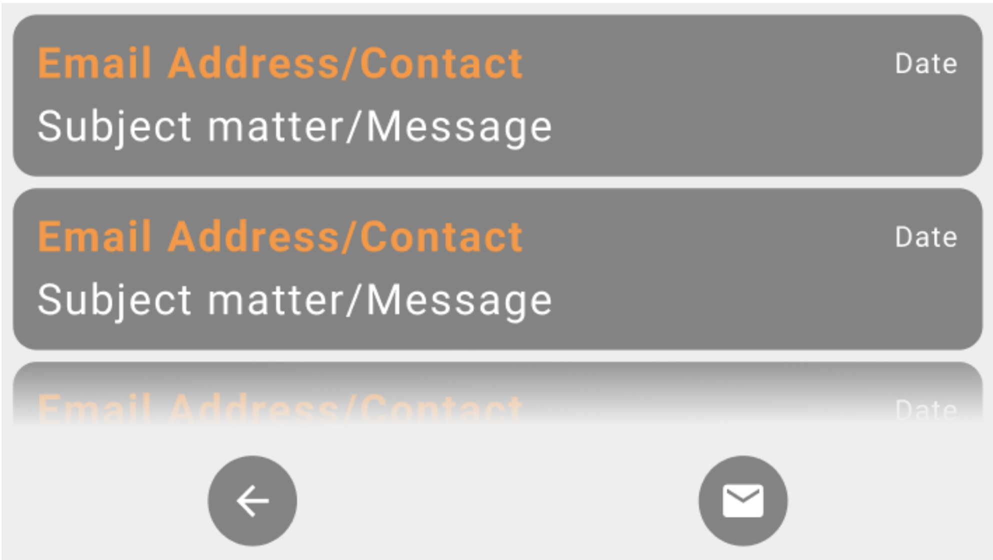

Figure A.4: List of e-mails.

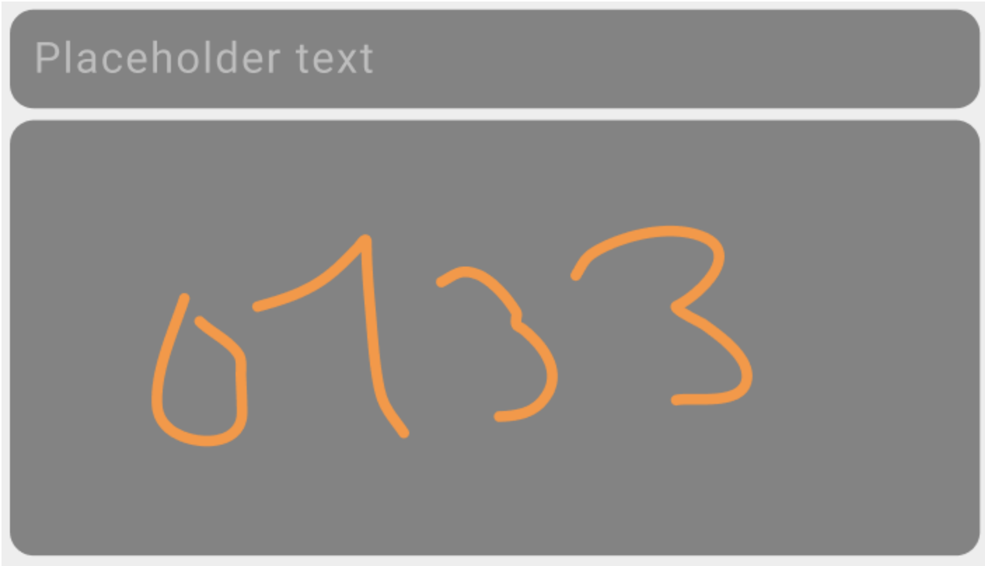

Figure A.5: Scribble mode.

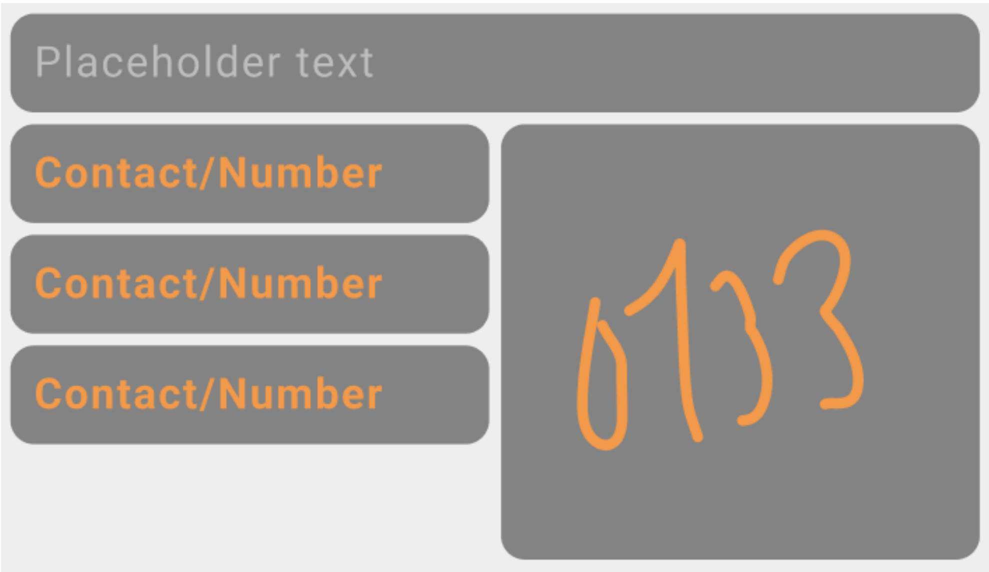

Figure A.6: Scribble mode with contact suggestions.

A.3.2 Final Design

These wireframes represent the final design of the system.

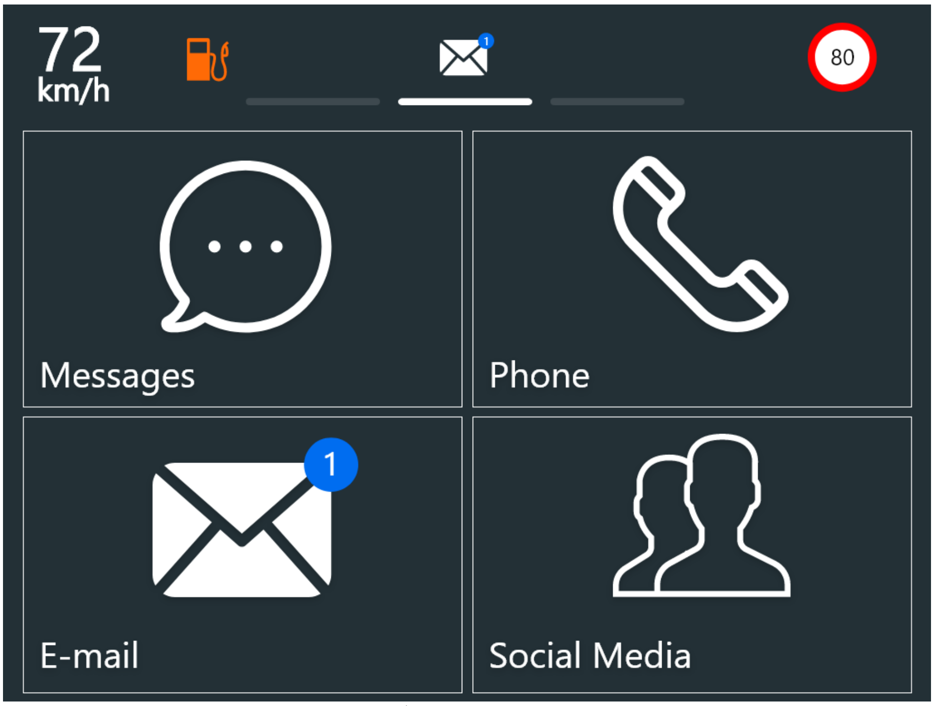

Figure A.7: Home screen.

