UNIVERSIDAD POLITÉCNICA DE MADRID

ESCUELA TÉCNICA SUPERIOR DE INGENIEROS INFORMÁTICOS

MASTER EIT DIGITAL IN HUMAN COMPUTER INTERACTION AND DESIGN

Understanding the Changes Needed in the Current Existing Technology for Making Autonomous Vehicles More Accessible to Users that are Blind, Deaf or Deaf-Blind

Master Thesis

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Madrid, July 2019

This thesis is submitted to the ETSI Informáticos at Universidad Politécnica de Madrid in partial fulfillment of the requirements for the degree of Master EIT Digital in Human Computer Interaction and Design.

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Acknowledgment

I would first like to thank my thesis advisors Mrs. Maria Klingegård (professional) from RISE Viktoria and Mr. Loïc Martìnez Normand (academic) from UPM. The door to their office were always open whenever I ran into some trouble spot or had a question about my research or writing. They consistently allowed this paper to be my own work but steered me in the right direction whenever they thought I needed it.

I would also like to thank all the colleagues from RISE and Pariception and to all the participants who were involved in the multiple studies conducted for this master research project. Without their passionate participation and input, the studies could not have been successfully conducted.

Finally, I must express my profound gratitude to my parents and my friends for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you.

Pournami Krishnakumari

Abstract

Accessibility and autonomous vehicles are popular and highly talked about topics as the issue of accessibility for people with disabilities is becoming relevant for business. Despite people with disabilities being regarded as "early adopters", there is a lack of testing and surveys during the design process relating to these target users. The potential of autonomous vehicles for the target group users are explored in this thesis, as well as the potential limitations or possibilities that would emerge when the driver is removed.

In this Master Thesis, multiple studies with different methods are used: expert reviews, usability testing, qualitative interviews and field observations. The findings from these studies indicate that there are many areas or functionalities (multi-mode for communication, emergency handling, proper alerts and notifications, customized services/information, accessible buttons or elements) that need to be focused on when developing and designing accessible autonomous vehicles in the future. Additionally, this thesis evaluates the limitations and possibilities of vibro-tactile guiding aids in helping the target users when tested in the context of the use of an autonomous vehicle. The results indicate that the vibro-tactile aids are highly helpful to users, especially users who are blind or visually-impaired, but less for the users who are deaf. The aid needs to have a communication line with the autonomous vehicle and should also support different modes of communication.

Chapter 1: Introduction

The issue of Accessibility for people with disabilities is becoming relevant for business. Companies have started giving importance to this area which has previously been ignored. The many studies and initiatives regarding accessibility show that the leading companies are focusing on this [1]. Within the transportation community, companies such as Uber are developing technologies which help the mobility and independence of transportation for users with disabilities [2]. The amount of research and studies in the area of accessibility of transportation services indicates the rise in the importance of accessible transportation for people with disabilities (blind, deaf, deaf-blind and many others). Several studies have provided many concepts, product ideas and/or products using new technologies to aid in navigating and guiding people with disabilities throughout their daily routines (see Section 2.2 and 2.3).

1.1. Problem statement

Accessibility and autonomous vehicles are popular and highly talked about topics, and the majority of the currently leading companies are developing designs and product concepts which would increase accessibility for all. Autonomous vehicles can benefit people with disabilities by extending their independence and smoothing their transportation experience (see Section 2.2.5).

Elderly and people with disabilities are considered the "early adopters", i.e., the first user group, for autonomous vehicles. Yet, these users are not always tested or surveyed during the design process [3]. Hence, there is a need to understand the accessibility requirements for people with disabilities who use autonomous vehicles better, and to identify missing features that should be added to the vehicles or the surrounding environment.

Today, transportation customers are used to the drivers providing the help they (may) need. Thus, it is important to understand and address the difficulties elderly and people with disabilities face when there is no human support when they travel. This Master Thesis focuses on a subset of people with disabilities: people who are blind, deaf or deaf- blind.

There are several guiding technologies available on the market, especially vibro-tactile aid in which the users receive information in the form of vibration signals as per their needs and knowledge. But there is a lack of overall studies that have tested them, a lack of empirical evidence on which solution is the best for the accessible transportation scenario. It is important to see which of these technologies or which mix of technologies are the best for assisting users who are blind, deaf or deaf-blind while travelling in these driverless/autonomous vehicles (see Section 2.2.4).

1.2. Research Questions

1. What are the implications for target users (people who are blind, deaf, or deaf-blind) when autonomous vehicles are introduced and there is no driver in the vehicle? (R1)
   a. What are the basic requirements of the target users during their transportation experience?
2. What benefits and limitations does the vibro-tactile method have for people who are blind, deaf and deaf-blind when used in combination with autonomous vehicles? (R2)
3. What are the main areas that need to be focused on during the design and development process of these autonomous vehicles? (R3)

1.3. Aim and Objectives

The aim of this Master Thesis is to explore the potential of autonomous vehicles for the specific target group users, and to identify the potential limitations and/or possibilities that emerge when there is no (human) driver. Additionally, the aim of this master thesis is to gather insights from persons who belong to the target group. Therefore, real users belonging to the target group are included in the process of the study.

To answer the research questions (see Section 1.2), the following objectives are identified:
1. Expert review of autonomous vehicles and their pain and pleasure points from an accessibility viewpoint.
2. Identify the role (actions, function) of the driver to identify the potential of autonomous vehicles.

a. Carry out interviews with bus/taxi drivers and target users to map their activity and interaction with the passengers.

b. Observation study of users of the target group using transport.

3. Identify the possibilities and limitations of the vibro-tactile guiding aid, for helping the target user in having a comfortable travel experience, by conducting an explorative user study of the prototype.

Table 1 provides information about each objective is connected to the research questions.

Table 1: Objectives and their research questions.

Research Questions	Objectives
R1, R3	Expert review of autonomous vehicles and their pain and pleasure points from an accessibility viewpoint.
R1, R3	Identify the role (actions, function) of the driver to identify the potential of autonomous vehicles.
R1, R3	Carry out interviews with bus/taxi drivers and target users to map their activity and interaction with the passengers.
R1, R3	Observation study of users of the target group using transport.
R1, R2, R3	Identify the possibilities and limitations of the vibro-tactile guiding aid, for helping the target user in having a comfortable travel experience, by conducting an explorative user study of the prototype.

This Master Thesis research activity has been carried out at RISE Viktoria, Sweden, in cooperation with Pariception.

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[1] All pictures with faces of participants in this Master Thesis has been used after getting permission from them.

Chapter 2: State of Art

This section discusses the major topics of this Master Thesis in detail. Furthermore, it lists the existing, launched and concept technologies currently available.

In the context of this Master Thesis, Accessibility means being accessible or adaptable or understandable for people with specific disabilities: persons who are blind, deaf or deaf- blind. These would be the Target Users in the context of this Thesis.

In this document, the terms Autonomous Vehicles, Self-Driving Cars, or Driverless Cars are considered to be equivalent.

2.1. Transportation and it's future

The face of transportation has changed a lot in the past decade. Within the transportation industry, autonomous vehicles, otherwise known as self-driving vehicles, are highly attractive and an emerging technology. Many are still discussing and debating on the pros and cons of this new change in the transportation ecosystem [4].

Levels of Automation

According to SAE, the Society of Automobile Engineers, there are 6 levels of vehicle autonomy [5]:

- ***Level 0 - No Automation, 'Full Human Control':*** At this level of autonomy, the driver controls all operating tasks such as braking, steering, and accelerating.

- ***Level 1 - Driver Assistance, 'Hands On':*** For this level of autonomy, the driver controls the major operating tasks like braking, accelerating and monitoring the surroundings, but the vehicle will assist the driver with some of these functions, such as instant braking when in close proximity to other vehicles.

- ***Level 2 - Partial Automation, 'Hands Off':*** This level of autonomy is currently being developed by most leading companies. At this level, the vehicle assists the driver with steering, acceleration and braking during certain

circumstances, for example, Audi Traffic Jam Assist or Mercedes-Benz Driver Assistance Systems. However, the driver remains fully responsible and must be ready to take control of the vehicle immediately.

- ***Level 3 - Conditional Automation, 'Eyes Off':*** For this level of autonomy, the vehicle monitors the environment and operates the vehicle for some predefined routes. The attention of the driver is still critical for this level of automation.

- ***Level 4 - High Automation, 'Mind Off':*** For this level of autonomy, the vehicle is capable of all operating tasks such as steering, braking, accelerating, monitoring the vehicle and roadway, as well as responding to events, determining when to switch lanes, turn, and use signals. However, the autonomous system notifies the driver when the vehicle is ready to activate auto-pilot mode. This level of automation does not work efficiently in dynamic driving situations such as waiting at traffic signals or merging into highways.

- ***Level 5 - Complete Automation, 'Steering Wheel Optional':*** For this level of autonomy, the vehicle is capable of controlling all critical operating tasks, monitoring the environment and work efficiently in dynamic driving situations. This level of autonomous driving does not require any attention from the driver. Thus, there is no need for a driver to control the wheels, pedals or brakes, everything is controlled by the autonomous vehicle system.

Leading vehicle manufacturing companies such as Tesla [6], Volvo [7] and BMW [8] have already made their mark in the autonomous vehicle industry by launching vehicles and concepts that are meant to change the face of personal transportation. As of 19th October 2016, all vehicles produced by Tesla included the hardware needed for a fully self-driving capability at a safety level which they promise to be substantially greater than that of a human driver [6]. Due to the increase in individual mobility needs, Volvo has developed a new concept called 360c (Figure 1). This new concept envisions a variety of experiences based on the needs of the passengers, including mood settings designed to help them relax. Volvo believes that such a standardized system would play an integral part in making autonomous vehicle travel in a safe and pleasant reality [7]. BMW is on the threshold of highly autonomous driving. They are already offering driver assistance systems, such as speed, steering and lane control

assistants. Additionally, they are working with developing more innovative technologies. However, the safety of their customers is their first priority [8].

Figure 1: Concept designs for the Volvo 360c [7]

Other leading companies like Google [9] and Aurrigo [10] are developing autonomous vehicle concepts and have even tested them in real roads. The main interesting fact about these concepts is how much of the effort is trying to bring this new technology into the shared transportation behaviours of public transport. Google started its autonomous project in 2009 with their Self-Driving Car Project named Waymo (Figure 2). Waymo One is their latest fully autonomous service. The vehicle understands the road and shows the passenger what it observes in its surrounding. The vehicle sees in all directions, is constantly vigilant and would be more experienced than any driver [9]. The company Aurrigo (Figure 3) are claiming to be the leaders in the autonomous PODS (autonomous shuttles/cars), which is the new phase of transporting people

effectively from the destination point to the last stage of their journey. Shopping centers, airports, heritage sites, sporting venues and other city transport initiatives are all actively moving forward with the application of driverless transport by trying to bring these autonomous POD concepts in helping the passengers have a smooth last mile journey. Autonomous POD's would play a significant role in the future development of transport systems within smart cities, eco towns and villages [10]. CLOUI is the world's first inclusive mobility concept for autonomous driving, which can be adapted to the specific needs of the users and this would be a huge support for people with disabilities as these vehicles adapt to the special needs of the passengers [11].

Figure 2: The World's Most Experienced Driver by Google's Self Driving Project since 2009 [9]
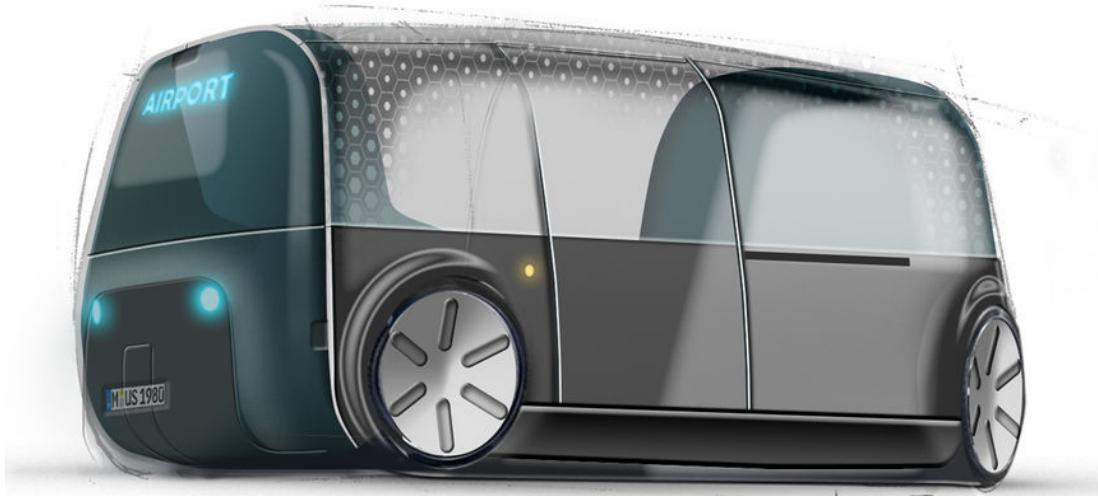

Figure 3: PARAVAN's concept of CLOUI offering the world's first inclusive mobility concept [11]

Despite its potential to improve traffic conditions, reduce the carbon footprint and significantly reduce crash incidents, there are some difficulties with autonomous

vehicles. The main barrier for the industry to adopt this new technology is the lack of public trust. There are often concerns about security and safety when any technology is autonomous. Studies and public debates about autonomous vehicles show that this emerging technology is still being tested, and many concept prototypes are being launched constantly [12].

Autonomous vehicles are considered one of the key players in the next technological revolution. These vehicles have the potential to substantially reform road transportation by increasing safety and traffic flow efficiency as well as ensuring mobility for all [3] [13]. A recent research study sponsored by the company Nissan [14] found that autonomous vehicles would contribute $17 trillion to the European economy by 2050. The study also found that autonomous cars would contribute 0.15% to Europe's annual growth rate over the coming decades. Autonomous vehicles, cars in particular, are seen as a means to provide increased mobility to aging Europeans and reducing isolation from and dependency on the state and family for assistance.

A research study [15] conducted by Lundquist in 2018 on "*creating a set of interaction strategies to provide an efficient and pleasurable journey for the passenger traveling with an autonomous bus*", gave interesting insights on what characteristics people look for in autonomous vehicles. Passengers use multiple platforms to search for the bus timings before the journey and during the journey. However, the information does not match most of the time. Thus, according to the aforementioned research study, **consistency** in the mode of information is highly important, especially a better AI (Artificial Intelligence) graphical layout of maps that show connection services. The lack of consistency leads to passengers using multiple devices or applications to receive customized information which can be hazardous. Therefore, **one device** or application where all information is easily accessible would be well received. Another key thing missing is the **information** itself. It can be difficult for passengers to find basic information about departure times, which exit to take, or even which bus to board, etc. Passengers acknowledge the improvements regarding the behavioral consistency of the bus when it is made autonomous. However, passengers who need to reaffirm certain information would lose an easily accessible source, the driver, otherwise available when they board and disembark from the bus.

Additionally, in Lundquist's study [15], most of the passengers who were interviewed/surveyed mentioned that they were not concerned about the **absence of**

a driver to operate the controls in an autonomous vehicle, rather they worry about handling a potential emergency when there is no driver present. **Trust** plays an important role in public transportation. Passengers trust and rely on the driver(s), especially in the case of an emergency. This is lost when a bus is made autonomous. However, according to the study, trust could be built through showing passengers the intentions of the bus, being transparent in error handling, and having a strong and reliable communication source. This can create understanding of all actions of the autonomous vehicle as well as the expected reactions.

One of the leading technology service companies, Bosch, recently conducted a survey to better understand the reaction of car owners towards autonomous driving and its features. This survey was participated by 1000 US based car buyers, mainly new. "52% of new car buyers in the U.S. expect to own at least one autonomous automobile in the next 10 years." People are either not aware about the Advanced Driver Assistance Systems (ADAS) on the current vehicles or the active safety systems. Another interesting trend found in the study was the awareness or attitude of car buyers towards the ADAS features on vehicles. The consumers find these features as a future innovation and not something that is that is accessible already in the market, which is not true. Most of the current vehicles in the market already have ADAS features such as automatic emergency braking, adaptive cruise control and active safety technologies such as electronic stability control and the buyers are not aware about these features. More than 52% of the participants from the survey believe that autonomous cars would become the next status symbol and nearly 50% of them believe that these cars would be able to offer the best passenger comfort for their passengers [16].

However, one of the studies, which was mentioned earlier, found that the main barrier to adoption of autonomous technology is the lack of public trust. Drawing on quantitative evidence, the study found that the ability of the driverless car to meet performance expectations and its reliability were important adoption determinants. Significant concerns included privacy (autonomy, location tracking and surveillance) and security (from hackers) [3].

Some of the other few drawbacks of this technology are the vehicle security and cybersecurity, the impact these vehicles have on the driving jobs, the cost and the passengers missing out on the joy of driving. Since these vehicles are autonomous, there is a chance for glitches that can happen on the system. These glitches have already

happened on the pilot testing of these vehicles that are carried out by major vehicle companies, such as the company Uber had a fatality when the vehicle flagged a "false positive" for a detection of a pedestrian who was passing by. These system malfunction can occur on rare cases. The vehicle even has to be smart enough to defend itself from any cyber-attacks or system hacks which can lead to many issues with data handling. There is always a section of people who gets affected by the invention of any new technology. One such section for this technology is the impact this would have on the drivers and their jobs. It is estimated that nearly 4 million jobs would be lost in America alone, due to the implementation of these autonomous vehicles These self-driving vehicles are supposed to be an expensive buy when it is launched in the market and this would always make these an unattainable purchase for an average American consumer. Then there is the joy of riding which is common among these car buyers. Most of the people love riding a vehicle and this technology is taking away that important feature from its functionality [12].

2.2. Accessibility

2.2.1. Accessibility and the Design Process

When conducting any user research it is a process in which the experts find and define any problems that the users may face using the product or service, at the earliest phase (initial design phase) as possible and about finding solutions or ways to address these problems through the design and development [17]. One of the major or most important criteria that has to be defined for any User Centered Design are the users' goals. These goals are defined by the user by understanding their end result and what they want to achieve in the end. Since most of the time, it is difficult for the users to find those exact or in-depth goals or needs, it is highly important to keep the target users always on the loop from the start of the design process (Figure 4) and make them a part of the information gathering process and test the earlier concepts and ideas and designs with actual users so as to create a more usable and user-friendly products or services [15].

There are numerous assistive technologies available in the market right now due to the numerous types of disabilities, from screen readers to keyboards that are modified according to the user's needs [1]. It goes without saying how important the smallest

details such as blue color on a link can affect the interpretation of content by different users and hence it has become a crucial function to include these smallest details in the design process so as to create an equal user experience. For instance, the cloud-based tools and service company Slack started its mission to approach accessibility by releasing features such as sidebar themes, screen reader improvements (iOS and Android devices), adjustable zoom preferences and the option for stopping any automatic animations on the screen. All these new features were clearly released keeping in mind of users with different disabilities or different assistive technologies in the market. The company is now on the process of developing the support for using the tool without a mouse.

Gains of using users during design process

❖ A richer understanding of a problem space from a different perspective. Potential users with disabilities contribute as active participants, rather than being considered by the design team only as abstract beneficiaries of accessibility guidelines. This helps organizations build practical empathy that can positively influence design and help spark innovation.

❖ Feedback on what works and what doesn't. You'll learn about features that are valued by people with disabilities and examples of good practices to follow (or not to abandon!). This helps isolate the high-priority design problems that you should focus on solving.

❖ First-hand experience of people with disabilities talking about and using technology, and the enabling impact it can have on their lives. This helps demystify and humanize accessibility and provides valuable stories that can be recorded and reused to educate and motivate.

❖ The change in the dynamic between the people who are producing the technology and the people who are using it. We're involving people with disabilities as partners in research and design—rather than as test pilots sent out to find flaws and barriers after a product has already been created. And when organizations integrate design thinking and inclusive design, that makes better products and services for everyone.

Figure 4: Some of the gains of using target users in the design process by Sloan, D [17]

Accessibility and UX Testing

One of the best and most popular methods of conducting user studies is the UX Testing method. It is highly important to consider the needs of people with disabilities in comprehensive usability testing. But for a better cost effectiveness and efficiency, it is better for these testing with people with disabilities to be conducted after all the other usability tests and accessibility evaluations. There are some main guidelines for conducting a UX testing with participants with disabilities (Figure 5). Always try to use the think-out loud technique as a methodology where the users would have high interaction with the facilitator. It is also highly important to make sure that the test focus is on the errors that are related to accessibility and not on the user satisfaction or

the time taken for completion of a task. The findings of the test should be the potential barriers for access rather than finding some general usage [18].

Planning consideration for conducting UX Testing on users with disabilities

- ❖ **Participant characteristics**: If you're testing for different disabilities, you'll need at least 3-5 participants for each disability. Be aware, though, that people with disabilities don't often fit neatly into categories.
- ❖ **How to recruit**: Connect with organizations for specific disabilities, local senior centers or university programs. Be sure to allow enough time to recruit, especially if your requirements are very specific.
- ❖ **Choosing the best location**: Many users may have trouble with transportation, and keep in mind the accessibility of your lab itself. Consider also whether it's best to provide a lab's assistive technologies or use the participant's.
- ❖ **How much time to allocate**: Testing time will be impacted by the participant's disability, so expect testing to take longer. It might be best to break up testing into shorter sessions as well.

Figure 5: Some of the considerations for planning and conducting UX Testing on users with disabilities [18]

2.2.2. Design for All Principles

According to the Center for Universal Design, Universal Design is the design of products or environments to be usable by all people, to the greatest extent possible, without any need of adaptation or customization in its design [19]. The Center for Universal Design has formulated seven principles (Figure 6) that could be applied for the purpose of evaluating existing designs or used as guidelines in the developmental stage of the design process. These principles can also have the educational purpose of informing designers and customers about how to develop a more usable and accessible products and/or environments [4].

Equitable Use	Design is useful and marketable to people with diverse abilities.
Flexibility in Use	Design accommodates a wide range of individual preferences and abilities.
Simple & Intuitive Use	Use of design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.
Perceptible Information	Design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.
Tolerance for Error	Design minimizes hazards and the adverse consequences of accidental or unintended actions.
Low Physical Effort	Design can be used efficiently and comfortably and with a minimum of fatigue.
Size and Space for Approach and Use	Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.

Figure 6: Seven Universal Design principles by the Center for Universal Design [19]

2.2.3. Accessibility in Transportation

People with disabilities, such as persons who can't see or hear or any other physical or mental disabilities, often rely on others or local government or nonprofit agencies for daily transportation [20]. Public transport being accessible to people with disabilities have gained a lot of importance in designing and evaluating transit system in terms of mobility and sustainability.

Many researchers have already revealed some impacts of public transport accessibility to the environment and other aspects it have on the daily life of the public. They found that the mobility through public transportation gives rise to the opportunity to decrease inauspicious effects of car usage on the environmental condition and healthfulness. It is also highly important to include accessibility factors in designing the infrastructure of public transport so as to provide a more attractive accessible public transport service [21] [22].

An interesting project was developed by four researchers from China and France where they created a concept for a dedicated public transportation service access system which supports and enhances the mobility experience for passengers with disabilities, named the **Mobi+ project** (Figure 7). This access system consists of three subsystems: *wireless communication subsystem*, that provides data exchange and network connection services between buses and stations in the complex urban environments; *bus subsystem*, that provides the DWB (disabled, wheel-chaired and blind) class detection and bus arrival notification services; and *station subsystem*, that implements the urban environmental surveillance and bus auxiliary access services. After the study on this prototype, the experiential results show that the system performance meets the design expectations and can also provide an effective bus access service for people with disabilities as this concept helps the users be aware of the right timing and notifications about the bus [23].
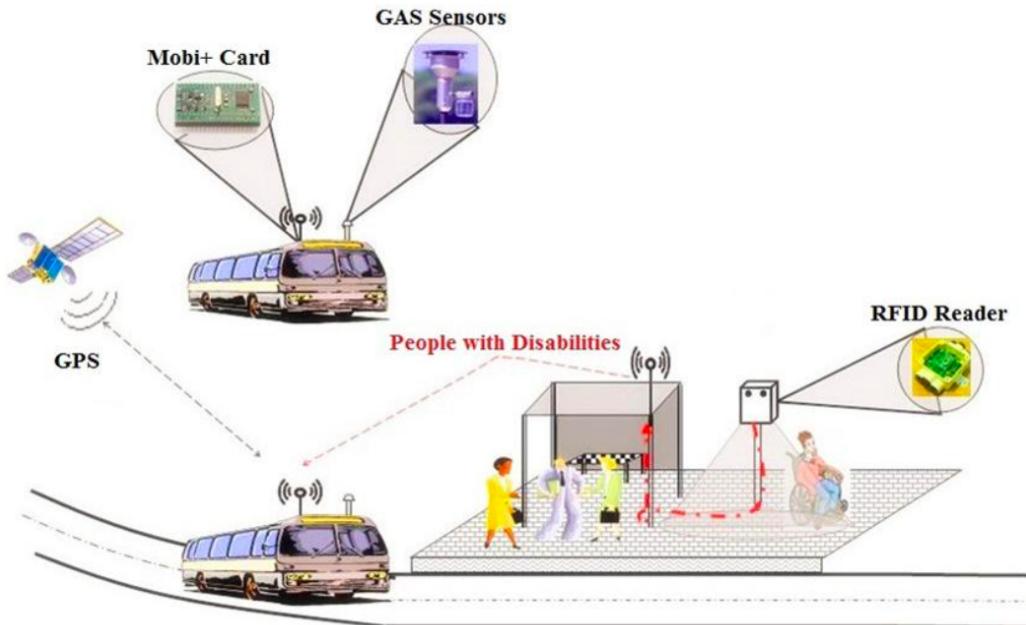
Figure 7: The Mobi+ Project framework of the concept [23]

The multinational transportation network company, UBER, is also taking a lot of steps in recent years to make their contribution towards making transportation accessible. Their technology is helping to increase the mobility and independence for passengers with disabilities during transportation, by launching new features and capabilities such as ***Cashless payments***, ***On-Demand transportation***, ***Upfront pricing***, ***Uber anti-discrimination policies*** and ***Sharing ETA*** (Estimated Time of Arrival) and ***location feature***. They even have special features for people with different types of disabilities. Passengers who are **blind or low-vision** can ride UBER smoothly and easily with their app which has VoiceOver iOS, Android TalkBack and wireless braille display compatibility. Passengers who are deaf or hard of hearing can make use of their app easily since audio is not needed for the functionality of the app. The app is highly adaptable for assistive technology such as visible and vibrating alerts and some in-app features such as ability to enter destination, able to facilitate non-verbal communication between the passenger and the driver-partner [2].

2.2.4. Accessibility and Navigation Guiding Tools

A lot of navigation guiding technologies for people with disabilities already exists in the market, at least in preliminary forms. These technologies are made to make the lives of people with disabilities smoother and easier. Microsoft released an app called "Seeing AI" and a research project concept called "Soundscape" recently. Seeing AI app acts as a visual or guiding aid for people who are visually impaired by using machine learning,

natural language processing and computer vision to understand the world or environment around and describe it in words to the user [20]. Soundscape is an audio-based technology that helps people with visual impairment or blindness by providing information about the users surrounding by creating the effect of 3D sound [24]. This section discusses some of the interesting navigation guiding technologies found during the research.

Outdoor Navigation System for Blind Pedestrians

The Outdoor Navigation System concept [25] is a novel, wearable navigation system for visually impaired and blind pedestrians which consists of a global positioning system (GPS) for the user outdoor localization and a tactile-foot stimulation for information presentation (Figure 8). The real-time data from the GPS by the smartphone is processed by a dedicated navigation software which determines the directions to reach the destination. These navigational directions are then encoded as vibrations and would be conveyed to the user using a tactile display which is inserted into the shoe. This prototype was evaluated in 2 stages.

The first test verified the interface's ability to transmit the tactile information to the user and the users understanding or comprehension level to the feedback received. The result from the first study showed that the users recognition rates for the feedback was high, which suggests that the displayed information is intuitive and fast to understand.

The second test evaluated the system and the user's performance in real outdoor environment. The result from the second study showed that the system is capable of guiding users from Point A to Point B by providing pertinent directional instructions.
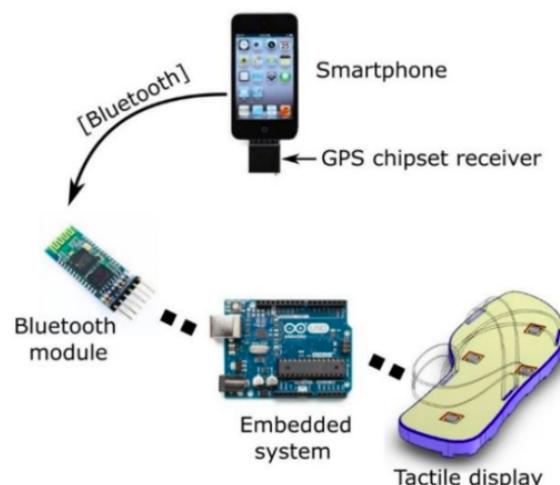
Figure 8: The framework for outdoor navigation system using GPS and tactile-foot feedback [25]

UbiBraille

UbiBraille [26] is a vibrotactile braille-reading device which allows blind users to leverage their knowledge in braille by using similar metaphor to traditionally known braille writing systems (Figure 9). This developed concept prototype consists of 6 actuators which are placed on the user's index, middle and ring fingers on both hands and this device takes advantage of the mnemonic association with braille characters by communicating letters through simultaneous stimuli on the user's fingers. The researchers conducted two user studies to assess both character and word reading performance. The result from the studies showed that the character recognition rated ranged from 54 - 100% and were highly character and user-dependent. During the study they also noticed that the participants with greater expertise in braille reading/writing were on a greater advantage and that they could achieve higher accuracy rates when compared with the rest of the participants. Another interesting finding from the study was that UbiBraille enables users to read complete sentences which is not achievable from other braille-based reading approaches.

One of the main limitations of this device found during the study was the six wired rings which had to be worn by the users. The researchers envision to create futuristic versions where the device is more miniaturized, wireless and easy to attach actuators.

Figure 9: The framework for UbiBraille prototype [26]

MoBraille

MoBraille [27] is also a novel framework that enables braille display users to benefit from android phone's GPS and 3G network connectivity features to interface with braille display through HTTP requests over Wi-Fi connection (Figure 10). The braille display would be tethered to the android phone over Wi-Fi and then the braille display user loads a MoBraille webpage on the display's built-in browser. This webpage would then send a request to the android phone, processed by a Java servlet and this servlet

can then access the sensors on the phone and enable braille display user access to a 3G network, GPS, a compass and other feature. This prototype is considered as a powerful device as it enables developers to write applications that interface with braille displays without any device specific knowledge. The developers just need to write an HTML page and a Java servlet that runs on android platform. MoBraille can facilitate the development of a low-cost braille application which has the potential to improve the public transit experience for blind and deaf-blind users.
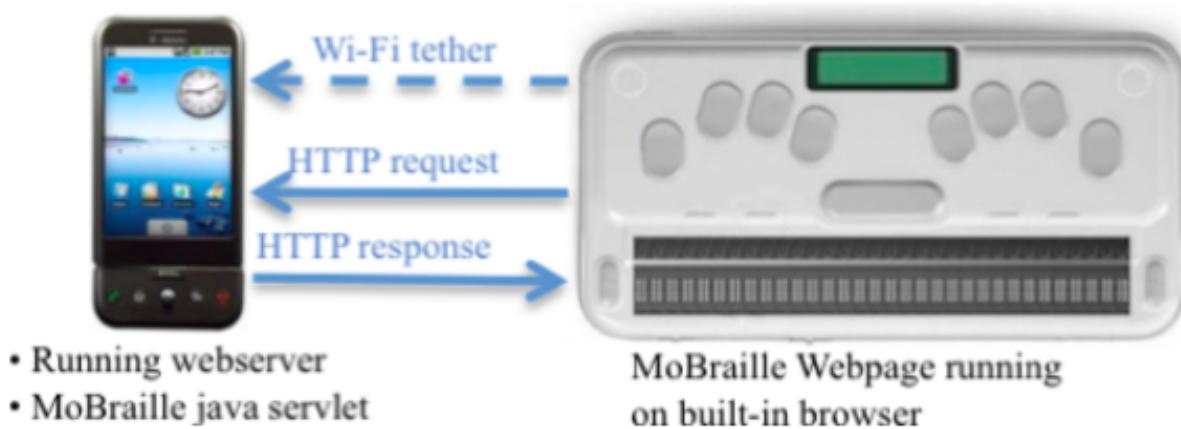
Figure 10: The framework for MoBraille prototype [27]

Monitor, a vibrotactile aid for environmental perception

Monitor [28] is a device that gives access to information about things happening in the surroundings for people with severe hearing impairment or deaf-blindness (Figure 11). This vibrotactile aid uses vibratory senses and is programmed to handle environmental sounds by detecting these sounds from the environment and adapts this to the frequency sensitivity range of the skin, using algorithms, transposition or filtering principles. The device translates these signals as vibrations and the user can detect them and identify the character and direction of the sound source. The researcher conducted a study using this aid and found that Monitor can help in improving the mobility, social interaction, forward planning and feeling of safety and decrease the users feeling of stress by using this device.