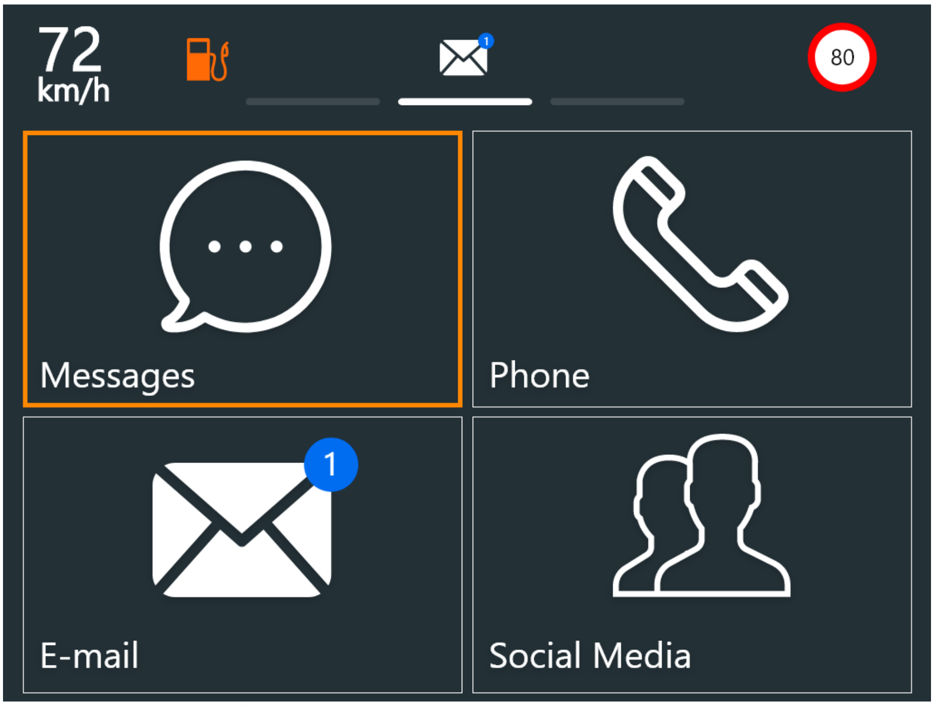

Figure A.8: Home screen with an element selected.

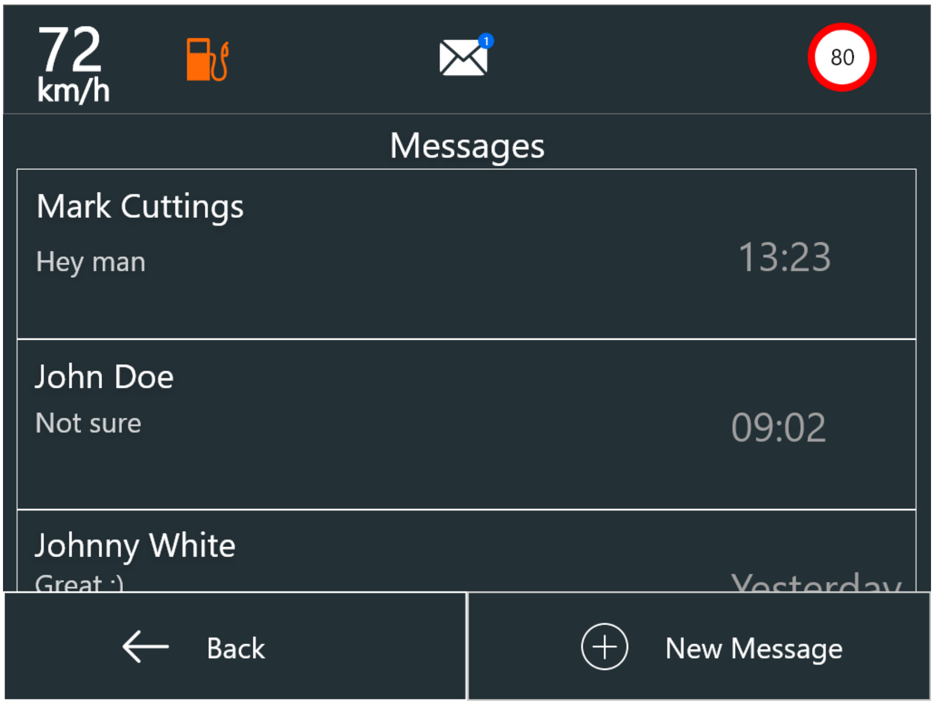

Figure A.9: A list of recent messages.

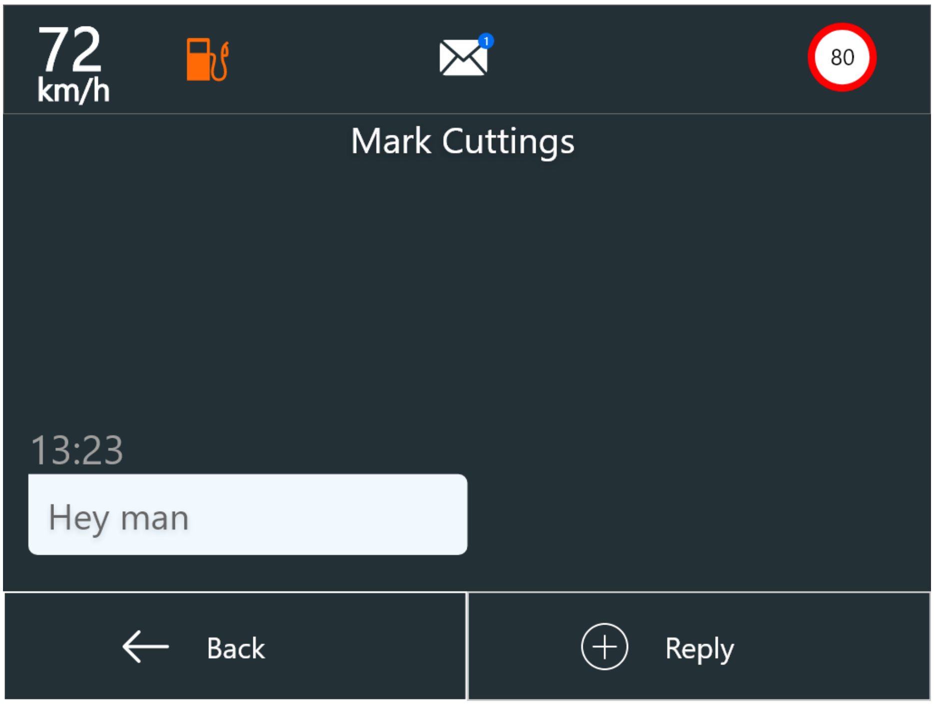

Figure A.10: Inside a conversation with one message.

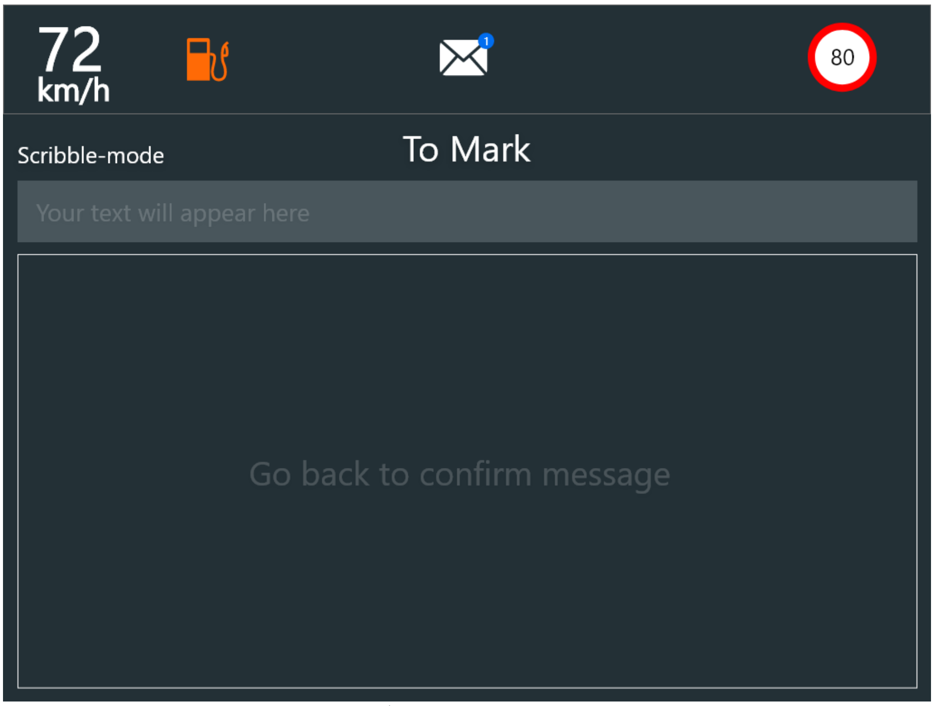

Figure A.11: Scribble mode.

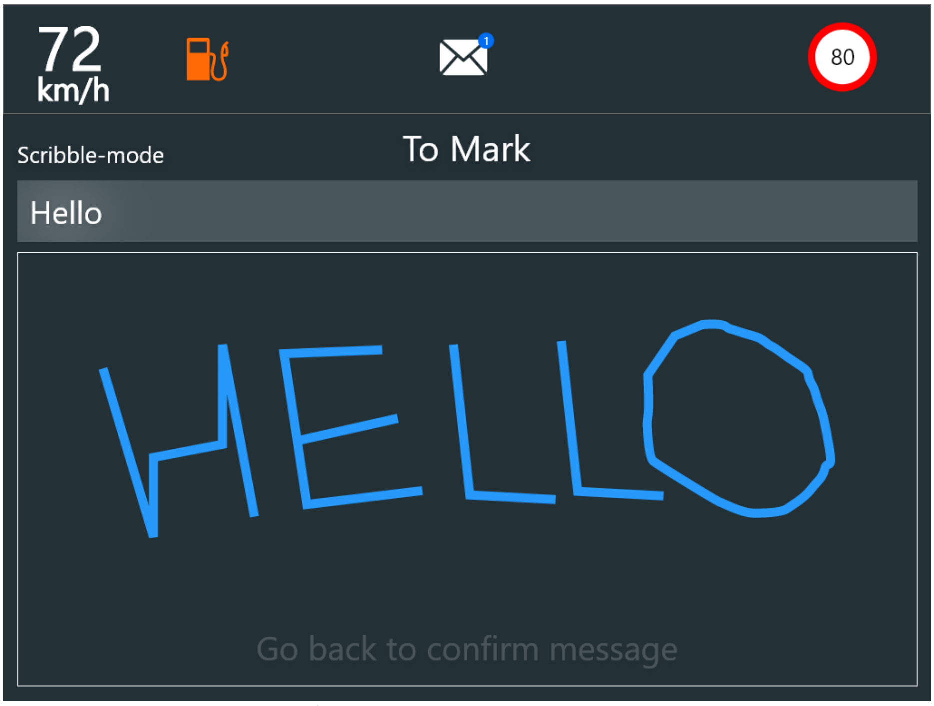

Figure A.12: Scribble mode with input.

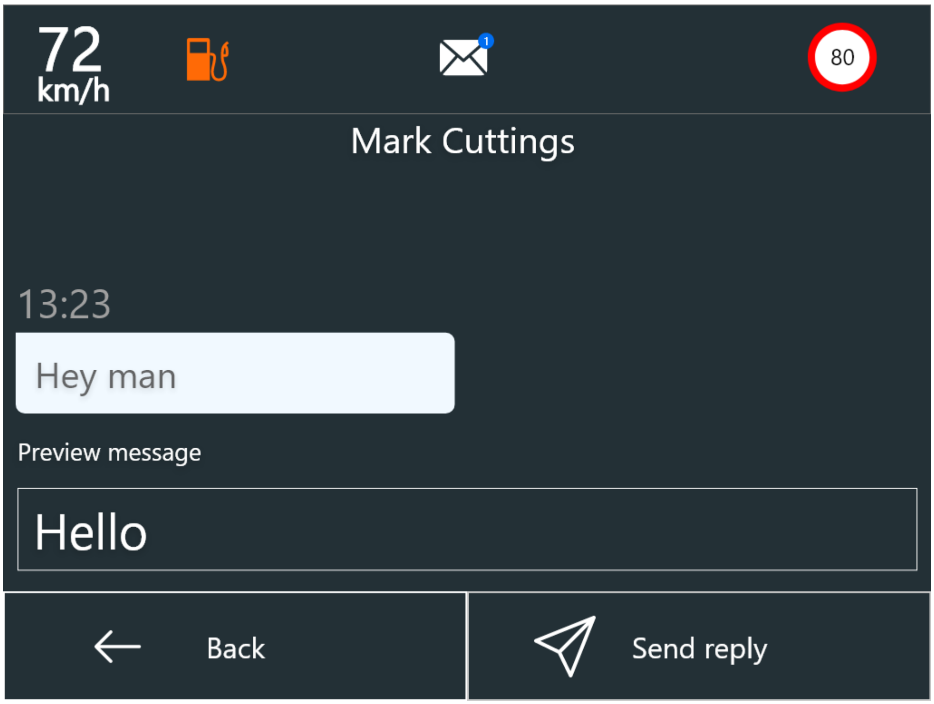

Figure A.13: Message preview.

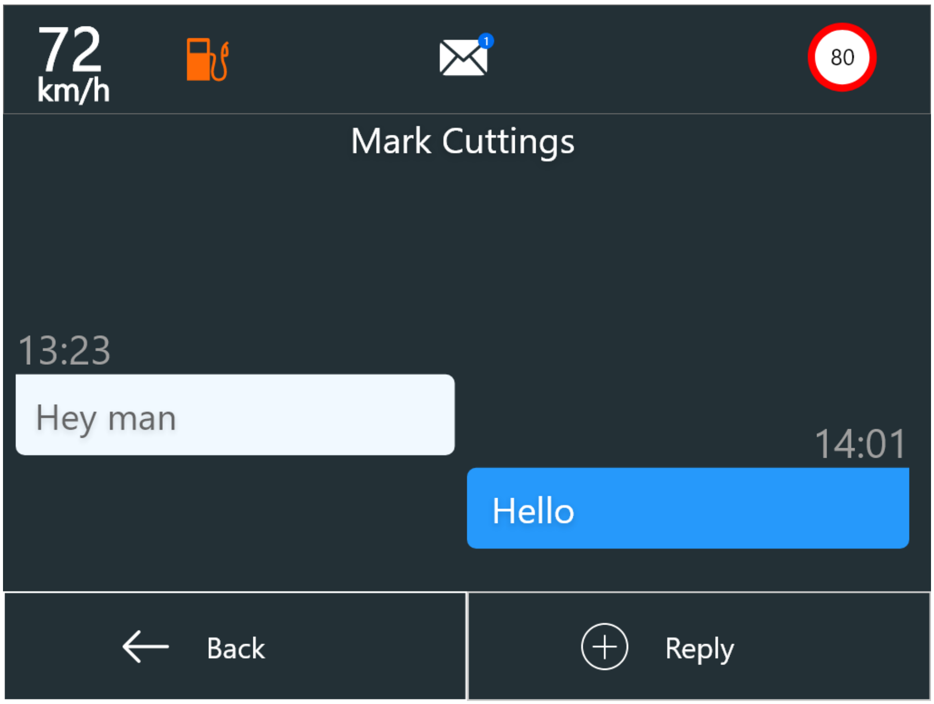

Figure A.14: Inside a conversation with two messages.

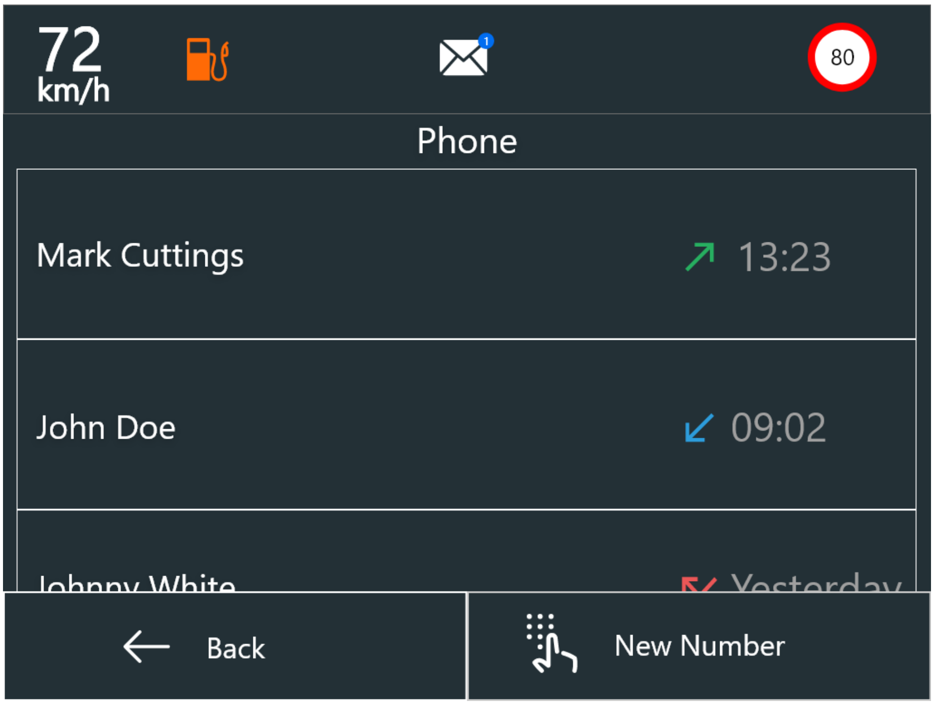

Figure A.15: A list of recent phone calls.