Figure 11: The framework for Monitor prototype and an image from the user study [28]

Smart Cane, outdoor navigation system

Researchers in Finland [29] build an outdoor navigation system in assisting visually impaired persons navigation that can help them navigate independently in urban areas, even if they have hearing issues as well. Smart cane is an augmented cane, with magnetic point or continuous metallic trails, a pulsing magnet apparatus and the transmission of serialized vibration braille encoded guidance. The sidewalks of the city would also be installed with trials of magnetic points or metal and pulsing magnet apparatuses. The users would be able to sense the magnet points or the metallic trial through the cane and the system would assist them to walk independently. After conducting testing with real users, the system received positive feedback from them and from the stakeholders. Out of 15 participants of the study consisting of blind and visually impaired persons, 13 of them were able to successfully complete the tasks given to follow the test track using the prototype.

OrCam MyEye 1

OrCam MyEye1 device [30] is a breakthrough invention for wearable artificial vision which was designed and developed to assist people who are blind, visually impaired or people who have reading difficulties or disabilities (Figure 12). This device has a highly intuitive and lightweight camera which is smart, so it instantly reads out printed and digital text aloud, but discreetly. This device can recognize texts from any surfaces, both printed and digital, but also can recognize faces, products and money notes and all this

is done in real time. This device helps in making things such as newspapers, books, computer and smartphone screens, restaurant menus, labels on supermarket products and street signs more accessible, that too in real time, more efficiently.

Figure 12: The advanced wearable AI Devices for the blind, OrCam MyEye [30]

Thea

Thea [31] is a concept which was developed for an artificially-intelligent, on-the-go navigation assistant for the blind and the visually-impaired (Figure 13). From the continuous positioning functionality from the 5G wireless technology, the device would recognize the most effective way to get around and would guide the user through the route mapped by the system. The main objective with this prototype concept is to design a near- future product or service which helps in improving mobility for people with disabilities.

Figure 13: The concept developed for Thea, artificial intelligent navigation assistant [31]

2.2.5. Accessibility and Autonomous Vehicles

The autonomous vehicles are a new way to think about transportation and accessibility. Their main potential is to change the neighborhoods and lives of people who cannot drive, especially people with disabilities. Autonomous vehicles would be able to provide significantly more independence to all people with proper planning and research [20].

A survey directed in the United States with around 500 participants with visual impairment was conducted to investigate the opinions of people with disabilities, such as blind or visually impaired, towards their acceptance, concerns and willingness to owning an autonomous vehicle. More than 50% of the participants had an extremely positive attitude towards the technology (50.18% extremely positive, 30.44% moderately positive and 7.75% slightly positive). The study clearly showed that the participants were slightly concerned about riding in a fully autonomous vehicle acting as the primary operator (38.96% slightly concerned, 22.82% moderately concerned, 16.70% very concerned and 21.52% not at all concerned). 93.18% of the participants had major concerns about equipment failure or system failure. 92.69% of the participants were concerned about getting confused in unexpected situations and 87.55% about the interaction between these autonomous vehicles with pedestrians and bicycles [32].

The National Federation for the Blind (NFB) in the US conducted a challenge, Blind Driver Challenge [33], where a blind participant from NFB drove a vehicle, which was customized, around a track which had obstacles and other vehicles. Dr. Dennis Hong, head of this study and leader of the team who designed the customized vehicle, estimated that blind drivers would be able to travel on the public roads within five to ten years, which is proving to be true. The test drives conducted on the customized vehicle was successful, but the vehicle did vibrate excessively, on which the team was working on for their next design [34].

Chapter 3: Methodology

Several methods have been used throughout the work carried out in this Master Thesis: expert reviews, usability testing, qualitative interviews and field observations.

3.1. Study 1: Expert Review

Expert reviews inspect the design to identify usability problems in compliance with heuristics, known usability guidelines and principles of usability-related fields such as human-computer interaction using the expertise and past experience of the reviewer in the field of user studies [35].

Aim and goal

The main goal with the expert review study was to understand the experience a user has while using the autonomous PODs. Autonomous vehicles are still not used frequently by many, and there are often trust issues related to these forms of new technology. The main aim of the study was to explore the PODs and investigate if they are user-friendly and provide useable service. More specifically, to research whether the vehicles have complicated functionalities which could confuse or create a negative approach for the users. In addition, the study also aims to identify if the PODs are accessible for all users by viewing them from the perspective of people with disabilities.

Procedure

The method used for the study was expert review where a list of questions or checklist (Appendix A1) was created. The researcher explored and analyzed 2 PODs (Figure 14) that are currently deployed in Stockholm and Gothenburg in Sweden, using these checklists as guidelines to find the pain and pleasure points people with disabilities face while travelling in these PODs. From the study, a list of pain and pleasure points that the passengers would face while using these autonomous vehicles was defined.

Figure 14: The PODs that are currently running in Stockholm and Gothenburg respectively which were used for the POD Expert Review studies.

3.2. Study 2: Usability Testing in the field

Usability tests are conducted to improve the usability of a product which is being tested [36]. The participants for the tests are real users who would be asked to perform some tasks which are observed and recorded for analysis.

Aim and goal

The main goal for conducting the usability test was to validate the findings of the previously conducted expert review on the PODs functionalities with actual users. Through the earlier expert study, it was identified that the PODs are not highly accessible for All users, especially the blind users, due to the lack of alternate or multiple modes for sharing information and many other functionalities. This study validated the findings (both pain and pleasure points) from the expert review study.

Procedure

The method used for this study was a Usability Study conducted in the field together with Qualitative Interview. This study was conducted with an individual (Participant ID: S2T1) and with a group of 4 participants (S2T2-S2T5). The participants were asked to perform tasks with the goal of identifying possible usability/accessibility issues that were compared to the findings of the previously performed expert review (Figure 15). The task was to take a return trip on the POD at Gothenburg to explore and experience it. The participants were asked to think-out loud during the ride. On the return trip, the participants were asked a few questions regarding the functionalities of the POD based on the pain and pleasure points identified from the expert review (Table 2).

The whole journey of each participant was recorded using a voice recorder and a video recorder, with their permission. Hand written notes during the interview are relatively unreliable, and the chances of missing some key points were high. The recording of the interview makes it easier for the researcher to focus on the interview content and verbal prompts. For a more detailed description of the participants tasks and the questionnaire of the study, refer to Appendix A2.

Table 2: Tasks/Questions created for the participants for validating the pain and pleasure points during commute in autonomous PODs.

Validation Points	Journey Time	Findings from expert review	Tasks/Questions for the participants
Pleasure	Before & After	**Proper Visual Signage**	Participants were asked to navigate and find the POD stop and the test leader observed if they were able to find the stop and enter the right POD and also if they deboarded at the right destination stop.

		Detailed description of timings	Not applicable to the test (due to the fact that the POD is currently running on demand timing, so it was not possible to validate this now).
		Wheelchair & Trolley accessibility	Test leader observed the participants while they boarded and deboarded the POD.
		Braille buttons for Door	Test leader observed the participants while they boarded the POD.
		Opening & Wheelchair access	Participants were asked to explore the buttons and functionalities on the POD and the test leader observed their actions and ease of accessibility and also the time taken for finding these buttons.
	During	Accessible Buttons: Big, Reachable, Braille	Participants were asked to explore the buttons and functionalities on the POD and the test leader observed their actions and ease of accessibility and also the time taken for finding these buttons.
		Visual Sign boards with the whole detail of route	Participants were asked about the status of the POD during the journey. Test leader observed their actions and answers.
		Visual signs for the Current status of POD	Participants were asked about the status of the POD during the journey. Test leader observed their actions and answers.
		Sufficient Space (Wheelchairs or Trolleys)	Participants are given scenarios where they will be asked to imagine carrying some luggage and test leader observes how they are acting accordingly.
		Easily reachable Emergency Stop Button	Participants were given another scenario where they were asked how they will react when there is an emergency and there is no one on the POD to help. Test leader observed their reaction and also the time taken for them to find the right button.

Pain	Before & After	Navigation Troubles	Participants were asked to navigate and find the POD stop and the test leader observed if they found the stop and enter the right POD.
		Only visual aids (no alternative media)	Participants were asked to navigate and find the POD stop and the test leader observed if they found the stop and enter the right POD and also if they deboarded at the right destination stop.
		Alerts and Notifications missing	Participants were asked about the status of the POD during the journey. Test leader observed their actions and answers.
		Huge Gap: Inaccessible for wheelchairs and trolleys	Test leader observed the participants while they board and deboard the POD.
	During	Only Visual Aids, missing alternative media	Participants were asked about the status of the POD during the journey. Test leader observed their actions and answers.
		Highly Sensitive touch for SOS button, no proper feedback	Participants were asked to explore the buttons and functionalities on the POD and the test leader observed their actions and ease of accessibility and also the time taken for the to find these buttons.

The severity rating [37] was used to give a rough estimate on how urgent it is to fix the usability problems found during the study. The urgency depended on three factors; frequency (how often does the problem arise), impact (how easy is it for the users to overcome the problem) and persistence (how bothered would the users be by the problem). A scale of 0 to 4 rating is used as a guideline for measuring the problem's severity:

- "0 = I don't agree that this is a usability problem at all"
- "1 = Cosmetic problem only: need not be fixed unless extra time is available on project"
- "2 = Minor usability problem: fixing this should be given low priority"
- "3 = Major usability problem: important to fix, so should be given high priority"

- "4 = Usability catastrophe: imperative to fix this before product can be released"

Figure 15: Pictures from the POD validation study conducted with the POD at Gothenburg, Sweden (With permission by the test participants).

3.3. Study 3: Qualitative Interview

Qualitative interviews are a type of communication where the participants and the interviewer produce different forms of information. This can be done both individually as well as in group. This method is particularly useful in assessing the attitudes and values of the participants. The term qualitative interview refers to in-depth or semi-structured interviews often referred to as "conversations with a purpose" by Burgess [38].

Aim and goal

A Qualitative one-on-one interview study was conducted with drivers and people with disabilities to understand and explore the role of drivers during the travel experience of these passengers. The context of transportation were either on a public transport facility such as busses or even on a private transport facility such as taxis.

Through this study, the researcher understood the areas or scenarios where the driver communicates with the passenger or acts as an aid to them. When drivers are taken away in autonomous vehicles, there would be no possibility for these interactions. This study helped in unveiling design solutions for these interactions that could happen during the travel of the users with disabilities in an autonomous vehicle.

Participants

The Study was conducted with 6 drivers (S3D1-S3D6) and 7 target users (S3T1-S3T7) of the age group of 25-70 years old. The driver category participants were all male, with nearly 3-40 years of experience in driving with diverse ethnicity (Swedish, British, Lebanese and Afghanistan). The target user category participants were all Swedish but with a mix of gender of 4 males and 3 females. The participants had a diverse set of disabilities such as Deaf, Blind since birth, Visually Impaired and recently Blinded.

Procedure

The method used for this study was Qualitative open/semi-structured in-depth interviews. The interviews were conducted using multiple methods for the convenience of the participants (Phone, Emails, Online Surveys, Field Surveys). In the beginning of the interview, the participants were asked to explain or revisit a recent journey experience they had in the recent times. They were asked to create a verbal narration of the journey in detail, explaining the whole experience from the start of the

journey, during the journey and when the journey was completed. If the participants were not able to recall such an event, they were asked to imagine a journey on a taxi/public transport with or as a passenger with disabilities. The participants were then asked a set of questions regarding the role of a driver during the whole journey.

A list of user needs/requirements when people with disabilities travel and the help they require from the drivers were found. A set of pain and pleasure points were derived from the study to see the areas or scenarios that would be affected when drivers are missing on the autonomous vehicles.

The method used for the data analysis of these interview transcripts was Open coding which is the first stage for the process of creating grounded theory by Strauss and Corbin [39]. This Grounded Theory Methodology (GTM) approaches the analysis of interview data by analyzing the text to find the answers within them. This theory is developed from data rather than imposing upon it. The process is repeatedly coded, reviewed and refined to get the answers. The researcher reads through the data multiple times to create labels for a set of data which summarize the meaning of the data. The examples of participant's quotes or citations are recorded, and each code would be given some properties (Table 4 in Section 4.3). The same method is used to explore the answers to the research questions.

3.4. Study 4: Field Observation

A field observation study followed by qualitative one-one-one interview was conducted to understand the role of drivers when people with disabilities travel and how tactile guidance using Vibro-Tactile aids can help the passengers before, during and after the journey.

Aim and goal

The goal of the study was to investigate the conditions and needs of passengers who are blind, deaf or dead-blind while using autonomous public transport and to test the vibro- tactile guiding technique in the different stages of their journey (before, during and after).

Participants

The study was conducted with 9 participants, out of which there were 5 blind and 4 deaf-blind participants. For a more detailed information about the recruitment process and other details, it is mentioned in Appendix A4.

Procedure

The participants evaluated the interaction with an autonomous vehicle (simulated) two times, with and without the tactile aids. The journey route was discussed and planned prior to the test date by the participant and the test leader. 3 sets of interviews (one for the initial background and travel habits, one for understanding the experience without the guidance and for deciding the tactile aid that would be used for the study along with the training session for the subjects with the aids and the final one for the experience with the tactile guidance of their choice) were conducted to map the problems and issues the participants face while travelling and to explore their experience in using the autonomous vehicles and the vibro-tactile guiding tools. The whole study was documented using audio and video (Figure 17).

Three tactile aids were introduced to the participants and they were given the choice to choose one. Ready-Move, Ready-Ride and Vibro-Braille (Figure 16). **Ready-Ride** device consists of two hand-held devices, a transmitter unit and a receiver unit which communicate using Bluetooth. The transmitter has 4 buttons which are used to activate the corresponding vibrators placed on the receiver. The receiver has 4 vibrators connected using wires which gets activated according to the signals or commands given on the transmitter. Different pattern of vibrations, including combinations of short and long signals can be used to give commands which are needed for the user. **Ready-Move** device consists of a number of vibrator units which can be placed in suitable places on the user's body and one transmitter and receiver (applications on the smartphone). The assistant can give coded signals (which are pre-defined as per the user's needs) as vibrations using the transmitter and the user feels the coded vibrations and act accordingly. **Vibro-Braille** device consists of a software (which is currently available in Android) that acts as a transmitter and a hardware which have around 6-8 vibrators. The software and the hardware communicate via Bluetooth and share information. Vibro-Braille gives information in the form of Braille where the points are exchanged for vibrators. The information that is coded and send as vibrations to the user can be downloaded from the mobile's notification list which

can be received from SMS, Messenger, Facebook, WhatsApp, or from any of the applications that the user has selected to send notifications to the list. The information can also be text written directly in the software in order to be delivered in the form of Braille. For the study, 8 out of 9 participants chose Ready-Move for testing as they felt that it was small, wireless and easy to use and wear.

Figure 16: Pictures of the devices Ready-Ride, Ready-Move and Vibro-Braille (from top to bottom).

The results are summarized and described in the form of field study observation after the analysis of the data. The data from the interviews were used to find the problems and the needs of passengers with disabilities while they travel and their inputs on the vibro-tactile aids, it's benefits and limitations when used in combination with autonomous vehicles.

Figure 17: Pictures from the Vibro-tactile field observation study with multiple participants.

Chapter 4: Results

4.1. Study 1: Expert Review

For the Expert Review study on the PODs, the test was conducted at 2 different locations, one in Stockholm and one in Gothenburg. The PODs structure and functionalities were slightly different at the two locations, and it was important to study the pain and pleasure points of both PODs to find the main things that are commonly missing in both the PODs.

4.1.1. POD Study in Stockholm

The expert study on the POD in Stockholm was conducted to understand the experience of users travelling in autonomous vehicles. From the expert review, a set of pain and pleasure points from before, during and after the journey were found (Figure 18 - Figure 21 and Table 3).

Table 3: *The list of pain and pleasure points passengers encounter while travelling in autonomous vehicles (Stockholm).*

Points	Journey Time	Findings	Description/Observations
Pleasure	Before & After	**Proper Visual Signage**	There were proper visual sign boards, even with the picture of the POD, on the bus stop of the POD to identify the stop easily (Figure 18).
		Detailed description of timings	The bus stop also had a board which had the details of the running times of the POD in the same style as the rest of the public bus stops in Stockholm (Figure 18).
		Wheelchair & Trolley accessibility	The bus stop had an easy access pavement, which would be convenient for wheel-chair and trolley (even though it was a bit difficult because of the gravel stones put on the ground for the snow) (Figure 18).
		Braille buttons for Door Opening &	The POD had big and identifiable buttons on the doors to open it, as well as buttons for the ramp access, with recognizable image markings on them.