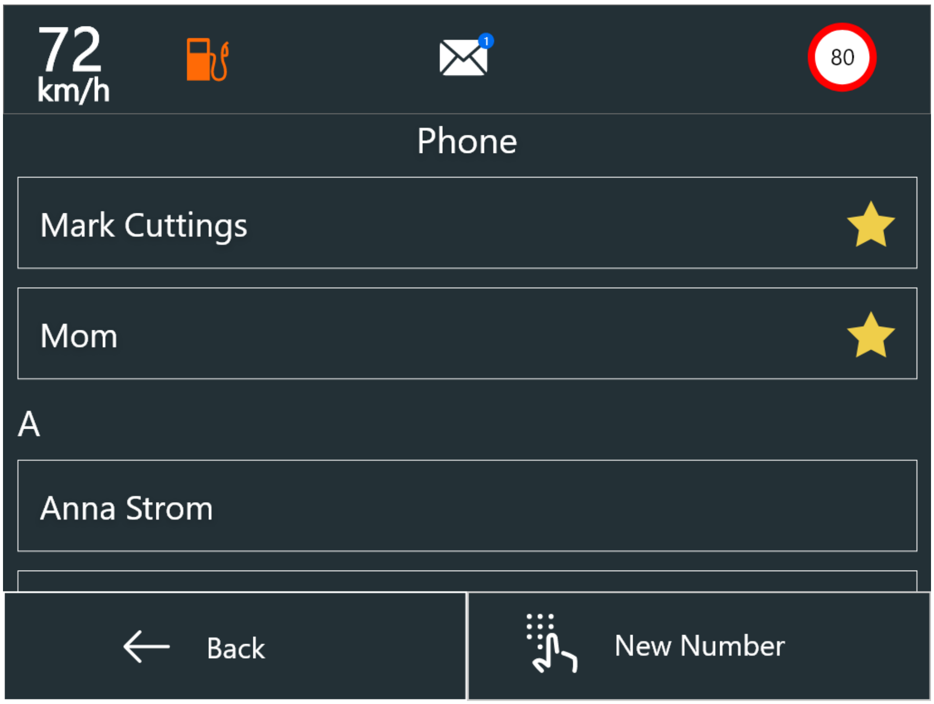

Figure A.16: A contact list.

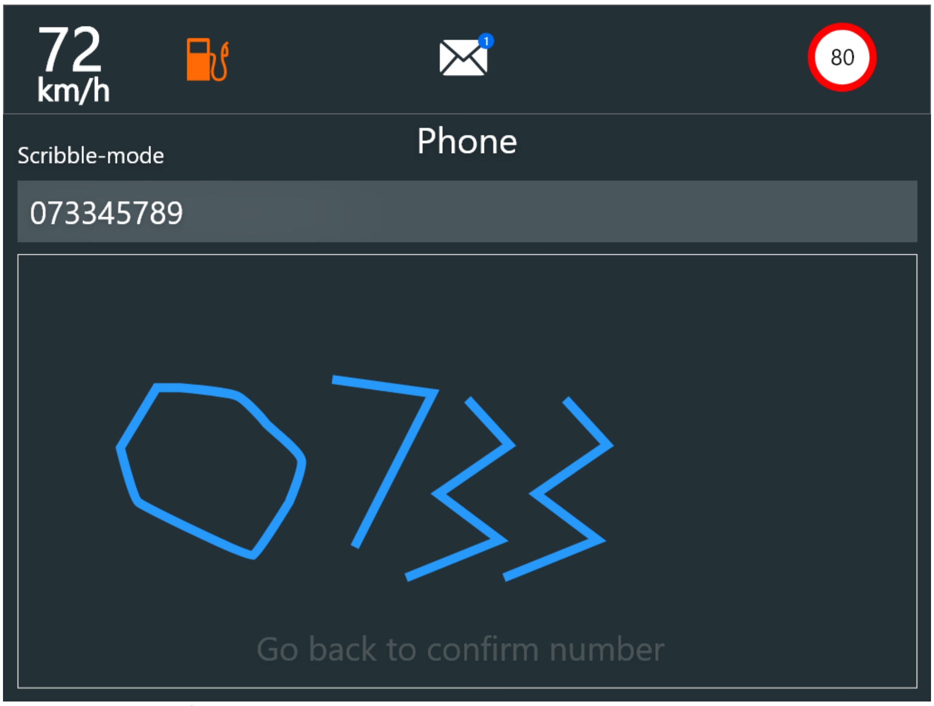

Figure A.17: Scribble mode with a phone number as input.

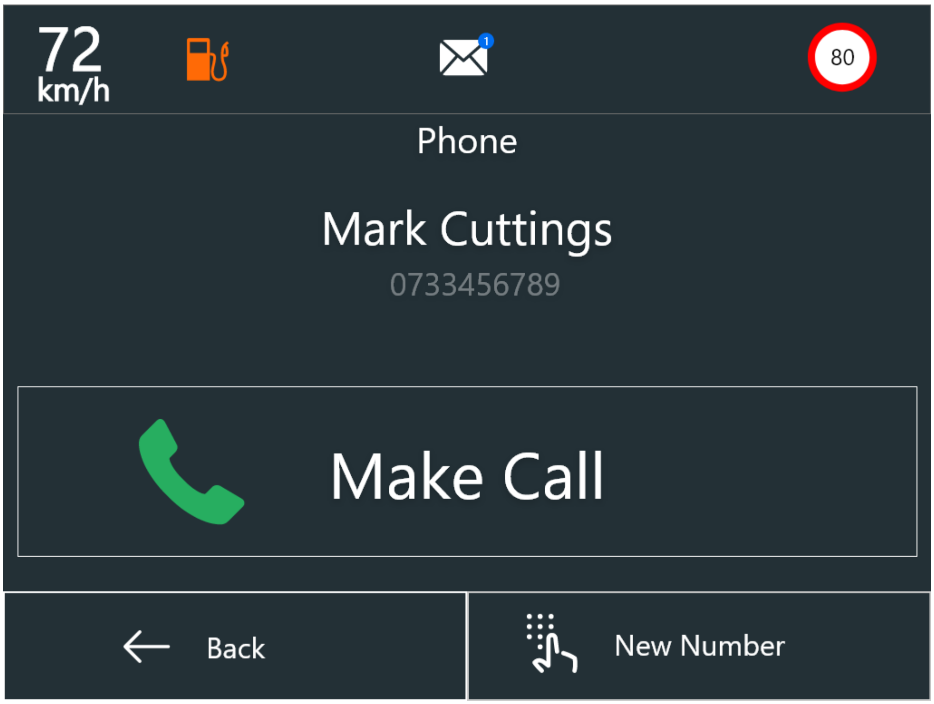

Figure A.18: Screen where the call is confirmed.

Figure A.19: An active phone call.

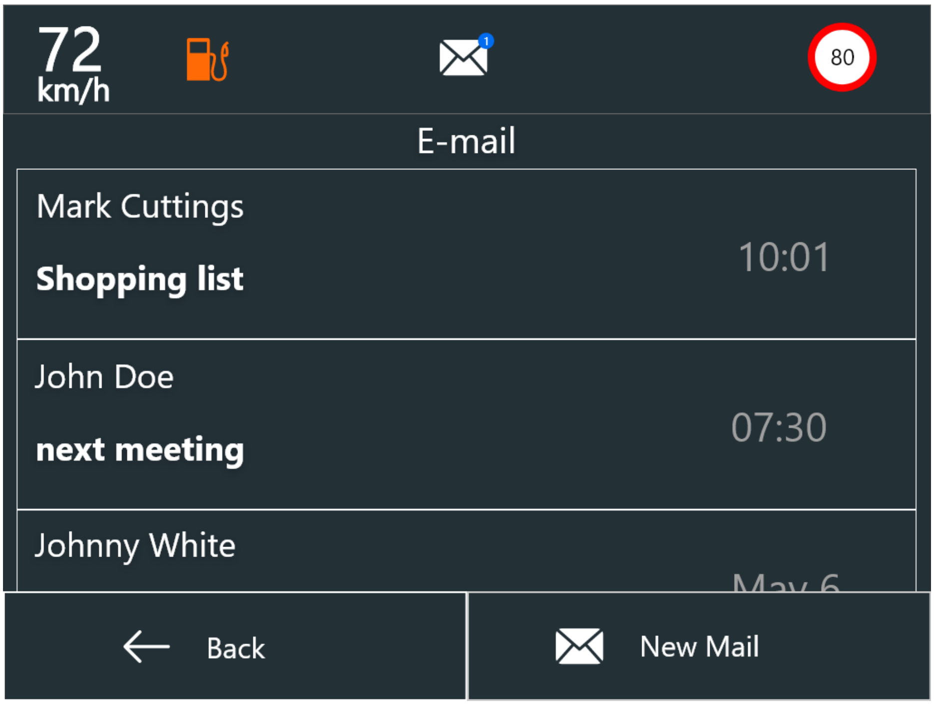

Figure A.20: A list of recent e-mails.

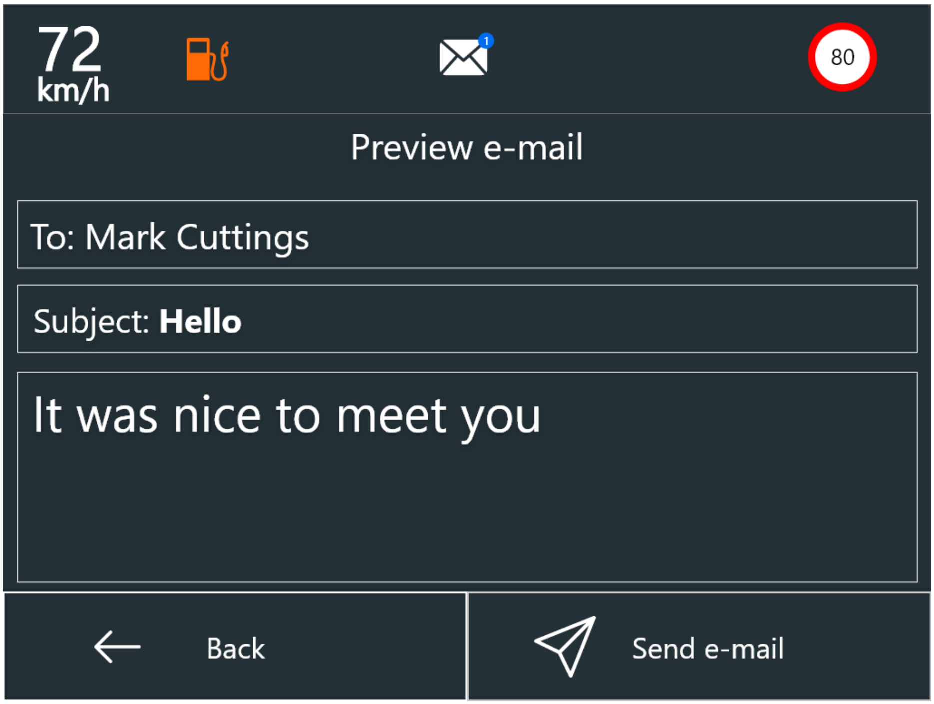

Figure A.21: Previewing an e-mail before sending it.

Icons features in these wireframes were collected from Flaticon [29–52].

A.4 Field Research

Pictures taken from the field research are featured below.

Figure A.22: Interior of a Citroën.


Figure A.23: Mercedes controls for interacting with their infotainment system.

Figure A.24: Tesla dashboard screen.

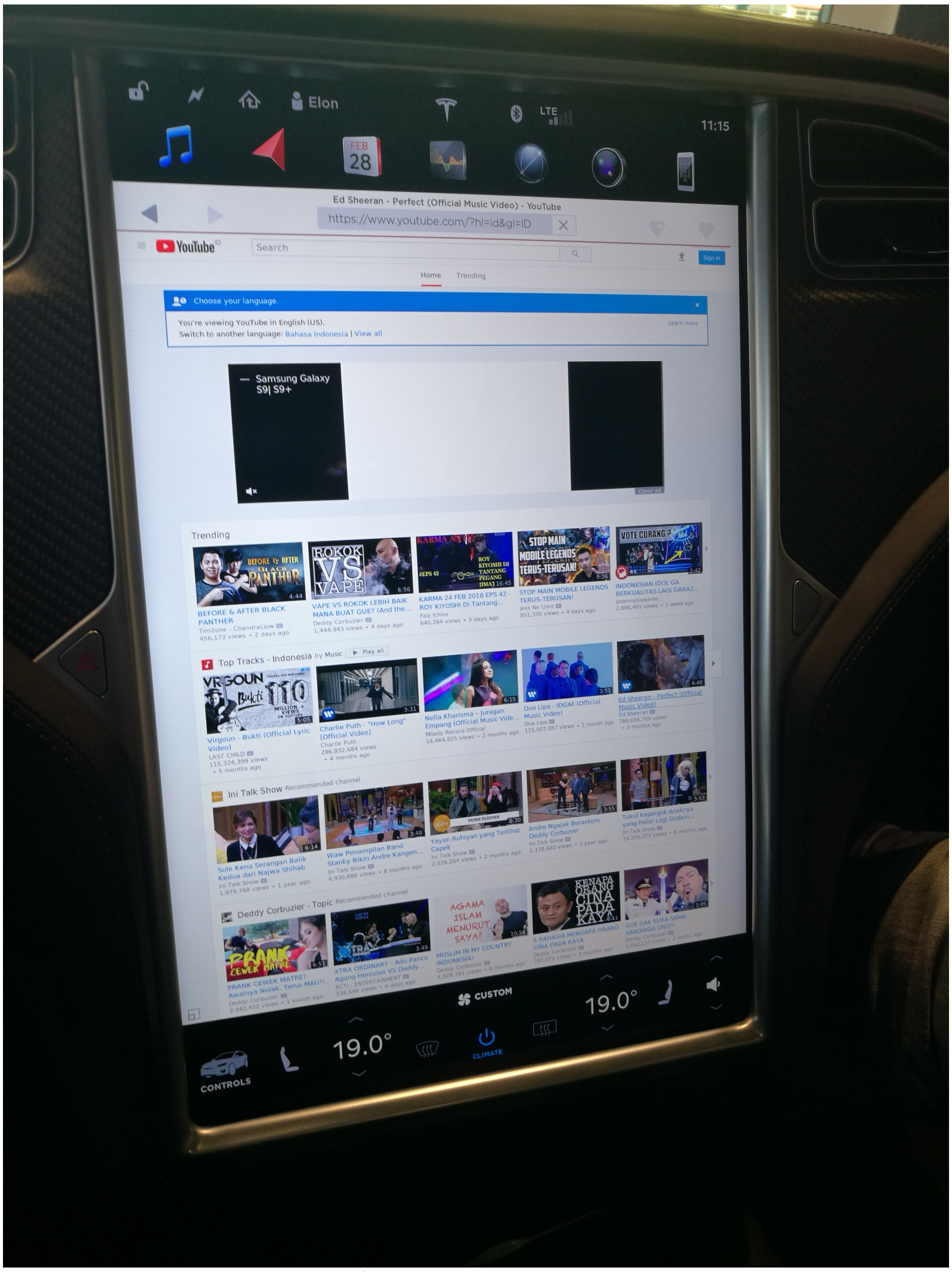

Figure A.25: Tesla center console.

Figure A.26: Volvo infotainment system interface.