		Wheelchair access	The buttons also had braille imprinted on them for braille users to identify and read it effortlessly (Figure 18).
	During	Accessible Buttons	Similar to the buttons on the outside of the POD, there were big buttons with image markings and braille inside the POD as well. These were reachable and accessible and very near the doors, which is the most commonly used placement for the buttons (Figure 19).
		Visual Sign boards with the whole detail of route	There was a digital screen inside the POD for the passengers to get all inputs of the POD, such as the routes, the next stop, the time taken to reach the next stop and the list of stops (Figure 19).
		Visual signs for the Current status of POD	The digital screen on the POD displayed the current status of the vehicle. The passengers will be able to see where the bus is, if it is waiting at the main stop, and the upcoming stop (Figure 19).
		Sufficient Space (Wheelchairs or Trolleys)	There was enough space in the POD for the passengers to put their luggage and for passengers on wheelchairs to easily board and find a suitable place for them inside (Figure 19).
		Easily reachable Emergency Stop Button	The POD had an emergency button which was placed near the other buttons, easily reachable and identifiable (red in color) for the users (Figure 19).
Pain	Before & After	Navigation Troubles	The navigation for the POD stop is not accurate. Google maps and Apple iMaps are not showing the right stop. The users will have a lot of trouble finding the right stop (Figure 20).
		Only visual aids (no	All media of information at the bus stop was visual. There were no other alternate media for information like audio, braille, sign language. This would make it difficult for passengers who are

			alternative media)	blind to get right and timely information (Figure 20).
			Alerts and Notifications missing	The SL application was most commonly used to check the timing of the POD in Stockholm. Even though the POD was more than 15 minutes late, and 1 out of the 2 PODs that are running on a regular basis were cancelled for the day, the passengers were not informed about any of these delays and cancellations (Figure 20).
			Huge Gap: Inaccessible for wheelchairs and trolleys	The gap between the pavement and the POD entrance was significant. Consequently, it would not be possible for a wheelchair or trolley to enter the vehicle without help from someone else (Figure 20).
		During	**Only Visual Aids, missing alternative media**	The main issue with the POD was that different media for sharing information was missing. The vehicle only had visual forms of information, except for a bell sound when the POD starts. This could be inaccessible for passengers who are blind or deaf-blind or have low vision impairment (Figure 21).
			Highly Sensitive touch for SOS button, no proper feedback	The SOS (emergency) button inside the POD was very sensitive. A small touch (even just feeling the braille info on the button), sends a call to the assistant for help. But there was no proper feedback from the button saying that it was pressed and that the call had gone through. The only response is a calling assistant icon on the screen and the voice of the assistant who has picked up the call (Figure 21).

| Proper Visual Signage | Detailed description of timings | Wheelchair & Trolley accessibility | Braille buttons for Door Opening & Wheelchair access |

Figure 18: *The pleasure points of passengers from before and after journey from the expert review.*

| Accessible Buttons: Big, Reachable, Braille | Visual Sign boards with the whole detail of route | Visual signs for the Current status of POD | Sufficient Space (Wheelchairs or Trolleys) | Easily reachable Emergency Stop Button |
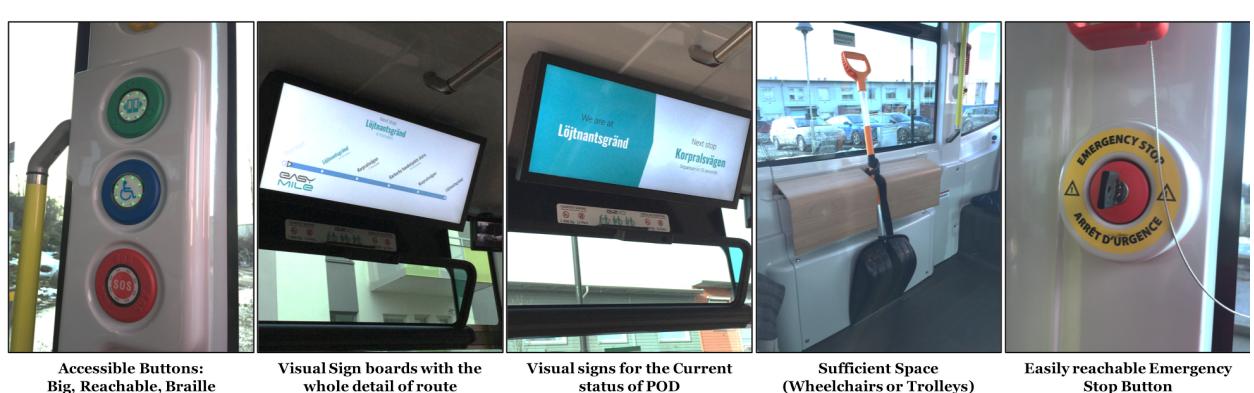
Figure 19: *The pleasure points of passengers from the during journey from the expert review.*

| Navigation Troubles | Only visual aids (no alternative medium) | Alerts and Notifications missing | Huge Gap: Inaccessible for wheelchairs and trolleys |
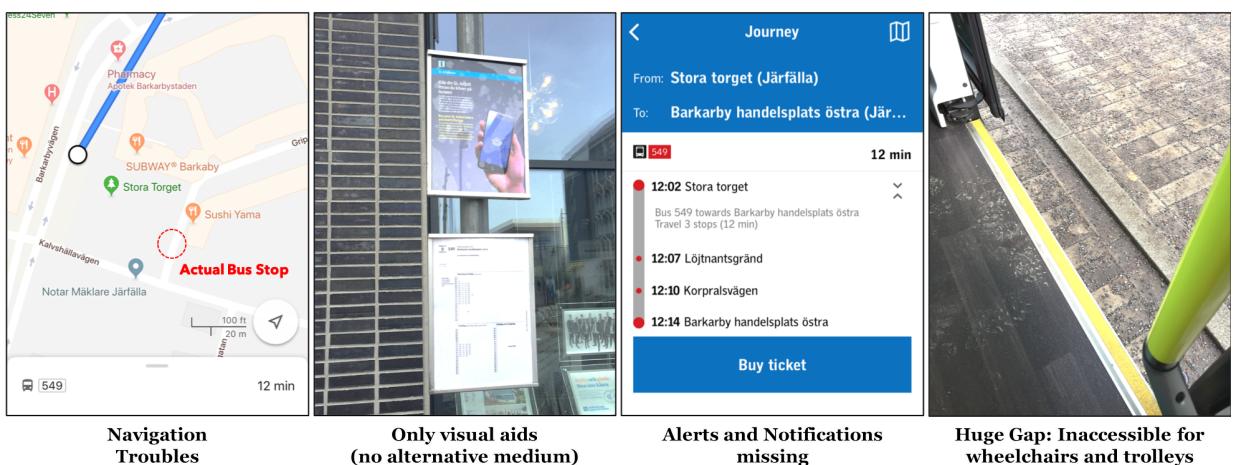
Figure 20: *The pain points of passengers from before and after journey from the expert review.*

| Only Visual Aids, missing alternative mediums | Highly Sensitive touch for SOS button, no proper feedback |
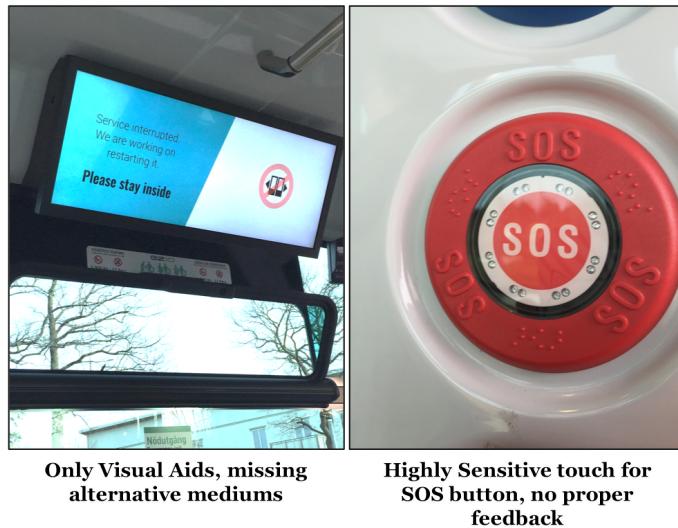
Figure 21: The pain points of passengers from the during journey from the expert review.

4.1.2. POD Study in Gothenburg
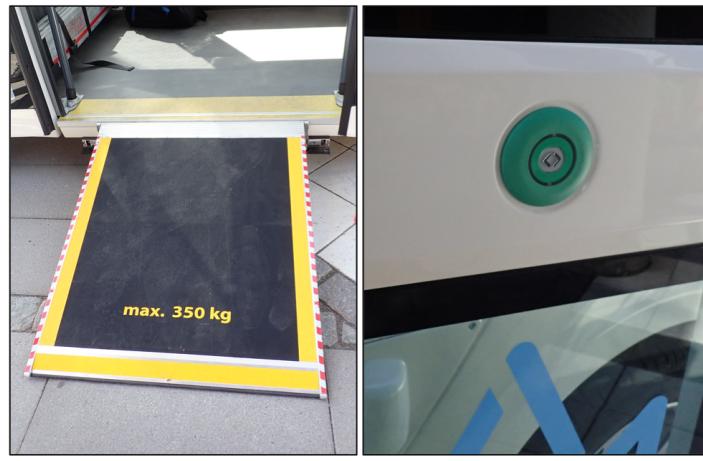
A list of pain and pleasure points that reflected on a blind person travelling in the POD were found in the expert review study in Gothenburg, which were compared to the results from the expert review from Stockholm to validate the findings. The study in Gothenburg identified aspects which were found in both tests, and additional complementary aspects which were found from the study in Gothenburg. The expert study on the POD in Gothenburg was conducted to understand the experience of a user while travelling in the autonomous vehicle. From this expert review study in Gothenburg, a set of pain and pleasure points from before, during and after the journey were found. (Figure 22 - Figure 25 and Table 4).

Table 4: The list of pain and pleasure points passengers encounter while travelling in autonomous vehicles (Gothenburg).

Points	Journey Time	Findings	Description/Observations & Solution
Pleasure	Before & After	**Great Wheelchair & Trolley accessibility**	The current bus stop of the POD was very accessible for passengers with wheelchairs and luggage. There is a proper full-length ramp which is at the bottom of the POD entrance and it adapts well to the height of the pavement (Figure 22).
		Braille buttons for Door Opening &	The POD had 2 big reachable buttons to open the doors and another button on the edge of the vehicle for the ramp access. Moreover, all buttons

		Wheelchair access	had a braille display and recognizable image markings on them (Figure 22).
	During	Accessible Buttons	Similar to the buttons on the outside of the POD, there were big buttons with image markings and braille inside the POD as well. These were reachable and accessible and very near to the doors, which is the most commonly used placement for these buttons (Figure 23).
		Seat belts for safety	All seats on the POD had seat belts for the safety of the passengers, with the universal design used in all cars and busses (Figure 23).
		Sufficient Space (Wheelchairs or Trolleys)	There was enough space in the POD for the passengers to put their luggage and for wheelchaired passengers to easily board and find a suitable place for them inside (Figure 23).
		Easily reachable Emergency Door Handle	The emergency door handle was placed near the rest of the buttons and was easily reachable and big and red in color. It also had a plastic glass cover to avoid any false or mistaken use of it (Figure 23).
Pain	Before & After	Navigation Troubles	The current map used for finding the location of the POD was a website link, which was very inaccessible. It was very complex and had bad designing, making it more difficult for people with disabilities to use them and navigate correctly to the POD (Figure 24).
		Alerts and Notifications missing	There is no specific application or media for sharing any kind of information regarding the POD. Passengers are not informed at the moment, if there are any delays or cancellations with the rides (Figure 24).

		No description of bus timings and bus stop	The vehicle's bus stop does not have any proper marking or sign to identify it as a bus stop (this is mainly because this POD was very recently deployed at the test location). Additionally, there is no information board to know the running times of the POD (Figure 24).
	During	**Only Visual Aids for sharing information**	Inside the POD there is a small screen which visually shares information with the passengers. Due to its small size and poor placement in the POD, it is inaccessible to all passengers. Moreover, there are no other media for sharing information with the passengers, except the horn signal that the POD gives as a warning when any objects are in close proximity outside (Figure 25).
		Harsh Braking	One major security issue of the current POD was its very harsh braking. It was very uncomfortable even with wearing the seatbelts (Figure 25).
		No proper feedback for SOS buttons and the button is complex	There were 2 types of buttons for emergency. The passengers could get confused as to what each of them does. The emergency button was to be used for making the POD stop and also to turn off its automation. It was difficult to find the button, since it was poorly placed and difficult to reach. The other one was the emergency handle, which when used makes the doors of the POD unautomated so that they could be opened manually. The passengers could get confused as to what each of these buttons do and especially since there is no proper feedback from these buttons (Figure 25).

Great Wheelchair & Trolley accessibility

Braille buttons for Door Opening & Wheelchair access

Figure 22: The pleasure points of passengers from before and after journey from the expert review.

Accessible Buttons

Seat belts for safety

Sufficient Space (Wheelchairs or Trolleys)

Easily reachable Emergency Door Handle

Figure 23: The pleasure points of passengers from the during journey from the expert review.

Navigation Troubles

Alerts and Notifications missing

No description of bus timings and bus stop

Figure 24: The pain points of passengers from before and after journey from the expert review.

| Only Visual Aids for sharing information | Harsh Braking | No proper feedback for SOS buttons and complex button |

Figure 25: *The pain points of passengers from the during journey from the expert review.*

From both the expert reviews, a set of pain and pleasure points were found. Even though the number of pleasure points were high, the aforementioned pain points play crucial role in making the transportation experience smooth for the passengers, especially for people with disabilities. The certain areas that need to be focused on would be to provide an alternate media for sharing of information especially audio or braille or tactile or even sign language. It is important that these vehicles shouldn't depend fully on the visual media for sharing of information.

4.2. Study 2: Usability Testing in the field

With the help of the previous study, a list of pain and pleasure points were found (Table 5). UX testing was conducted to validate these points found by the expert (Table 2) using actual users and to explore more problems or issues the target users face while they travel. The study was conducted at the POD that was recently deployed in Gothenburg.

Currently the only source for getting information to passengers about the POD was using a link to an internet website, to see the live status of the vehicle on a map. This map was then tested through the participants and it was revealed that it was inaccessible in its current form. The participants felt that it would be beneficial to integrate it with other applications that are currently being used by the public for other public transportations (such as Google Maps, Apple Maps, Västtrafik, Reskollen, Nästa vagn). The map's color contrast was inadequate. Moreover, it lacked information (the stops, the timing of the POD and route with the street were mentioned clearly

however). The map's voice-over function was also inaccessible on the internet webpage for the map and the overall zooming option was poor. Both of which are major sources of help for passengers who are blind or visually impaired.

The buttons used for opening and closing the POD's door and the ramp access button were not accessible. The participants felt that it was difficult to identify and differentiate between the buttons since they all were of the same size and shape. The buttons had different colors and small image markings on them to show their difference, along with braille description on them. However, passengers who are blind, visually impaired or color-blindness did find it highly difficult to differentiate between the buttons. They also felt that the POD's door should have a different color from the rest of the POD so that it is easier for them to identify the exact entrance to the POD. The ramp access button was placed towards the edge of the POD which the passengers felt that was less accessible and they felt that the placement of the button should be along with the door opening button since that is where it is normally placed in other public transport vehicles. The ramp that the POD currently had was accessible, but the participants felt that it wouldn't be the best solution and completely accessible, unless the ramp is automatically lowered at all stops for consistency, such as how the busses do currently by lowering it's right side at every stop according to the height of the pavement.

A major issue that was raised by all participants during the study was the lack of information that was provided. The participants wanted to know information such as the running time of the POD, the stops or the route the POD takes and other detailed information. They became confused when the POD stopped at the signal and asked if the destination has been arrived. They felt that the POD missed giving some important information that a passenger requires while travelling. POD currently has an audio signal for warning pedestrians and other vehicles if they are too close to the POD. The passengers did get confused with that signal and mentioned that there should be a different audio signal for informing passengers, especially when the POD is starting, when the doors are opening and closing, and when the destination has been reached. Participants mentioned that they would prefer a similar type of information board that is currently used in other public transportation, such as a digital screen and audio announcements that informs passengers about the final destination of the bus (to confirm if they are on the right bus). Additionally, the participants wanted

announcements about the following stops (to prepare to disembark from the vehicle), and when the destination has been reached. For a more detailed description of the journey (some passengers prefer to be informed of every turn taken, and every street travelled on), the passengers felt that there should be an option in their phones that can be customizable according to their needs to receive this information whenever they want it.

Another major problem that the passengers felt concerned the emergency situation handling. There was a lot of confusion about the emergency handle and the emergency button which were inside the POD. They both had different purposes and the passengers did not know what they did, and the placement of the emergency button was inaccessible. It was difficult to find the emergency handle & the button and the test leader had to show it to the participants at the end. Even after finding the button, participants found it highly complex to handle. They felt that they would not have found the button or the handle without help from someone, and they would not have known how to activate them without any support. Some passengers mentioned that they would have preferred if there was an audio/visual manual which gives clear guidance on how to react when there are any malfunctions or emergencies. Also, once the button/handle is pressed/turned, there was no feedback from the POD that it is now sending help or that the automation has stopped. They felt that it would be good to receive a confirmation that the button had been pressed, and additional information about what the next action should be, both in visual and audio form.

Even though the passengers had a really great experience riding the autonomous POD, they did feel that the POD needs to take into consideration a little bit more functionalities to make it more comfortable and smoother for them. All the passengers rated their experience a 6/10, which clearly states that it needs some improvements in their current functionalities and that if at least some of the major suggestions they provided are fixed in the POD, they would be able to use the POD in their daily travel without any need of extra help or support from the drivers or co-passengers.