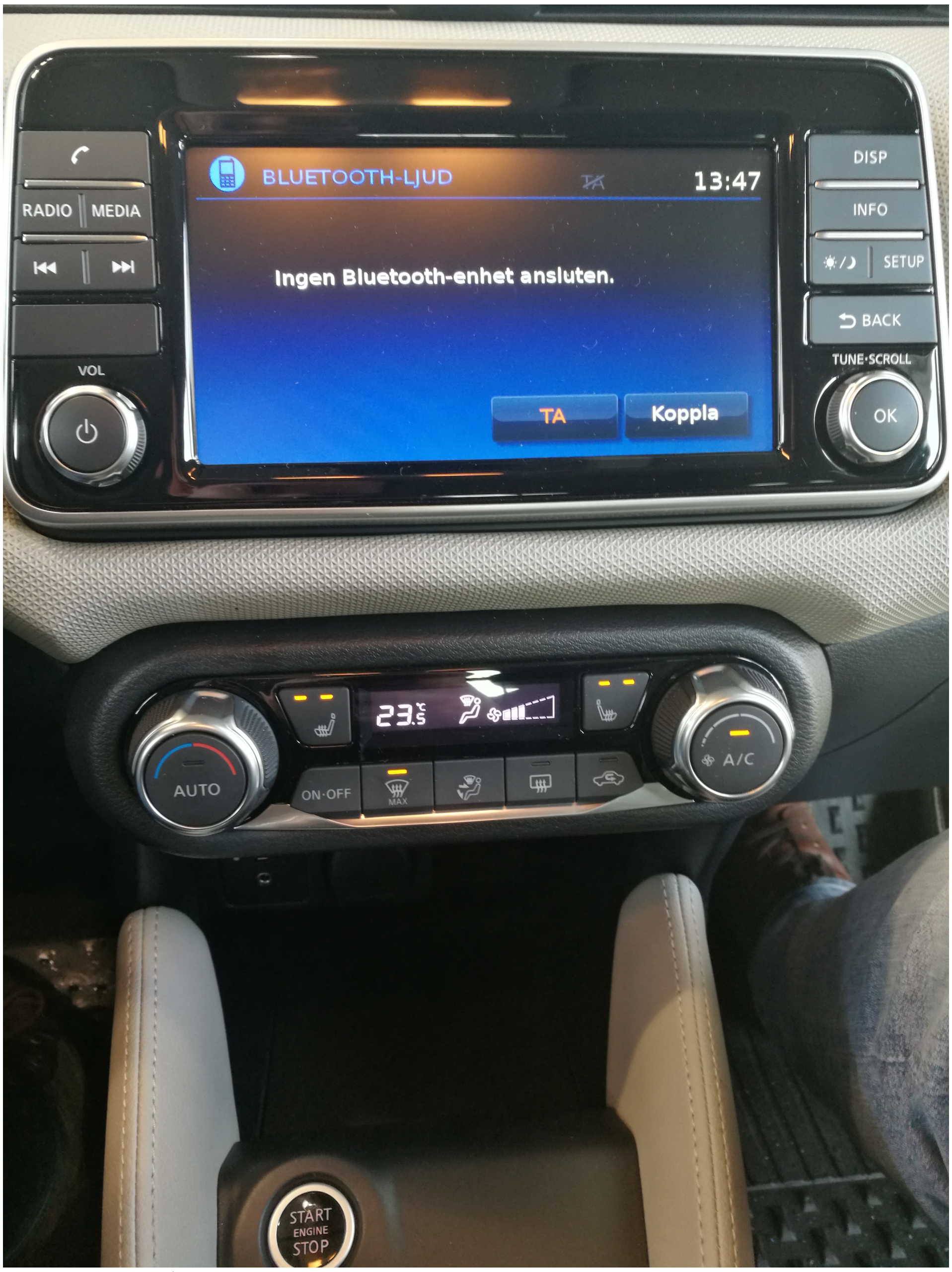

Figure A.27: Nissan infotainment system interface and controls.

A.5 User Survey

Driving habits

We are conducting this survey as part of a research project of driving habits in motor vehicles with advanced driver assistance. We hope you can spare 5-7 minutes by answering some questions. Your answers will be part of an exciting project meant to benefit future motor vehicles!

Note: This survey assumes you have a driver's license. All information is confidential and not to be distributed!

* Required

Background

In this section you answer general questions about yourself.

1. **What is your gender?** *
   Mark only one oval.
   - Male
   - Female
   - Other
   - Rather not say

2. **What country are you from?** *

3. **What is your age group?** *
   Mark only one oval.
   - 18 - 24
   - 25 - 34
   - 35 - 44
   - 45 - 54
   - 55 - 65
   - 65 +

4. **How long have you had a driver's license?** *
   Mark only one oval.
   - Less than 2 years
   - 2 to 5 years
   - 6 to 9 years
   - 10 to 19 years
   - 20+ years

General driving habits

This sections contains questions about your every day driving habits.

5. **How often do you drive?** *
Mark only one oval.

- ( ) Daily
- ( ) Once or a few times a week
- ( ) Once or a few times a month
- ( ) Once or a few times a year
- ( ) Never (or rarely)

6. **How long are your average driving sessions?** *
Mark only one oval.

- ( ) Less than 30 minutes
- ( ) 30 - 59 minutes
- ( ) 1 - 3 hours
- ( ) 4+ hours

7. **What are you primary reasons for driving?** *
Choose 1 or 2 options.
Check all that apply.

- [ ] To get to and from work or school
- [ ] As part of my job
- [ ] To perform small errands now and then
- [ ] It's more convenient compared to other options (bycicle, public transport, etc.)
- [ ] I have no other means of transportation
- [ ] I don't drive or I drive very rarely
- [ ] Other: ____________________

8. **If you answered 'as a part of my job' on the previous question, what type of vehicle do you drive for the job?**
Mark only one oval.

- ( ) Car
- ( ) Truck
- ( ) Other: ____________________

9. **What environments do you drive in mainly?** *
Mark only one oval.

- ( ) Highways, country roads and/or rural environments
- ( ) Cities
- ( ) Both of the above *Skip to question 25.*
- ( ) None *Skip to question 56.*

Advanced driver assistance

In this section we ask you questions about your familiarity with motor vehicles with advanced driver assistance. A motor vehicle with advanced driver assistance have systems that automatically allows the vehicle to keep a fixed distance to the motor vehicle in front by adjusting the speed and/or systems for staying in the middle of the lane.

10. **Have you ever driven a motor vehicle with advanced driver assistance enabled?** *
Mark only one oval.

- Yes
- No

11. **Do you own or primarily drive a motor vehicle with advanced driver assistance from any of these brands?** *
Mark only one oval.

- I don't own or drive a motor vehicle with driver assistance
- Acura *Skip to question 19.*
- Audi *Skip to question 19.*
- BMW *Skip to question 19.*
- Buick *Skip to question 19.*
- Cadillac *Skip to question 19.*
- Chevrolet *Skip to question 19.*
- Chrysler *Skip to question 19.*
- Daimler *Skip to question 19.*
- Dodge *Skip to question 19.*
- Fiat *Skip to question 19.*
- Ford *Skip to question 19.*
- GMC *Skip to question 19.*
- Honda *Skip to question 19.*
- Hyundai *Skip to question 19.*
- Infiniti *Skip to question 19.*
- Jeep *Skip to question 19.*
- Kia *Skip to question 19.*
- Lexus *Skip to question 19.*
- Lincoln *Skip to question 19.*
- Mazda *Skip to question 19.*
- Mercedes-Benz *Skip to question 19.*
- Nissan *Skip to question 19.*
- Peugeot *Skip to question 19.*
- Tesla *Skip to question 19.*
- Toyota *Skip to question 19.*
- Volkswagen *Skip to question 19.*
- Volvo *Skip to question 19.*
- Other: ____________________ *Skip to question 19.*

Performing non-driving tasks while driving

Here we ask question regarding what non-driving tasks are being performed while driving in your usual driving environment (either highways or city driving), as well as how often you perform them and how comfortable you are with them.

12. **How much do you perform any of these tasks while driving in your usual driving environment?** *
Tasks can be performed on a mobile phone or on built-in interfaces in the motor vehicle (infotainment system, buttons on the steering wheel, etc.).
Mark only one oval per row.

	Never	Rarely	Occasionally	Regularly
Social media (e.g. Facebook, Instagram)	◯	◯	◯	◯
Direct messages (e.g. SMS, Whatsapp, Messenger)	◯	◯	◯	◯
Voice calls	◯	◯	◯	◯
Email	◯	◯	◯	◯
Browse the web	◯	◯	◯	◯
Games	◯	◯	◯	◯
News, blogs or forums	◯	◯	◯	◯
Videos or movies	◯	◯	◯	◯

13. **How comfortable are you performing these tasks while driving in your usual driving environment?**
If you never perform a specific task, then don't choose any alternative for that task.
Mark only one oval per row.

	Not at all	A little	Very	Completely
Social media (e.g. Facebook, Instagram)	◯	◯	◯	◯
Direct messages (e.g. SMS, Whatsapp, Messenger)	◯	◯	◯	◯
Voice calls	◯	◯	◯	◯
Email	◯	◯	◯	◯
Browse the web	◯	◯	◯	◯
Games	◯	◯	◯	◯
News, blogs or forums	◯	◯	◯	◯
Videos or movies	◯	◯	◯	◯

14. **Do you perform any other tasks while driving in your usual driving environment?**
Describe the tasks, how you perform them, and how comfortable you feel performing them.

15. **What tasks would you engage in more, if the motor vehicle took responsibility of applying gas and brakes, as well as steering, while driving?**
Assume you still have to keep track of the road and be aware if the motor vehicle can no longer drive.

Task interaction

In what way you interact with an interface to complete a task.

16. **In what ways do you perform these tasks while driving in your usual driving environment?**
E.g. do you call someone by selecting a person with a touch screen or using numbers to give a command to call a person? If you do not perform a specific task, then do not select an option.
Check all that apply.

	Speech	Touch	Buttons or dials	Other
Social media (e.g. Facebook, Instagram)	☐	☐	☐	☐
Direct messages (e.g. SMS, Whatsapp, Messenger)	☐	☐	☐	☐
Voice calls	☐	☐	☐	☐
Email	☐	☐	☐	☐
Browse the web	☐	☐	☐	☐
Games	☐	☐	☐	☐
News, blogs or forums	☐	☐	☐	☐
Videos or movies	☐	☐	☐	☐

17. **If you chose 'Other' for any of the tasks above, what type of interface do you use to complete those tasks?**

18. **What would you change in order to make you more comfortable performing tasks while driving, which you normally would not perform?**
Assume you still have to keep track of the road and be aware if the motor vehicle can no longer drive.

Skip to question 47.

Performing non-driving tasks while driving with active driver assistance

Here we ask question regarding what non-driving tasks are being performed while driving in your usual driving environment (either highways or city driving) with driver assistance active, as well as how often you perform them and how comfortable you are with them.

19. **How much do you perform any of these tasks while driving in your usual driving environment and when driver assistance is active?** *
Tasks can be performed on a mobile phone or on built-in interfaces in the motor vehicle (infotainment system, buttons on the steering wheel, etc.).
Mark only one oval per row.

	Never	Rarely	Occasionally	Regularly
Social media (e.g. Facebook, Instagram)				
Direct messages (e.g. SMS, Whatsapp, Messenger)				
Voice calls				
Email				
Browse the web				
Games				
News, blogs or forums				
Videos or movies				

20. **How comfortable are you performing these tasks while driving in your usual driving environment and when driver assistance is active?**
If you never perform a specific task, then don't choose any alternative for that task.
Mark only one oval per row.

	Not at all	A little	Very	Completely
Social media (e.g. Facebook, Instagram)				
Direct messages (e.g. SMS, Whatsapp, Messenger)				
Voice calls				
Email				
Browse the web				
Games				
News, blogs or forums				
Videos or movies				

21. **Do you perform any other tasks while driving and when driver assistance is active?**
Describe the tasks, how you perform them, and how comfortable you feel performing them.

Task interaction

In what way you interact with an interface to complete a task.

22. **In what ways do you perform these tasks while driving in your usual driving environment?**
E.g. do you call someone by selecting a person with a touch screen or using numbers to give a command to call a person? If you do not perform a specific task, then do not select an option.
Check all that apply.

	Speech	Touch	Buttons or dials	Other
Social media (e.g. Facebook, Instagram)	☐	☐	☐	☐
Direct messages (e.g. SMS, Whatsapp, Messenger)	☐	☐	☐	☐
Voice calls	☐	☐	☐	☐
Email	☐	☐	☐	☐
Browse the web	☐	☐	☐	☐
Games	☐	☐	☐	☐
News, blogs or forums	☐	☐	☐	☐
Videos or movies	☐	☐	☐	☐

23. **If you chose 'Other' for any of the tasks above, what type of interface do you use to complete those tasks?**

____
____
____
____
____

24. **What would you change in order to make you more comfortable performing tasks while driving, which you normally would not perform?**
Assume you still have to keep track of the road and be aware if the motor vehicle can no longer drive.

____
____
____
____
____

Skip to question 48.

Advanced driver assistance

In this section we ask you questions about your familiarity with motor vehicles with advanced driver assistance. A motor vehicle with advanced driver assistance have systems that automatically allows the vehicle to keep a fixed distance to a motor vehicle in front by adjusting the speed and/or systems for staying in the middle of the lane.

25. **Have you ever driven a motor vehicle with advanced driver assistance enabled?** *
Mark only one oval.

◯ Yes
◯ No

26. **Do you own or primarily drive a motor vehicle with advanced driver assistance from any of these brands?** *

Mark only one oval.

- I don't own or drive a motor vehicle with driver assistance
- Acura *Skip to question 38.*
- Audi *Skip to question 38.*
- BMW *Skip to question 38.*
- Buick *Skip to question 38.*
- Cadillac *Skip to question 38.*
- Chevrolet *Skip to question 38.*
- Chrysler *Skip to question 38.*
- Daimler *Skip to question 38.*
- Dodge *Skip to question 38.*
- Fiat *Skip to question 38.*
- Ford *Skip to question 38.*
- GMC *Skip to question 38.*
- Honda *Skip to question 38.*
- Hyundai *Skip to question 38.*
- Infiniti *Skip to question 38.*
- Jeep *Skip to question 38.*
- Kia *Skip to question 38.*
- Lexus *Skip to question 38.*
- Lincoln *Skip to question 38.*
- Mazda *Skip to question 38.*
- Mercedes-Benz *Skip to question 38.*
- Nissan *Skip to question 38.*
- Peugeot *Skip to question 38.*
- Tesla *Skip to question 38.*
- Toyota *Skip to question 38.*
- Volkswagen *Skip to question 38.*
- Volvo *Skip to question 38.*
- Other: ______________________ *Skip to question 38.*

Highway driving - performing non-driving tasks

Here we ask question regarding what non-driving tasks are being performed while driving on highways, country roads and rural environments, as well as how often you perform them and how comfortable you are with them.

27. **How much do you perform any of these tasks during highway driving?** *

Tasks can be performed on a mobile phone or built-in interfaces in the motor vehicle (infotainment system, buttons on the steering wheel, etc.).
Mark only one oval per row.

	Never	Rarely	Occasionally	Regularly
Social media (e.g. Facebook, Instagram)				
Direct messages (e.g. SMS, Whatsapp, Messenger)				
Voice calls				
Email				
Browse the web				
Games				
News, blogs or forums				
Videos or movies				

28. **How comfortable are you performing these tasks during highway driving?**

If you never perform a specific task, then don't choose any alternative for that task.
Mark only one oval per row.

	Not at all	A little	Very	Completely
Social media (e.g. Facebook, Instagram)				
Direct messages (e.g. SMS, Whatsapp, Messenger)				
Voice calls				
Email				
Browse the web				
Games				
News, blogs or forums				
Videos or movies				

29. **Do you perform any other tasks during highway driving?**

Describe the tasks, how you perform them, and how comfortable you feel performing them.

30. **What tasks would you engage in more, if the motor vehicle took responsibility of applying gas and brakes, as well as steering, while driving on highways?**

Assume you still have to keep track of the road and be aware if the motor vehicle can no longer drive.

City driving - performing non-driving tasks

Here we ask question regarding what non-driving tasks, i.e. tasks other than those directly related to driving, are being performed while driving in cities, as well as how often you perform them and how comfortable you are with them.

31. **How much do you perform any of these tasks during city driving?** *
Tasks can be performed on a mobile phone or built-in interfaces in the motor vehicle (infotainment system, buttons on the steering wheel, etc.).
Mark only one oval per row.

	Never	Rarely	Occasionally	Regularly
Social media (e.g. Facebook, Instagram)				
Direct messages (e.g. SMS, Whatsapp, Messenger)				
Voice calls				
Email				
Browse the web				
Games				
News, blogs or forums				
Videos or movies				

32. **How comfortable are you performing these tasks during city driving?**
If you never perform a specific task, then don't choose any alternative for that task.
Mark only one oval per row.