Table 5: The list of findings from the expert review that was validated by the users from Study 2

Findings from expert review for validation	Validation by the users	Severity Rating (0-4)
Proper Visual Signage	The participants felt that there was no information provided in the POD or at the POD stop.	**4**
Detailed description of timings	No details were provided	**3**
Wheelchair & Trolley accessibility	There was a ramp that was accessible using the button.	**0**
Braille buttons for Door	There were multiple buttons outside the POD and they were of the same size and shape. This made it difficult for the users to identify and differentiate them.	**3**
Opening & Wheelchair access	The wheelchair access was adequate. However, the button still caused confusion.	**3**
Accessible Buttons inside the POD	The buttons inside the POD were of the same size and shape. Consequently, it was difficult to identify each of them and differentiate their purpose.	**3**
Visual Sign boards with the whole detail of route	There was no visual or audio or any other media for sharing information.	**4**
Visual signs for the Current status of POD	There was no visual or audio or any other media for sharing information.	**4**
Sufficient Space (Wheelchairs or Trolleys)	There was sufficient space for luggage. However, when it was full, it did not have sufficient spacing.	**1**
Easily reachable Emergency Stop Button	The emergency button and handles were complex and difficult to understand and differentiate. Moreover, there was no proper feedback from pressing the button	**4**

Navigation Troubles	The map used for finding the POD's location was not adequately accessible.	4
Only visual aids (no alternative media)	The POD bus stop did not have any sign board or audio information button for receiving any information about the POD or to identify the bus stop.	4
Alerts and Notifications missing	Neither the POD, the visual board inside the vehicle, nor the map for the POD's location gave any alerts or notifications about the actions done by it, such as the starting of the POD, reaching destination, door opening and closing, cancellation or delays.	3
Huge Gap: Inaccessible for wheelchairs and trolleys	The ramp of the POD was highly accessible, and suitable for people with luggage and/or wheelchairs.	0
Only Visual Aids, missing alternative media	The visual board inside the POD was small and did not have much information on it.	4
Highly Sensitive touch for SOS button, no proper feedback	The emergency button and the handles were confusing and complex to the point of being inaccessible. There was no feedback available once the button had been pressed.	4

4.3. Study 3: Qualitative Interview

The interview with the drivers and target users were done to find out the roles of drivers when passengers with disabilities travel in taxis or busses or trams. A list of pain and pleasure points were found from the interviews (Table 6 and Table 7).

Drivers

Most participants mentioned that they would receive detailed descriptions about passengers before trips, so that they know if the passengers require special assistance or if there are people with disabilities. Then, the drivers would act according to the needs and requirements of the passengers. The drivers also mentioned that they feel certain passengers (especially blind, deaf-blind and wheel-chaired) need help in guidance or navigating from their pick-up point to the vehicle's doors or from the

vehicle's doors to the destination point. The location provided in the digital map display is not always accurate, then the drivers need to contact the passengers and find out their exact location to pick them up. Drivers are always ready to help them if they are travelling with luggage or wheelchairs.

Many participants also talked about the preferences passengers have regarding their seat while travelling. Especially if it is a shared taxi (Färdtjänst), they want to know if there are other passengers in the car. Some passengers prefer to sit in the front, while others prefer to sit in the back. Being flexible is something that is expected from the drivers and they try to always adapt to the situation. Some drivers also mentioned that they have done errands for passengers, gone flower shopping or grocery shopping for them, and made pit stops in between destinations. This extent of freedom and flexibility in the overall journey is something that can be provided by drivers.

Sharing the right information at the right time is essential while travelling, and drivers make sure that passengers receive sufficient information. Passengers with disabilities need to be informed at a regular interval in particular. The information could be about the route to the destination (highway or city roads), if there is a traffic jam, if the driver is taking a different route or if they are re-routing for any particular reason, in case of any emergencies, unusual or special situations or scenarios on the way, if they are delayed due to traffic or a bridge opening, including the approximate time the delay might take, and information about the weather. Different passengers require different information. Some passengers prefer to be silent and require no information during the journey, some prefer to receive information about every action of the vehicle and everything happening on the roads. When travelling with newly blinded people there are more questions and queries and the driver would keep updating them on the location periodically, whereas people who are blind from birth are either used to the route or their good sense of direction does not require constant updates during the journey. The drivers would adapt and act according to the needs and moods of the passengers. They feel and understand that it's their job to be social with the passengers, make them comfortable, and be flexible enough to adapt and act according to the passengers' wants and needs. However, the drivers are also slightly worried about treating passengers with disabilities too differently. Passengers do not always appreciate being treated differently because of a disability. In the interviews, many drivers said it is a fine line that needs to be tread very carefully. The drivers also

attempt to observe and notice passenger's reaction and mood at the beginning of the journey and adapt their own behavior accordingly.

One major role that was pointed out by all participants of the study concerned the media for communicating with the passengers. Every passenger have their own preferred media for communicating, and the drivers would adapt accordingly. For example, the drivers would communicate with a person who is deaf using texts or some basic sign language or gestures to share information. Similarly, with blind passengers, drivers would use voice and try to avoid gestures while communicating. Regarding the deaf-blind passengers, the drivers mentioned that since it is highly difficult to communicate with them, these passengers are always accompanied by an assistant, a family member family or a friend. The drivers would then communicate the information through that person.

Table 6: The pain and pleasure points from before, during and after journey found from the interviews of the driver participants

Points	Journey Time	Findings	Illustrative/Example Citations
Pleasure	Before & After	Receive information about passenger (need of special assistance) before arriving at the pick-up location.	"We get all the inputs about the passenger on our screen before the ride. Whether that person is deaf or blind or is in wheel-chair." (D1)
		Help with guiding to the car and to destination location.	"If I see that the person is blind (white cane), then I would ask them if they need help in finding the way to the car seat and also after reaching, finding the way to the destination." (D3)
		Find a good/ preferred seat for them and help them to get seated.	"Choice of seat is a high priority for most of them. Some like to sit in the front, some prefer back seat. So, I always ask them and then help them get seated." (D6)
	During	Highly flexible	"They ask us anything, we try to do everything for them. They may ask us to stop to pick up some flowers on the way or even change the destination in between the journey." (D4)

Pain	Before & After	Finding the right pick-up point.	"Sometimes it's difficult to talk to them and find the exact pick-up location, if the address they gave was not accurate, I need to call them and then it could be difficult to understand what they are trying to say." (D5)
		Treat them as an equal.	"They don't want to be treated differently. So, it's very difficult to ask them the right amount of help they need without sounding too empathetic." (D3)
	During	Different moods of the passengers, need to act accordingly.	"Some passengers like to talk, some just wants to drive silently, some want music, some want radio. It all depends on what they want and what they tell us." (D3)
		Constant Updates on the road and give timely information	"Since they can't see or hear, I feel the need to always talk to them and tell them where we are and why we are slowing down or stopping and so on." (D3)

Target Users

The participants for the qualitative interviews were blind, visually impaired and deaf target users. All participants feel that the main role of drivers is a physical source of customized information and responding to their special queries and doubts when needed. Passengers have trouble receiving information about the journey and the vehicle, confirming if they are in the right vehicle, if they have reached their destination, if there are any issues with their travel card. Furthermore, they lack help with seat belts, information about any re-routes or cancellations, traffic problems or delays and changing busses, trains or trams due to cancellation or re-routes. Blind and visually impaired passengers cannot read the signs on the bus/tram, and the announcement does not work all the time either. The same issues arise when they travel in taxis. There is no other way to confirm if they are in the right vehicle without help from the driver. They need the help of the driver or co-passengers to get this information most of the time. Passengers who are deaf mentioned that if all signs and stops have adequate visual information, they do not require much help from the driver during their journey. The information is crucial if passengers are travelling in any unknown or new location when compared to travelling on regular or familiar routes.

Some passengers prefer to get detailed description of the entire journey, which they get from the driver if needed and asked for. If the driver is absent and if the vehicle is not able to provide information to the passengers, they do not receive important information regarding the journey, if not helped by someone else.

Socializing is a very personal thing for passengers and it varies depending on their mood, the length of the journey and how comfortable they are with the driver. Many participants mentioned that most drivers sense the mood of the passengers and behave accordingly. However, some of the participants were not happy with the behaviour of the majority of drivers they had encountered. These participants feel that sometimes the drivers attitude changes completely when they realize that the passenger has a disability. Either they ignore them entirely or try to be overly helpful. Since the target users feel that these drivers are not educated enough to handle these kinds of situations, they often find it difficult to communicate with them. Sometimes drivers use gestures or certain terms ("like go in that direction, what is that direction?") to convey information to the passengers and people who are blind or visually impaired cannot understand the information when it is communicated in this way. One participant mentioned that it is actually the 'Big Dream' of deaf people that all drivers learn sign language to facilitate better communication.

One common finding in this study, and the previous studies as well, was the lack of alternate media for sharing information. Most vehicles are highly dependent on visual media and tend to neglect other media for sharing important information. Busses, trams and bus stops in Sweden are usually equipped with audio announcements and visual sign boards. However, drivers often either turn them off, lower the sound volume (not at all audible in crowded vehicles/at stops), or forget to turn them on in the first place. This creates a huge issue for people who cannot depend on visual media for receiving information.

Another interesting and vital role that was discovered in the study was the importance of a driver in any kind of emergency situations. The passengers feel that the drivers are a source of security for them, that there is always someone in charge and control of the situations and the vehicle. In case of any kind of emergencies or malfunction, the passengers believe that the driver would take charge and find a solution and help them handle the situation. A sense of security and trust in the vehicle and the driver is always an important factor when people travel.

Table 7: *The pain and pleasure points from before, during and after journey found from the interviews of the target user participants*

Points	Journey Time	Findings	Illustrative/Example Citations
Pleasure	Before & After	Ask for personalized information: Right stop/right vehicle	"If I am travelling to a new place, I always prefer entering from the main entrance of the bus, so that I can ask the driver for information about the location and also find a seat near the door." (T3)
		Conformation from Drivers	"Need to confirm with the driver if I am entering the right vehicle and also about the right stop/location to get off at." (T5)
	During	Socializing (if wanted)	"Sometimes I like talking to the driver and have a good conversation during the ride. At times I just need to be quiet throughout the journey. The Driver understands it from my behavior, or I tell them." (T6)
		Emergency handling	"We trust the drivers a lot, we know that if there is some issue/malfunction with the vehicle or if there are any emergency situations during the travel, I know that they will take care of the situation and that they would help the passengers. A feeling that someone is in charge is always there." (T3)
Pain	Before & After	Media/Mode of communication	"I would love if all the drivers could sign language. That's our dream. But unfortunately, it isn't possible, so we instead remain silent during the rides." (T1)
		Uneducated in Socializing with Customers	"Some drivers don't know how to treat or behave with people. Some doesn't speak at all, they use body language to show something, which doesn't work for me as I can't see what they are trying to say." (T4)
	During	Change in Attitude	"Some drivers ignore or stop talking to us, when they realize we are deaf.' (T1)

		Audio Announcement not working, only visual information.	"Sometimes the drivers will turn off the audio announcements or even forget to turn it on, then it's difficult for me to know the stops or if I am on the right bus. Then I will have to go to the driver and ask him to turn it on for me. I wish they never turn it off. They should always have it on." (T4)
		Miss out important information	"If there is a delay or re-routes, there are times I have missed those because they sometimes don't announce it. Then I will need to take the help from people near me or the driver." (T3)

4.4. Study 4: Field Observation

From the field observations and the qualitative one-on-one interview with the participants, the needs and expectations of the target users while travelling in public transport were found. Also, the limitations and possibilities of the vibro-tactile aids in combination with autonomous vehicles were also derived from the study.

It was found that majority of the people with disabilities prefer travelling in taxis, rather than public transports as they feel that taxi can provide a more customized and help with special needs services. Taxi routes are mostly from point A to point B, with no stops in between, but the other public transportations have multiple stops in between. Another reason for the preference of taxi was the flexibility of time while travelling in a taxi. Busses run on a particular strict schedule and almost all the time, it doesn't wait for anyone. They are not very flexible with time.

Almost half the participants mentioned that the engine sound of the approaching vehicle (if the roads are not crowded and doesn't have other cars) is a signal for assuming that their vehicle has arrived for pick-up. They usually confirm that it is the right vehicle with the help of the drivers or co-passengers. The deaf passengers usually use their vision to see if the car has arrived and again, check and confirm with the driver if it is the right one. They also make use of their phone (text and call) to confirm if the vehicle is for them. The passengers who depend on the sound of the vehicle engine are having a huge problem now, as most of the new vehicles are nearly silent and their engines doesn't produce much sound outside, especially the autonomous PODs that were studied in this master thesis.

Finding the way to and from the vehicle are very difficult tasks for the participants. When it is a bus/train/trams, the important factor is that they all have a permanent fixed stop which are easily accessible or known to the users. And passengers who use their mobile GPS for finding the way can use the maps to find the exact location of these stops. Some of the passengers use GPS based apps for navigating, but they also feel that they are a bit unreliable and cannot be trusted all the time. The one problem that was raised by multiple participants regarding travelling with taxi, were about finding the exact location of the vehicle at the pick-up point. Taxis doesn't have a designated stop for them at the pick-up location, so it is difficult for the target users to find the car without any help. This situation would become more difficult, if the location was an unknown place to the user, it depends on the familiarity of the surroundings and environment.

For the blind and visually impaired passengers, audio announcements help in getting information about the routes, delays and cancellations. Without the announcements, they need help from others to get all kinds of information regarding the journey. Similarly, the passengers who are deaf, completely rely on the visual information board to get all the information. Most of the participants mentioned that they put a lot of trust on the drivers and their work. They believe that the driver would take them to the right destination and that they would give all the necessary information on time in a way that is understandable by the passengers. But there were few participants who felt that they are not ready to trust the drivers completely (especially if it's an unknown driver at an unfamiliar location) and would trust technology more than that. They felt that in case they need to know the route and the location of the vehicle, they would use GPS based map applications (Google Maps, BlindSquare) which provides them with the detailed description of the route taken by the vehicle. Drivers find it difficult to share information with passengers who are deaf during the journey since they are not able to use their hands for gesturing or for typing the texts to show to the passenger.

Finding an empty seat to sit in a bus or train or even taxi (shared) is very difficult for passengers with visual impairment or blindness. Most of the participants mentioned that they require the help of the driver or a co-passenger at most of the times to find an empty seat inside the vehicle. Some participants had special preference for getting seated especially if it's in the bus, they prefer to enter from the front main door and sit near the driver so that they have easy and quick access to the driver for any information

or help. When it is a shared taxi or any other public transportation, the participants felt that it would be super helpful for them to know the seating arrangements inside the vehicle and also if there was a way to guide them or let them know about the empty seats.

Guiding Tool

The guiding tools used for the study mainly helped the passengers in getting the information about the arrival of the vehicle for pick-up and also about the arrival at the destination points. The participants were given specific commands for these two scenarios and they felt that this functionality could help many passengers who are blind or visually-impaired or even for all users, this vibratory signal can act as an alert for informing the users about the arrival of the vehicle.

The aid also helped guiding passengers towards the vehicles door and also the destination door using coded signal commands for 'left', 'right', 'start' and 'stop'. The passengers felt that it would be super helpful for them, especially if they have blindness or visual- impairment, in an unknown/unfamiliar location and also if there are multiple vehicles around the area. The participants who could see the vehicle felt that this functionality of the aid was not very useful for them as they have the capability to find and identify the vehicle using their vision.

A very important behaviour that was found in the study was the difference in people's needs about the type of information that should be provided. All the participants prefer to get all the information in one place and importantly need information about the timings and notifications. But few of the participants mentioned that they require the full detailed route of the vehicle, even the turns and streets the vehicle is taking. But they also mentioned that they require an option where they can stop this information if needed. Some of the participants were not interested in knowing the detailed route, they preferred very minimal information and also less social with the drivers too. The vibratory signals that was given by the aid for informing the passengers about the routes were just 'left', 'right' and 'stop'. The participants felt that this could be useful if they knew the route very well and also that they needed to concentrate really well on all the signals to not miss out on any of the information.

The passengers were also interested in finding ways to help them get any information about any delays or any kind of notifications that affect their journey. Most of the

participants shared that they were hoping for an information board in every public transport vehicles and taxis in the future, which contains multiple media for sharing information: visual, audio, text, sign language, braille.

More than the majority of the participants felt that the current prototype of the vibro-tactile device could be of a little help for them as they are used to travel in familiar places. They felt that some changes or modifications had to be made on the device to make it more accessible and useful for them. They also mentioned that the device would be very useful for them in particular situations like if they are travelling in an unfamiliar place, if it is dark and have issues with the lighting.