	Not at all	A little	Very	Completely
Social media (e.g. Facebook, Instagram)				
Direct messages (e.g. SMS, Whatsapp, Messenger)				
Voice calls				
Email				
Browse the web				
Games				
News, blogs or forums				
Videos or movies				

33. **Do you perform any other tasks during city driving?**
Describe the tasks, how you perform them, and how comfortable you feel performing them.

34. **What tasks would you engage in more, if the motor vehicle took responsibility of applying gas and brakes, while driving in cities?**
Assume you still have to keep track of the traffic and be aware if the motor vehicle can no longer drive.

Task interaction

Task interaction

35. **In what ways do you perform these tasks while driving?**
E.g. do you call someone by selecting a person with a touch screen or using numbers to give a command to call a person? If you do not perform a specific task, then do not select an option.
Check all that apply.

	Speech	Touch	Buttons or dials	Other
Social media (e.g. Facebook, Instagram)	☐	☐	☐	☐
Direct messages (e.g. SMS, Whatsapp, Messenger)	☐	☐	☐	☐
Voice calls	☐	☐	☐	☐
Email	☐	☐	☐	☐
Browse the web	☐	☐	☐	☐
Games	☐	☐	☐	☐
News, blogs or forums	☐	☐	☐	☐
Videos or movies	☐	☐	☐	☐

36. **If you chose 'Other' for any of the tasks above, what type of interface do you use to complete those tasks?**

37. **What would you change in order to make you more comfortable performing tasks while driving, which you normally would not perform?**
Assume you still have to keep track of the road and be aware if the motor vehicle can no longer drive.

Skip to question 47.

Highway driving - performing non-driving tasks with active driver assistance

Here we ask question regarding what non-driving tasks are being performed while driving on highways, country roads and rural environments, with driver assistance active, as well as how often you perform them and how comfortable you are with them.

38. **How much do you perform any of these tasks during highway driving and when driver assistance is active?** *

Tasks can be performed on a mobile phone or built-in interfaces in the motor vehicle (infotainment system, buttons on the steering wheel, etc.).
Mark only one oval per row.

	Never	Rarely	Occasionally	Regularly
Social media (e.g. Facebook, Instagram)				
Direct messages (e.g. SMS, Whatsapp, Messenger)				
Voice calls				
Email				
Browse the web				
Games				
News, blogs or forums				
Videos or movies				

39. **How comfortable are you performing these tasks during highway driving and when driver assistance is active?**

If you never perform a specific task, then don't choose any alternative for that task. If you never engage in highway driving with driver assistance active, then you can go to the next section.
Mark only one oval per row.

	Not at all	A little	Very	Completely
Social media (e.g. Facebook, Instagram)				
Direct messages (e.g. SMS, Whatsapp, Messenger)				
Voice calls				
Email				
Browse the web				
Games				
News, blogs or forums				
Videos or movies				

40. **Do you perform any other tasks while driving on highways and when driver assistance is active?**

Describe the tasks, how you perform them, and how comfortable you feel performing them.

City driving - performing non-driving tasks with active driver assistance

Here we ask question regarding what non-driving tasks are being performed while driving in cities, with driver assistance active, as well as how often you perform them and how comfortable you are with them.

41. **How much do you perform any of these tasks during city driving and when driver assistance is active?** *

Tasks can be performed on a mobile phone or built-in interfaces in the motor vehicle (infotainment system, buttons on the steering wheel, etc.).
Mark only one oval per row.

	Never	Rarely	Occasionally	Regularly
Social media (e.g. Facebook, Instagram)				
Direct messages (e.g. SMS, Whatsapp, Messenger)				
Voice calls				
Email				
Browse the web				
Games				
News, blogs or forums				
Videos or movies				

42. **How comfortable are you performing these tasks during city driving and when driver assistance is active?**

If you never perform a specific task, then don't choose any alternative for that task.
Mark only one oval per row.

	Not at all	A little	Very	Completely
Social media (e.g. Facebook, Instagram)				
Direct messages (e.g. SMS, Whatsapp, Messenger)				
Voice calls				
Email				
Browse the web				
Games				
News, blogs or forums				
Videos or movies				

43. **Do you perform any other tasks while driving in cities and when driver assistance is active?**

Describe these tasks below, how to perform these tasks and how comfortable you feel.

Task interaction

In what way do you interact with an interface to complete a task.

44. **In what ways do you perform these tasks while driving?**
E.g. do you call someone by selecting a person with a touch screen or using numbers to give a command to call a person? If you do not perform a specific task, then do not select an option.
Check all that apply.

	Speech	Touch	Buttons or dials	Other
Social media (e.g. Facebook, Instagram)	☐	☐	☐	☐
Direct messages (e.g. SMS, Whatsapp, Messenger)	☐	☐	☐	☐
Voice calls	☐	☐	☐	☐
Email	☐	☐	☐	☐
Browse the web	☐	☐	☐	☐
Games	☐	☐	☐	☐
News, blogs or forums	☐	☐	☐	☐
Videos or movies	☐	☐	☐	☐

45. **If you chose 'Other' for any of the tasks above, what type of interface do you use to complete those tasks?**

46. **What would you change in order to make you more comfortable performing tasks while driving, which you normally would not perform?**
Assume you still have to keep track of the road and be aware if the motor vehicle can no longer drive.

Skip to question 51.

Expectations with driver assistance

Here we ask you what your expectations with motor vehicles with driver assistance.

47. **What do you know about the current state of motor vehicles with driver assistance, how well they perform and what their capabilities are, etc?**
Please elaborate.

Skip to question 56.

Experience with driver assistance

In this section, we will ask you questions about the driver assistance systems you are using.

Abbreviations:
CC = Cruise Control, keeps a constant speed of the vehicle automatically
ACC = Adaptive Cruise Control, advanced cruise control which automatically keeps distance to the vehicle in front by adjusting the speed
LC = Lane Centering, steers and keeps the vehicle in the middle of the lane automatically

48. **How often do you use these systems while driving in your usual driving environment?** *
Mark only one oval per row.

	Never	Rarely	Occasionally	Regularly
CC				
ACC				
LC				

49. **How much do you trust these systems while driving in your usual driving environment?** *
Mark only one oval per row.

	Not at all	A little	A lot	Completely
CC				
ACC				
LC				

50. **Are there any other driver assistance systems which you have used? In that case, what are your experiences with them?**
Please elaborate.

Skip to question 56.

Experience with driver assistance

In this section, we will ask you questions about the driver assistance systems you are using.

Abbreviations:
CC = Cruise Control, keeps a constant speed of the vehicle automatically
ACC = Adaptive Cruise Control, advanced cruise control which automatically keeps distance to the vehicle in front by adjusting the speed
LC = Lane Centering, steers and keeps the vehicle in the middle of the lane automatically

Highway driving

This includes highways, country roads and rural environments.

51. **How often do you use these systems when you drive on highways?** *
Mark only one oval per row.

	Never	Rarely	Occasionally	Regularly
CC				
ACC				
LC				

52. **How much do you trust these systems while driving on highways?** *
Mark only one oval per row.

	Not at all	A little	A lot	Completely
CC				
ACC				
LC				

City driving

53. **How often do you use these systems when you drive in cities?** *
Mark only one oval per row.

	Never	Rarely	Occasionally	Regularly
ACC				
LC				

54. **How much do you trust in these systems while driving in cities?** *
Mark only one oval per row.

	Not at all	A little	A lot	Completely
ACC				
LC				

Other driver assistance systems

55. **Are there any other driver assistance systems which you have used? In that case, what are your experiences with them?**
Please elaborate.

Followup Questions

56. **Do you have any other thoughts or comments?**

57. **Do you want to participate in future surveys?** *

Including questionnaires and interviews.
Mark only one oval.

- Yes
- No

58. **Do you want to participate in future user tests?** *

A user test can mean testing different prototypes where we observe and ask questions. The user tests will be conducted in Gothenburg.
Mark only one oval.

- Yes
- No

59. **Do you want to participate in future user tests?** *

Mark only one oval.

- Yes
- No

60. **If you answered yes on any of the previous questions, how can we contact you?**

Please specify your email and/or phone number

Stop filling out this form.

Thank you for your participation, feedback?

61. **What did you think of the survey? Describe below what you though was positive, and what was negative.**

E.g. something was hard to understand or an alternative was missing in the answers?