Majority of the participants felt that the vibro-tactile aid (Ready-Move) was easy to understand and use, especially since there were only 2 vibrators used for the study and also the commands were simple and easily understandable. They felt that the aid would get complex or a bit difficult if there are more than 2 or 3 vibrators. Most of the participants felt that the guiding aid could be pretty reliable as it works using the smartphone. But they were also concerned that the guiding is done by a person at the moment and hence the reliability completely depends on the trust the user has on the person guiding and also the knowledge and skills that person has. So the participants doesn't trust or rely 100% on the device as it could have some malfunctions or battery issues or some technical glitches.

One main point that all the participants mentioned during the study was about their possibility in the future to travel/drive without any assistance or help from another person. They all want to be independent and want to have the opportunity to drive and travel like any other person. They are very excited about the concept of autonomous vehicles and how much it can help them in achieving this dream of theirs.

4.5. Summary of studies

Since all the four studies had qualitative data, the open code method (Section 3.3) was used to analyze and summarize the data and thus helped in answering all the research questions. The label "open code" are abstract and concrete categories of the sorted data identified after analyzing the interview data which are given some adjectives or adverbs to compliment the categories "properties".

Research Question 1: What are the implications for target users (people who are blind, deaf, or deaf-blind) when autonomous vehicles are introduced and there is no driver in the vehicle? a) What are the basic requirements of the target users during their transportation experience? (R1)

Qualitative Data from all four studies (Study 1-4) helped in understanding the needs and requirements of the target users when autonomous vehicles are used for travel and there are no drivers to help them. Few functionalities and their properties are described in the table below (Table 8) supported by the observations of the researcher and the citations/quotations of the participants from different studies.

Table 8: The open codes for Research Question 1

Open Code	Properties	Observation from Studies
Safety	Technology Malfunction, Error Handling	*Study 1*: "There is a button for contacting help, but it has only one media (call and talk to the help desk person. There is no proper feedback from pressing the button as well." (Stockholm) "Very small and hard to find button for contacting help in case of any malfunctions or help needed." (Gothenburg) *Study 2*: "There is no clear guidance or manual (audio/visual) for how to handle or react when there is any malfunction." Study 3: "We (Drivers) are extra cautious and careful when travelling with people with disabilities." *Study 4*: "I trust the driver, I know that there is a responsible person on the vehicle and it is his duty and job to fix things if there is something wrong."
Door-to-door Service	Pick up from door, Drop off at destination door	*Study 1*: "The POD has a bus stop which is accessible." (Stockholm) "There is no specific marking for identifying the POD bus stop, which is hard for people to find the location of the starting point. (Not Applicable since it's a newly launched pilot version)." (Gothenburg) *Study 2*: "The map provided for finding the bus stop was not

		very helpful. It doesn't work with voice-over software as well. Need your (researcher) help in finding the POD stop."
		Study 3: "Sometimes we (drivers) need to contact them (target users) and check the exact pick-up or drop points to help them come to the right car and also to find the handle to the door, if not we go out and help them and guide them to the vehicle and also help them sit on the seat."
		Study 4: "Since I cannot hear, I have to always keep checking the window to see if the taxi I ordered have arrived. I am scared that if I don't check every time, I may miss it and they would leave without me."
Customized Service	Being Social, Seat allocation, Luggage and Wheelchair, Different media for communication	*Study 1*: "There is no one to ask help from, even the digital interface inside the vehicle is not very user-friendly." (Stockholm)
		"There is no option for getting information regarding the POD timings or stops." (Gothenburg)
		Study 2: "There was no audio announcement on the POD, I (target users) personally want to know each and every action of the vehicle, but also need the option to stop it whenever I don't want to know."
		Study 3: "We (drivers) make them comfortable and understand the mood of the passenger and start conversations accordingly."
		Study 4: "I prefer taxis a lot because they are more flexible than other public transportation, especially with timing. I can be a bit late, without missing the strict timings of the busses and trains and all."
Emergency Handling	Individual support/help, Timely information and Action	*Study 1*: "When there is any emergency, the chances of them (target users) being aware about the situation is less. There is a need for providing warnings which should be accessible." (Stockholm)
		"During any emergencies, it is difficult for them (target users) to react efficiently, without any help." (Gothenburg)
		Study 2: "I (target users) don't know what to do when there is any emergency. I couldn't even find the button, not even the emergency exit."
		Study 3: "During any emergency situations, drivers will act

		more efficiently and quickly."
		Study 4: "Whenever there is any strange things happen during the journey, I like being informed. If there are any changes in the route, accidents or any kind of emergencies."
Source of Information	Route information, Emergency information, Waiting times, Unusual Situations and Weather	*Study 1*: "The POD was delayed for more than 15-20 mins and there was no place or person to get the information from. Didn't know if the POD left early, was it cancelled, was it late. No designated place for getting that information." (Stockholm) "When the POD was cancelled for the day, there was again no place to get the information and there is no place to get the running times of the POD currently." (Gothenburg) *Study 2*: "I (target users) think, I need to talk to the driver only when I need to get any sort of information." *Study 3*: "When I (driver) understand or get information that my passenger is disabled, I will try to give information about the status of the vehicle at every short time interval, if I get the feel that they want to know." *Study 4*: "Whenever there is any strange things happen during the journey, I like being informed. If there are any changes in the route, accidents or any kind of emergencies."
Alerts and Notifications	Bus stops, Door Opening and closing doors	*Study 1*: "Even though the POD was late for more than 15 minutes and 1 out of the 2 PODs that are running on a regular basis was cancelled for the day, the passengers were not informed about any of these delays and cancellations." (Stockholm) "There is no specific application or media for sharing any kind of information regarding the POD. Passengers are not informed at the moment, if there are any delays or cancellations with the rides." (Gothenburg) *Study 2*: "The vehicle gives no signal or audio announcement when the destination is reached. Nor when the doors were closing. That could be dangerous at times." *Study 3*: "It is difficult to know if the vehicle has reached the destination or not. Is the sound or signal for the doors opening or like a horn for the vehicle?" *Study 4*: "I like getting all the detailed information about the ride. I want to know each and every turns and streets it takes

		and any obstacles that comes on the way."

From all the four studies it was found that there were certain areas in which people with disabilities are going to be affected when autonomous vehicles are introduced and there is no driver on the vehicle:

- **Safety**: Many passengers trust drivers more than the vehicle or it's technology. The people are worried that if there are no drivers, there is no responsible person who they can trust and who is ready to act when there is any malfunction with the vehicle or if something happens to the functioning of the vehicle.
- **Door-to-door service**: Many passengers face the issue of not knowing when their vehicle has arrived for pick-up or when they have reached the destination. Usually it's the drivers who come to their doors and inform them about it. This could become a problem for the users when there are no drivers. But the current technology does have many other ways (including the vibro-tactile aid that was tested in the study) to inform the users about these.
- **Customized Service**: The passengers are used to receiving special or more flexible support from the drivers during travel. Many drivers help the users with their luggage, finding a good seat for them and some are highly social, and they even try to adapt to the specific medium of communication that the passengers use. This freedom of receiving a tailor-made service is not available in the autonomous vehicle right now. But even this is something that could be altered and added as a new feature in the technology.
- **Emergency Handling**: In case of any emergency that happens during the journey, the drivers are responsible for handling the situation and the passengers can travel at ease knowing that there is a responsible person in the vehicle. Many of the passengers are worried about the situation of emergency when they are alone in the autonomous vehicles with no human support available to help them handle or help them get out of the vehicle during any emergency scenarios. If these vehicles have simple and user-friendly emergency handles and the users are aware of them and knows how to react to and use the necessary tools during such a scenario, it wouldn't be an issue.
- **Source of Information**: One of the major roles played by the driver is to act as a physical source of information. The passengers approach the drivers with any doubts or queries or for knowing any information about the journey and

it's the duty of the driver to answer them. In autonomous vehicles, this form of tailor- made information is missing currently.

- **Alerts and Notifications**: The autonomous vehicles missed giving out notifications and alerts when there is any action done by the vehicle, both during the journey (inside the PODs) and even before the journey (at bus stops and even while using the travel or navigation apps). The passengers usually receive this information either from their regular apps or receive help from the drivers and co- passengers.

Research Question 2: What benefits and limitations does the vibro-tactile method have for people who are blind, deaf and deafblind when used in combination with autonomous vehicles? (R2)

Qualitative Data from Study 4 helped in understanding the benefits and limitations of vibro-tactile aid have on the target users when autonomous vehicles are used for travel. Few functionalities and their properties are described in the table below (Table 9) supported by the observations of the researcher and the citations/quotations of the participants from different studies.

Table 9: The open codes for Research Question 2

Open Code	Properties	Observation from Studies
Navigation	Way to and from the vehicle, way to the destination	*Study 4*: "The aids helped me in finding the way from the vehicle to the doors of the hospital with the left and right and stop commands. It was very helpful in finding the door without any obstacles on the way."
Source of Confirmation	Help in confirming their actions or queries, Seat preference	*Study 4:* "How will I know if this is the correct vehicle? The aid should be able to give some signals to let me know that this is the vehicle, and this is where I need to sit."
Alerts and Notifications	Arrival of the vehicle at pick-up or destination location, Delays, Disruptions	*Study 4*: "It is usually difficult for me to know if my car has arrived to pick me up. The vibrations from the aid gave me a signal which alerted me and informed me that the vehicle is here. This helped."
Customized Information/ Services	Detailed information about the journey, Waiting for pick-up	*Study 4*: "I like getting all the detailed information about the ride. I want to know each and every turns and streets it takes and any obstacles that comes on

		the way."
User Friendly Aid (Ready-Move)	Ease of use, Small, Wireless	*Study 4*: "I chose Ready-Move because it was small enough to fit in my wrist as a band, and also wireless. It was not very difficult to understand the commands of the aid, if you are ready to spend around 10 mins max. But I do think that it was much easier because there were only 2 vibrators, if there were 4 or more, it would get more confusing."

From study 4, it was found that there were certain areas in which people with disabilities are going to be benefited or have some limitations when they use vibro-tactile aids while travelling in autonomous vehicles:

- **Navigation**: People with disabilities normally rely on the navigation apps such as google maps and apple maps for finding locations. These applications can be unreliable at times as they are not accurate and not accessible to people with disabilities. The vibro-tactile aid provides a good alternative by giving the users proper guidance signals and can inform them about hindrances and blocks that are ahead of them and can help really well in the first and last mile (from pick-up point to vehicle and from vehicle to destination point) of their journey.

- **Source of Confirmation**: Most of the times, the passengers receive confirmation about their queries and other information from the drivers such as whether it is the right vehicle or about the routes they are taking or about the number of passengers in the vehicle, etc. The vibro-tactile aid is also missing the same thing right now. So, it would be a big limitation for the passengers when the drivers are taken away in the autonomous vehicles. The vehicle and the guidance aid need to adapt to this need of the users.

- **Alerts and Notifications**: The autonomous vehicles missed giving out notifications and alerts when there is any action done by the vehicle, both during the journey (inside the PODs) and even before the journey (at bus stops and even while using the travel or navigation apps). The passengers usually receive this information either from their regular apps or receive help from the drivers and co- passengers. The guidance aid act as a benefit for this as they provide vibratory signals for specific alerts and notifications. This needs to be more fine-tuned to make these notifications less complex and providing a

separate interface or integrating it with the passenger's smartphones to make it more user-friendly and easier to use.

- **Customized information/services**: The passengers are used to receiving special or more flexible support and information from the drivers during travel. In autonomous vehicles, this form of tailor-made information is missing currently. The guidance aid is customizable according to the needs and wants of the users. The number of vibrators and the signals can be changed according to the knowledge and skill of the user as well. This helps in providing a comfortable experience to the users.

- **User Friendly Aid (Ready-Move)**: All the participants who used Read-Move aid felt that the aids were highly user-friendly as it was easy to use, it was small, could be worn on their wrist and the vibrations were strong enough to be felt by the users but not loud for others around the users. The aid needs to make some modifications on it's functionality, especially to include multi-mode for communication to make it more appealing for the users.

Research Question 3: What are the main areas that need to be focused on during the design and development process of these autonomous vehicles? (R3)

Qualitative Data from all four studies (Study 1-4) helped in understanding the major functionalities that are to be given more focus on during the design and development process of designing these autonomous vehicles. Few functionalities and their properties are described in the table below (Table 10) supported by the observations of the researcher and the citations/quotations of the participants from different studies.

Open Code	Properties	Observation from Studies
Media for Information	Alternate media: Visual, Audio, Text, Sign language, Vibrations	*Study 1*: "All media of information in the bus stop was visual. There were no other alternate media for information like audio, braille, sign language. This would make it difficult for passengers who are blind to get right and timely information." (Stockholm) "There are no proper or efficient method used for sharing information in this vehicle. The small display board inside the POD was not accessible at all." (Gothenburg) *Study 2*: "I believe that both having the possibility to follow the bus on an accessible digital screen and the availability of a voiced shout out with station names could help a lot." *Study 3*: "I would love if all the drivers could sign language. That's our dream. But unfortunately, it isn't possible, so we instead remain silent during the rides." *Study 4*: "There should be speech function that communicates with me and that I should be able to set up how detailed information I want. "
Colors	Button Colors, Doors color, color contrasts	*Study 2*: "Changing the color of the door to a different one from the rest of the POD would help in identifying the exact position of the doors." *Study 3*: "Since I have low vision, it is difficult for me to differentiate between colors like yellow and red and blue looks the same to me."
Buttons	Less Sensitive, Proper Feedback, Easily Reachable and Identifiable	*Study 1*: "The SOS (emergency) button inside the POD was very sensitive. A small touch (even just feeling the braille info on the button), sends a call to the assistant for help. But there was no proper feedback from the button saying that it was pressed and that the call was going through." (Stockholm "The buttons gave no response when pressed. They need to have some kind of voice and vibratory feedback to let the passenger know that the button is successfully pressed." (Gothenburg) *Study 2*: "It is very difficult for me (target user) to differentiate buttons with just the colors."
Emergency Handling	Easy to find, easy to operate, Eye-catchy, Button design and placement.	*Study 1*: "The SOS (emergency) button inside the POD was very sensitive and The only response it has is a calling assistant icon on the screen and also the voice when the assistant have picked up the call." (Stockholm) "It was difficult to find the emergency button, since it was not

		placed at a good reachable place. The passengers could get confused as to what each of these buttons do and especially since there is no proper feedback from these buttons." (Gothenburg)
		Study 2: "I could not find the emergency button without help. And when I found it, it seemed rather complicated to handle. I didn't know what to do."
		Study 3: "During any emergency situations, drivers will act more efficiently and quickly."
		Study 4: "Whenever there are any strange things happen during the journey, I like being informed. If there are any changes in the route, accidents or any kind of emergencies."
Signage	Proper signs for the details of the vehicle and sharing information	*Study 1*: "There were proper visual sign boards, even with the picture of the POD, on the bus stop of the POD to identify the stop easily." (Stockholm) "Inside the POD there is a small screen which visually shares information with the passengers. Due to it's small size and not very well placed in the POD, these are inaccessible to all. There are no other media for sharing information with the passengers, except the horn signal that the POD gives when any objects are close to it outside as a warning." (Gothenburg) *Study 2*: "I didn't know at all what stop the vehicle was at. I couldn't see any available signs that was accessible." *Study 3*: "Sometimes the drivers will turn off the audio announcements or even forget to turn it on, then it's difficult for me to know the stops or if I am on the right bus. Then I will have to go to the driver and ask him to turn it on for me. I wish they never turn it off. They should always have it on." *Study 4*: "I do wish if there were screens or some display on the vehicles that I could interact with using voice (since I can't see) and give me all the information I need."
Alerts and Notifications	Arrival of the vehicle at pick-up or destination location, Delays, Disruptions, Bus stops, Door Opening and closing doors	*Study 1*: "Even though the POD was late for more than 15 minutes and 1 out of the 2 PODs that are running on a regular basis was cancelled for the day, the passengers were not informed about any of these delays and cancellations." (Stockholm) "There is no specific application or media for sharing any kind of information regarding the POD. Passengers are not informed at the moment, if there are any delays or cancellations with the rides." (Gothenburg) *Study 2*: "The information was not available at all. The info screen was hard to see at all. Bad contrast, structure and letter size. I want to know information in audio and visual about where I am or where I am heading to. I want to know

		all stops, in audio and visual."
		Study 3: "It is difficult to know if the vehicle has reached the destination or not. Is the sound or signal for the doors opening or like a horn for the vehicle?"
		Study 4: "I like getting all the detailed information about the ride. I want to know each and every turns and streets it takes and any obstacles that comes on the way."
Navigation	Proper & efficient mapping	*Study 1*: "The navigation for the POD stop is not accurate. Google maps and Apple iMaps are not showing the right stop. The users will have a lot of trouble finding the right stop." (Stockholm)
		"The current map used for finding the location of the PODs was a website link, which was very inaccessible. It was very complex and had bad designing, making it more difficult for people with disabilities to use them and navigate correctly to the POD." (Gothenburg)
		Study 2: "The map was "shit" if you can't see at all and it was hard to use the voiceover on iPhone. It isn't sufficient that the map is integrated in västtrafiks app. It should be in text also and work better with the accessibility on the iPhone. If there are audio calls for the stops, line and headings in the POD its sufficient. But also, it is needed outside the POD, at the stops so I know the line and where it is heading to."
		Study 3: "Sometimes it's difficult to talk to them and find the exact pick-up location, if the address they gave was not accurate, I need to call them and then it could be difficult to understand what they are trying to say."

From all the four studies it was found that there were certain areas that needs to be focused more on while designing and developing autonomous vehicles so that it would be more accessible to people with disabilities:

- **Media for Information**: Autonomous vehicles are missing different modes for communicating information to the users. There should be an interface that is adaptable to share all information about the journey and the vehicle in all mediums: visual, audio, text, gestures/sign language, vibrations. It is highly important that the new technology caters to the specific needs of the users so that users do not miss out any important information.
- **Colors**: Colors are something that are mostly overlooked as a small accessible issue. But people with low vision and color blindness are not able to identify and distinguish elements on the vehicles if the only form of identification is

colors and image markings. The buttons used on the vehicles need to have alternate form for separating different buttons (such as different shapes and sizes). Even painting a different (colors that can be visible even to visually impaired users prefer yellow) color for the buttons and the doors of the vehicle can help the users in finding these easily and to differentiate them from other elements next to it.

- **Buttons**: The placement of the buttons need to be accessible so that it is easy for users to reach and use the button. The buttons also need to have a proper feedback (multiple medium such as audio, visual and vibrations) so that the users are aware that the button is pressed and that this is the action that the vehicle is going to take. They should also be allowed to make mistakes, in case of any wrong actions, they should also have the option to undo their action (such as if they pressed the button for opening the door, they should also be able to close the door with another press/button).

- **Emergency Handling**: The vehicles are equipped for handling emergency situations (such as they have emergency doors, hammers, emergency buttons and handles and even call for help using a call button). The major problem with emergency handling for the target group is they are not aware of the situation happening and they find it difficult to understand what to do in such kind of situation. Since there are multiple options inside the vehicle, they find it confusing and complex to interact with the functions on the vehicle. They need to be aware of each of these elements and what each of them does. There are no feedback from these buttons to help the users identify what they are and what is the function of each of them.

- **Signage**: There were no proper signs (multimedia) both outside and inside the vehicle that gives out the most important and necessary information about the vehicle and the journey (such as the timing of the bus, the route the bus is taking, the stops in between, the time taken for the journey and so on). Most users prefer to receive less information, and some prefer more detailed ones. So, it is vital that the most important information is properly given to the users and there must be an option for the users to receive detailed and specific information if needed.

- **Alerts and Notifications**: The autonomous vehicle missed giving out notifications and alerts when there is any action done by the vehicle, both

during the journey (inside the PODs) and even before the journey (at bus stops and even while using the travel or navigation apps). It is important to the users that they get notified when their vehicle had arrived, when they are reaching their destination, when there are any delays or cancellations and about any other special or unusual information that could affect the journey.

● **Navigation**: The navigation apps such as google maps and apple maps that people with disabilities rely on for finding locations are unreliable most of the times, as they are not accurate and not accessible to people with disabilities. It is highly important that a glitch-free solution is found for helping the users with navigating to and from the vehicle, without any hindrance or obstacles on the way.

Chapter 5: Conclusion

It is evident from the study that current autonomous vehicles are lacking certain functionalities or features which can make a huge difference in making the transportation a valid and valuable service for people with disabilities. Some of the major areas that need focus for the design and development of these vehicles and their technology are discussed below.

Mode of Communication: The existing vehicles don't support multiple media for sharing information. There should be multiple alternate forms for giving information such as audio, text, sign language, braille or vibrations. The tactile aid device, Ready-Move needs to have an interface that supports multimedia form of sharing information which could also be customizable according to each user needs. The users must also be able to communicate back with the aid and ask for doubts or clarifications if needed.

Emergency Handling: There are highly confusing and complicated buttons on these vehicles right now which makes it impossible for the users to handle them during any kind of emergency situations. These buttons have to be easily identifiable and must be usable and accessible. It is also highly important to have proper feedback (they must have multiple modalities for communication) when these buttons are pressed.

Alerts and Notifications: Passengers need to have a platform where they receive all the notifications or alerts on the changes that are happening on their journey. It could be about route changes, delays, cancellations... People with disabilities often miss out important information since they are not available in an accessible manner.

Customized Information/Services: Some passengers require only specific details of the journey whereas some requires the whole detailed descriptions such as the timing of the vehicle, the routes, etc. The vehicle or the technology must be able to adapt and act according to the needs of the specific user.

Accessible Buttons/elements: There are multiple buttons available in these vehicles which have different purposes. They need to have diverse markings, colors and shapes to help differentiate them, along with proper feedback when these buttons are used. The users must always be informed about what the reaction is going to be for each of their actions. All the elements inside and outside the vehicle should be made easily accessible to all users.

Navigation: It is important that the passengers receive accurate information regarding the route to reach the vehicles stop. The maps used for this technology must be made more reliable and accurate. The vibro-tactile aids can also help in guiding the passengers to the right location using their vibratory signal commands.

The autonomous vehicles are going to be fully automated in few years where there would be no driver to help or support the passengers. It is highly important to take these aspects or points into consideration while developing and designing these fully autonomous vehicles, as these are the regularly occurring problems or needs the passengers have while travelling. Passengers want the ability to interact with and have control over the vehicles using different modes of communication (voice, gestures or touch) as well. Different user groups have different needs and these needs change due to their disabilities. During the study, it was found that the passengers who are deaf don't require as much help as expected from the guiding aids. Since they have vision, they are able to see and acknowledge the situations happening during the test journeys. Persons with disabilities would be able to have a smooth commute on these autonomous vehicles once these design functionalities are either incorporated or taken care of.

Chapter 6: Limitations and Future Work

One main limitation was the number of participants that were recruited for the studies. Since the target group for this master thesis was a small group, it was difficult to support the study with quantitative data. For future work on similar kind of studies, a much vaster number of target group can be used over a long period so that a solid quantitative analysis can also be done.

Another interesting insight was how participants categorized as people with deaf-blindness were not totally blind. The participants had low vision or some kind of visual- impairment. The questionnaire for the studies could have been made more aligned towards their needs or queries according to their disabilities, rather than a set of general questions for people with disabilities.

Due to the easy and convenient nature of Ready-Move device, almost all the participants of the test chose to ride using that aid. Even though this was good to find the positives and negatives of the device, the other future studies should focus on individual devices, rather than asking the participants to choose from a set.

Next step for this study should be conceptualizing and finding the technological feasibility for implementing these changes into the existing test POD models that are currently available in Stockholm and Gothenburg. The PODs need to have some changes in their functionalities and those changes should be tested again with real users to explore if these alterations have made the PODs accessible for all!

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Appendix

A1. Expert Review of PODs

Checklist for Accessibility testing on POD

- ☐ Where is the vehicle's current status (while waiting at the bus stop)
- ☐ When is the vehicle arriving? Has it arrived?
- ☐ Is it on time? Or is it late?
- ☐ Is the one that arrived now the correct one to board?
- ☐ How will I know if the bus I want to board is cancelled?
- ☐ How will I know when the next bus is going to come, if the one I was waiting for is cancelled or I missed it?
- ☐ How will I find or navigate to the entrance of the vehicle?
- ☐ How will I know if the vehicle has stopped and de-boarded other passengers and that it is time for me to board.
- ☐ How can I inform the vehicle that I may need extra time to board the vehicle because of wheelchair or if I have luggage to take with me?
- ☐ What will I do if my ticket shows some error or doesn't work?
- ☐ How will I know if there is an emergency happening inside the bus?
- ☐ What do I do if there is an emergency of any kind?
- ☐ How do I get help during an emergency?
- ☐ Does the vehicle have a stop button that needs to be pressed for stopping at stations and how can the passenger identify that and are these buttons accessible enough?
- ☐ How do I find a place inside and or find an empty seat? Navigating inside the bus?
- ☐ How will I inform the vehicle if I need a change in destination? (not for the POD)
- ☐ How do I communicate with the vehicle that I need a detour or a different route for the journey? (not for the POD)
- ☐ How will I know where to keep my wheel-chair/stretcher or my luggage?
- ☐ How will I know if there is any luggage space in the vehicle?
- ☐ How can I ask the vehicle to open the boot space of the vehicle? (not for the POD)
- ☐ How can I identify if the vehicle is slowing down or stopped for a traffic signal or for my stop?
- ☐ How will I know if there is any malfunction for the vehicle?
- ☐ Or if the vehicle met with an accident?
- ☐ How will I know the path I am taking and also the estimated duration of the journey?
- ☐ How will I know if the area for wheel-chair is already occupied?
- ☐ Or if the vehicle is full and not able to accommodate more passengers?
- ☐ How is the door accessibility? Is it automatic or clickable? If clickable is it located at a convenient place for access to all?
- ☐ What happens if door gets stuck or is not opening?
- ☐ How will I know when my stop is arriving and what is the estimated time for it?
- ☐ How can I inform the vehicle that I may need extra time to de-board the vehicle?
- ☐ How do I know if the door is opened and is ready for disembarking the vehicle and if there is no hurdle in front of the exit that is dangerous?
- ☐ How will I know which side/direction I should exit from the vehicle? (sense of direction?)
- ☐ How is the ramp access for the vehicle? Easily accessible?

Figure A1: Set of questions/checklist for the expert review study

A2. POD Validation Study using Usability Testing

Process

The study was conducted at Lindholmen Gothenburg, Sweden on May 17th, 2019. The study was a two-way ride on the POD. The test started at the entrance to lindholmen science park. The study took around 1 hour.

1. The participants were greeted at the entrance of the Lindholmen Science Park and were briefed about the study structure at the reception counter. A small set of background information was gathered at that time. They were informed about everyone present and their role in the study.

2. Once the briefing was over, they were given the location of the POD start point or the POD stop. The participants were asked to locate the bus stop (task 1). The participants had to use their mobiles and navigation tools to reach the POD stop. In cases where they don't use any tools, they were asked about the method of navigation they usually use. When they needed help, the test leader guided them to the correct position.

3. After reaching the stop, they took the first ride where they explored and experienced the POD journey. They were asked to think-aloud to easily find out and document their observations. The ride was for approximately 10 mins. After reaching the destination stop, they deboarded the POD to make the whole trip complete.

4. They were asked to take the POD once again (return trip) in which the participants were asked some questions/tasks that validated the findings of the earlier expert study of the POD. They were asked to explore the buttons and other objects and functionalities inside the POD. They were also asked about some questions to get to know the accessibility of the POD.

5. After reaching the destination stop (back at Lindholmen Science Park), the participants were taken into the reception area to have the final interview. A summary of the overall experience on the POD was also asked during this time.

Table A1: Overall detailed time-plan or structure of the study

#	Phase	Activities	Data collection	Timings
1	Introduction + Initial Interview	Information about the study (briefing): purpose, goal, data collection, anonymous participation, can choose to stop, the structure of the study and what they need to do. The test leader read out loud and get information from participants.	Consent form (statement read out loud and they were asked to say their name and that they agree to the terms) Background questionnaire Test leader made observations and took notes. Audio and Video recording of the whole process.	10 min
	Locate bus stop	Participants were asked to navigate to the POD stop as they would normally do to a public transport. Choice of navigation method was observed.	Test leader made observations and took notes. Audio and Video recording of the whole process.	5 min
2	First ride	Participants had the freedom to explore the POD and investigate the functionalities within the POD.	Test leader made observations and took notes. Audio and Video recording of the whole process.	10 min
3	Waiting time	Waited for the POD (return trip)		1-2 mins
4	Second ride	Participants were asked specific scenarios as questions and they checked and explored the POD to answer those questions.	Test leader made observations and took notes. Audio and Video recording of the whole process.	10 min
5	Final Interview	Walked to the reception area to conduct the final interview. General and summary of the overall journey was asked to the participants.	Test leader took notes. Audio and Video recording of the whole process.	15 min

Questionnaire

Table A2: Initial Interview Questions asked by the test leader before the tasks.

Questions	Answers
Name	
Age/Age Group	
Gender	
Nationality	
Occupation	
Type of disability	
How long have you been blind?	
Is this your first time on the POD? When was the last time you tried the POD?	
How often do you take public transport? Do you travel by yourself?	

Table A3: Interview Questions asked and Observations made during the first and second ride on the POD.

Questions		Answers	Test Leader Observations	Metrics Checklist
POD Door: Opening **Braille Buttons**	Did they find the button?			**Success Rate** Yes No
	Were they aware of it?			**Help Needed (Find button)** Accessible Less Accessible Not Accessible
	Did they need help in finding the button?			**Help Needed (Differentiate buttons)** Accessible Less Accessible Not Accessible **Time taken to find the button:** **Feedback from Button** Accessible Less Accessible Not Accessible **Usability Issues**

				No: Severity Rating: **Subjective**
Entering the POD: **Gap between the pavement & entrance:** Was it difficult to enter or was it accessible?				**Success Rate** Yes No **Usability Issues** No: Severity Rating: **Subjective**
Do you know the status of the bus? The stops in between and the current stop the bus is at?				**Success Rate** Yes No **Help Needed (Find board)** Accessible Less Accessible Not Accessible **Help Needed (Interpret Information)** Accessible Less Accessible Not Accessible **Time taken to find the board:** **Feedback from board** Accessible Less Accessible Not Accessible **Usability Issues** No: Severity Rating: **Subjective**

When the POD slows down or stops at a signal. **Where do you think we are right now?**			**Success Rate** Yes No **Help Needed (Find board)** Accessible Less Accessible Not Accessible **Help Needed (Interpret Information)** Accessible Less Accessible Not Accessible **Time taken to find the board:** **Feedback from board** Accessible Less Accessible Not Accessible **Usability Issues** No: Severity Rating: **Subjective**
Imagine you are carrying something heavy, like a trolley or some luggage.**How would you place it on the POD?**			**Success Rate** Yes No **Help Needed (Find space)** Accessible Less Accessible Not Accessible **Help Needed (find space)** Accessible Less Accessible Not Accessible **Time taken to find the space:** **Usability Issues** No: Severity Rating: **Subjective**

In case of emergency, what would you do? Do they find the emergency button, was it accessible?			Success Rate Yes No **Help Needed (Find button)** Accessible Less Accessible Not Accessible **Help Needed (Differentiate buttons)** Accessible Less Accessible Not Accessible **Time taken to find the button:** **Feedback from Button** Accessible Less Accessible Not Accessible **Usability Issues** No: Severity Rating: **Subjective**

Table A4: *Final Interview Questions asked after the second ride on the POD*

Questions	Answers
Navigation method used	
Is the map currently available sufficient for you? What do you need? Is it sufficient for the bus to be integrated in the "västtrafik app"? How would you do? Ask someone to help you or do they have any other way?	
How did you find the POD bus stop? Was it difficult to find?	
How did you know you were at the right bus stop?	
How do you usually check the timing of the busses? **How did you know the timing of the PODs**	
How did you know you reached the destination?	
What do you think of the ride? Was riding with the POD as you expected?	
Will you be able to take this POD ride from point A to point B alone without any help from others? What makes it possible/impossible? If the POD traveled between for	

you to known places? Is it necessary for you to be able to travel in a POD by yourself?	
Do you think this is more challenging than taking a normal bus?	
What would you improve in the POD or what other functionality would you add in the POD?	
What is most important for you to make POD a part of your travel?	
On a scale of 1-10, how satisfied were you from the trip?	
Other Remarks	

Figure A2: *Set of pictures from the usability testing for the POD validation study*

Interview Transcripts

Table A5: Transcripts from the interview of the POD validation study participants.

# Interviewie Number			V1		V2	V3	V4	
Questions			**Answers**		**Answers**	**Answers**	**Answers**	
Name			Annette Wilhelmsson		Erik Lonnarth	Anders Ziethen	Mathias Palm	
Age/Age Group			70		33	29	30	
Gender			Female		Male	Male	Male	
Nationality			Swedish		Swedish	Swedish	Swedish	
Occupation			Availability Questions in the city, Small Publishing house (books for children)		Ombudsman	Intern	Unemployed	
Type of disability			Visually Impaired		Visually Impaired	Visually Impaired	Visually Impaired	
How long have you been blind?			10-15 years		10 years	22 years	25 years	
Is this your first time on the POD? When was the last time you tried the POD?			No, tried the autonomous car once before, 1 year back		No, second time, 1 year back	Yes	Yes	
How often do you take public transport? Do you travel by yourself?			Yes, daily. mostly by herself		Almost everyday. Mostly alone	Everyday. Yes, most of the time	Daily, Mostly alone.	
				Test Leader Observations			**Test Leader Observations**	**Metrics**
POD Door: Opening Braille Button	**Did they find the button?**		Not without help	Yes, but was confused with other buttons which were on the outside of the POD	Yes	yes	Not immediately	Yes, but they did feel that the color of the door should have a different color from the rest of the POD, so that it is more evident.
	Were they aware of it?		When I got help to find it.	Yes, every vehicle has a button to open. She asked if it was automatic, or did the operator opened it or if someone else did? (the door was already open)	Yes	Not before it was mentioned in conversation. Though it is similar to the positioning on the trams which made it simple enough to guess the function of the button. However better markings would be advised for clarity. Particularly as there are other buttons on the Pod.	Yes	Yes
	Did they need help in finding the button?		Yes	Yes, especially to find the exact location of the buttons and also to differentiate. Buttons had same size and shape and also the colors looked the same. The placement of button was not very accessible.	No	No, though as I am only visually impaired and not blind this could be different for others. Particularly if the individual is short or has sloping shoulders that makes it difficult to look up. I did'nt look for it but if there where a line to follow to the door opening button from the lower part of the door, that could be useful. It could be shaped as small arrows for clarity.	Someone had to point it out to me	No	Success: Yes; Less Accessible; Severity: 4;
	Entering the POD: Gap between the pavement & entrance: Was it difficult to enter or was it accessible?		Easy	She used her walking stick to understand the height of the POD step and entered the POD without any issues.	Easy for me	The gap as it is now was very high. I do not think the ramp is the best solution for the visually impaired or blind. Not unless the ramp is obligatorily lowered at every stop to ensure consistency and reliability of height and location of the exit.	It was difficult in difference of height between pavement and the entrance. And it was no handle to support you	It was easy because the ramp was used and also it was a group of participants,	Success: Yes; Severity: 2
	Do you know the status of the bus? The stops in between and the current stop the bus is at?		I am not sure what you mean with the status of the bus. But I asked the man working in the bus a little about this. Otherwise I could not know about it. I wanted to know as much as possible.	When the POD stopped at traffic, she thought we reached destination. The board in the bus was inaccessible. She asked for audio-information, if available. She keeps enquiring about each and every actions of the POD.	The only status/info I got was from the map (link), wich normally wouldn't be enough. I want to know time to next bus, a list of stops along the way etc.	No, didn't and yes. There should be more diversity as of the signals the buss emits. Particularly between opening the door and the signal to warn those who walk too close to the pod. I would also like to have input both along the way to understand the road the buss is taking (which can be useful after leaving the buss) and to know when we are about to arrive to be able to prepare to leave the pod. I believe that both having the possibility to follow the buss on an	The information was not available at all. The info screen was hard to see at all. Bad contrast, structure and letter size. I want to know information in audio and visual where I am or heading to. I want to know all stops in audio and visual. Because if a want to chance my destination.	This was missing and the participants asked about this issue.	Succes: No; Not accessible; Severity: 5

Question							Success / Severity
				accessible digital screen and the availability of a voiced shout out with station names could help a lot.			
When the POD slows down or stops at a signal.Where do you think we are right now?	We talked about why the bus stopped, i asked. Sometimes it stopped with a jerk and I asked why. There was a lady coming to near and I asked: how near she was. I asked how long the ride was... about 12 minutes and 1.2 kms so I was not surprised or confused.	She got confused and thought the vehicle have arrived at the destination.	It would be better with different sounds for different actions. I knew where we were, but without any clear confirmation it might make passengers confused and frustrated when doors stil closed etc.	Yes, particularly due to the sound being the same for every eventuality.	Yes, I thought that we had reached the destination.	Some of the participants were a bit confused and thought that we have reached the destination. This was a common mistake evryone face, especially when its an unknown destination.	Succes: No; Not accessible; Severity: 4
Imagine you are carrying something heavy, like a trolley or some luggage.How would you place it on the POD?	I really don´t know if there was place for more than one wheelchair and not much place for luggage. Perhaps behind our seats? No, I don´t think so. I can carry my own luggage..... but if five people have luggage there will be some problem. I wonder if its meant that everyone shall sit or if you can stand in the middle of the bus.	She kept her things on the seat next to her, since there were no other passengers on the POD.	I would put it under the seat or in the windshield.	I don't think this was clear at all. My intuition suggests that the spot for luggage and trolleys would be at the fold down seats in the middle of the pod. If there were other alternatives. I don't think they were clear. Thus, help would not be necessary. IF however, there are roof outcrops to place the luggage. I believe that there are many visually impaired that could need help both to know and to reach these.	Some shells above your head for smaller luggage and also for bigger place for luggage in some place in the bus, like the trains and the public transport has. In some case it would be good with a helping hand with luggage, trolley or wheelchair.	It was really crowded on the bus, so they did need help from the test leader and the POD operator to find the seat and also with the seatbelts	Succes: No; Less accessible; Severity: 3
In case of emergency, what would you do? Do they find the emergency button, was it accessible?	I could not find the emergency button without help. And when I find it , it seemed rather complicated to handle. What kind of help? It depends on the problem , a fire, a collision, if, the doors can`t be opened, if someone gets a heart attack... I expect to come to the emergency help that can decide what has to be done. Ambulance, police , fire brigade, ...a person that can make the right decision.	She was confused with the emergency handle and the emergency button She needed help to find the emergency button since it was not very visible or accessible and she also needed help in handling the emergency handle as well.	I would try to get out as fast as possible. The emergency handle wasn't clear enough and might be better with better contrasts/markings. It would be nice to get some kind of confirmation from pressing the button or instructions for how to react after using the handle.	Most of the information were written in an inaccessible way. I where able to identify the emergency handle after it was pointed out to me that it existed. I believe that this should be more easily identified, and I am uncertain that someone who is visually impaired immediately would know that this is an emergency door opener. Same with the buttons. Better markings would be required to understand that it was an emergency button. Further, I believe that it would be good for the internal system to let you know when you have pressed the button or pulled the handle to confirm to the user that they were successful in using the appliance.	In case of a emergency I don't know what to do. I was not able to find the emergency button or door handle. The button should have more color, clear text. And positions was big high if your are in a wheelchair or smaller. The surrounding of the handle should have the same color as the handle. And it was litte high positioned to. It should be some audio signal where the door handle are positioned in a emergency. And also signal that the door are opened same signal in normal case. A sound where the doors are so you can find them and a signal when the are opening.	No, they all had issue finding and understanding the emergency buttons on the POD.	Succes: No; Not accessible; Severity: 5
Navigation method used	I was helped to find the bus. In places I do not know I need help. When I am familiar with a place / manage om my own with the computer an app and the phone.		Usually I look for markers that confirms that I´m on the right track. For example in this case a windbreak, signs or some kind of platform.	I usually try to find the location ahead of time. If that isn't possible, I would use my phone both to look at signs and to confer with maps.		It was not as usually when I moved to the POD. A public transport stop looks like a stop. The POD stop didn't look like that with caution, contrast stones at all.	
Is the map currently available sufficient for you? What do you need? Is it sufficient for the bus to be integrated in the "västtrafik app"? How would you do? Ask someone to help you or do they have any other way?	I can´t see a map. I am helped when I can listen to information. Press a button and I can hear When the bus Is coming and the number of the bus. I must plan when I go by bus or tram or boat really careful. I often use Västtrafik and think I can manage. I have to ask people around me in new places and every time I go with a bus without loudspeaker.		The function is important, but the contrast was bad and it should be more logical to find my nearest stop/station. It would be interesting to get a list of stops, time to next vehicle etc.	The map helped with finding the stop but as mentioned at the trial. The lines where most unclear. Mainly it helped to find the general location. Thereafter it helped that the pod was at the stop already upon arrival. I do think it would be good to have it integrated in the app. The less apps to switch between the better. If I were unable to solve it myself, I might have to ask someone. Though that depends on how the information where accessible at the stop. It's easier to ask someone if they can find it easily to. Another possibility		The map was "shit" if you can't see at all and it was hard to use the voiceover on iPhone. It isn't sufficient that the map is integrated in västtrafiks app. It should be in text also and work better with the accessibility on the iPhone. If there are audio calls for the stops, line and headings in the POD its sufficient. But also, outside the POD at the stops so I know the line and heading. I could ask someone if there are someone to ask but it not sure that the person answer or know	

				is to have a pressable button that told you the line you'r at and when the next pod arrives. It could aklso be useful to know how many spots are left on the pod. If its crowded or not etc. which could be useful information for someone that is blind.	
	How did you find the POD bus stop? Was it difficult to find?	Pournami helped me.	Thanks to the map it was easy, but it might be harder for someone that doesn't like using maps.	By use of the map and visual confirmation. It could be useful to have some form of sound confirmation when you reach the bus stop though. Either at the stop, like a soundpoint at the stop or a confirmation in the app telling you that you have reached a stop and the name of the stop.	I passed it on my way to the meeting. But if I didn't had passed it on my way to the meeting it had been difficult
	How did you know you were at the right bus stop?	Pournami helped me.	Thanks to the company.	At this point, I only did because the pod where there I think.	I didn't know at all what stop it was. I couldn't see any available signs that was accessible. It was no caution, contrast or ledstråk at the stop that makes it easier to recognize as a stop.
	How do you usually check the timing of the busses? How did you know the timing of the PODs	I check the time with Västtrafik to know the time for the tram and the ferry and I use the app in the mobile, Next tram, bus.....	Through the app "Reskollen"	Usually by checking in the västrafik app or sometimes by osing a "prator" that reads the times and lines from the display at the stop. I did not know anything about the timing of the pods.	I use the app "Nästa vagn" that Göteborgs spårvägar have made it more compatible with the accessibility support on iPhone like Vocieover and Zoom. I didn't know the timing at all I was told and expected the time because we was a study group
	How did you know you reached the destination?	I have made an appointment and was picked up at the ferry.	Thanks to the company and seeing the Pod.	By visual conferment. There where no sound telling us that we reached to buss stop that where unique to the buss stopping at a station.	I didn't know at all that we made the stop. I was told so by the personnel onboard and that is not how it works in IRL. It should be audio/visual calls that we made the stop. And signals where the doors are so you can find them and a different signal when the doors are opened. So you know where they are. But also so you know if they POD is still or getting in motion.
	What do you think of the ride? Was riding with the POD as you expected?	I thought it would be more smooth, that it should be a bit longer drive., a bit more comfortable, that the emergency button would be more available. Now I think it could as will be more like a tram .	Yes it was nice.	It was fantastic. Though I can't wait until the speech update arrives. But the ride felt good and I believe that the scanning mechanism that both made it sound and stop if people and objects where to close is a good thing. But the variety of sounds could be better. A small complaint could be that the seat's form limits you depending on your size and requires you to sit in a certain place. During rush hour, this might be a bit difficult to find easily without sitting down on a seatbelt or the line between two chairs. Something that could be quite uncomfortable.	I like the ride but the glas sealing and the clear windows made it hard to see in POD. The seats were small and made it crowded
	Will you be able to take this POD ride from point A to point B alone without any help from others? What makes it possible/impossible? If the POD traveled between for you to known places? Is it necessary for you to be able travel in a POD by yourself?	Yes, when I know the circumstances for getting out and calling for help. I am interested in finding solutions for the future where you don't need a car of your own and you think of the climate.	Yes. Because we´ve already did the trip once. Yes.	As it is now, yes if A and B are known places and there is enough daylight. However, without a spoken confirmation of where the pod is, I would not be able to know which stop we're at. And YES, of course it's necessary to be able to travel in a POD by myself. Most people wish to be able to act independently and visually impaired are no exception. The only reason that we can't do everything ourselves is because there is a lack of accessibility in society. I think that if anything, the leap that the POD's might stand for makes it necessary for them to be accessible enough	If all that I have mention above works I will be able to travel A to B but also to C and D. If every stop has audio and visual calls for each stop and heading inside the POD I can travel myself. And also audio, visual and line calls at the stops I can travel myself. If that works I can travel alone

			to allow for us to travel alone. Otherwise, it's not just about cutting us of from traveling in the POD independently, but of cutting us of from our independent travel in the future.	
Do you think this is more challenging than taking a normal bus?	Yes, now it is , your have to work with it more.	No	No, not necessarily. The thing that might make it different in the future is if there is a host or something similar working in the pod or not. Otherwise, the main difference is that you won't be able to ask a driver for directions.	If all works and the thinking of accessibility are in the mind in the design from beginning. It should works like the normal bus, tram, train and ferry
What would you improve in the POD or what other functionality would you add in the POD?	Going smooth and not like this with jerks. Audiodescription that describe what you cant see with your eyes, the buttons , the hammer m the emergency stuff. I think the buses need a sound to announce coming, it is very difficult for a blind person to hear a electrified bus coming. A voice telling us when we are at one stop and the final stop.	Audio-information and confirmation. Comfort. Travelling speed. Contrast markings. Lightening.	Voice. Better digital displays for stops and times inside the tram. A better solution for the gap between the POD and the ground. Larger signs and better markings and explanations for buttons, both on the inside and on the outside.	I would improve all that I have mention above. The coloring of handels should be yellow as in todays public transport. Emergency handles, buttons should stand out more in red, text and braille. The ramp should go out first than the opening of the doors. Like the trains do today. A signal where the doors are at the stop and also a different signal when opened.
What is most important for you to make POD a part of your travel?		Audio confirmation.	Better, clearer map and the ability to navigate by hearing such as read out stops and external speakers to allow me to know that a pod has arived and which pod it is. For me, feeling secure in where I am and where I am going of is imperative to if I ever use these myself.	That all that have mention works
On a scale to 1-10, how much satisfied were you from the trip?	6	6	6	6
Other Remarks	I am happy that you do this availability work. It is great!!!!! Continue the project to be better and better 😊			The response from the onboard personnel where some ignorant on our problems and remarks on the POD test. If you want accessibility and that all groups of people will use the POD take notice of our remarks and do not answerer that that is sufficient. I didn't see the handles or emergency stop button at all. And that are not sufficient.

A3. Qualitative Interview for understanding the role of Drivers

Process

The study was conducted through multiple methods: Online, Phone-in and Field Interviews. The participants were given a brief introduction, where they were informed about why this study was done and also how the collected data will be used for the study. They were also informed about the data collection and a verbal contract was signed by all participants.

Methods for gathering participants:

- Drivers:Contacted Taxi Companies and got permission for interviewing their employees. This was approached in 2 ways. One was to get a special permission letter from the company and go to the popular taxi stands (Arlanda, Solna, Bromma, and many more) and get participants on the spot for the interviews. Another way was to get a list of interested voluntary participants from the taxi company and arrange a suitable time slot for each participant for the individual interviews. Also, contacted Vastrafik and arranged a set of drivers under their contacts.
- Target Users (Passengers with disabilities):Contacted Victor from RISE and Parivash from Pariception for arranging blind, deaf, deaf-blind or mobility disabled users.

Criteria for selection:

- Must have driven or had a ride on a bus/taxi in the few recent months.
- Available for a face-to-face interview or even a telephone interview (maximum of 1 hour of interview).
- Have no issue with recording and the usage of data for the master thesis.
- Drivers: Must have travelled at least once with a passenger with disabilities.
- Passengers: must be blind, deaf or deaf-blind.

The whole interview was recorded using a voice recorder, with the agreement of the participants. The participants were informed about this during the selection process itself and were asked for their consent. The name and personal details of the

participants were not shared with anyone else, it was completely anonymous, apart from the people who were directly involved in the study.

List of Questions (Drivers)

1. Name:
2. Age/Age Group:
3. Gender:
4. Nationality:
5. Bus/Taxi Driver:
6. Years of Experience as a Driver:
7. How often have you travelled with a passenger with disabilities?
8. Have you very recently driven someone with any kind of disabilities during your work hours, especially someone who is deaf, blind or deaf-blind?
    a. Can you brief us on the overall journey you had with that passenger?
       (If the subject needs a set of questions to answer the above one, ask them questions from b, c)
    b. What kind of disability did the passenger had?
    c. Did you converse with the passenger during the journey? How did you communicate with the passenger (if he could not see, or talk, hear you)?
        i. Was there any special help they needed while entering the vehicle?
        ii. Was there any special request or doubts they had before entering?
        iii. Did they ask anything or communicate with you during the journey?
        iv. Did you feel any need to communicate with them throughout the journey? If yes, what and why?
        v. Did you help them or communicate with them while they were getting off the vehicle?
9. Can you give us a scenario where you had to help one of these passengers?
10. How did you support/help them? What role do you consider having in the interaction with a passenger with disabilities?
11. Is there any special assistance that these passengers require when compared to other passengers on your vehicle? What does typically change when you have passenger with disabilities compared to other people?
12. What are the common or frequently asked doubts or questions, or actions expected from you during the journey (from the perspective of a passenger with disabilities)?
13. What do they typically ask you to do for them? What do they request from you?
14. What do you inform the passenger? Does it change or remains the same for all the passengers?
15. What are the main differences when you are driving with a passenger with disabilities?
16. What are the main similarities you notice between these passengers?
17. What according to you, is the major challenge when driving a passenger that are blind, deaf, blinddeaf?
18. How do you see your function/role as a driver of passengers with disabilities?
19. Email ID (for a Thank you note):

Figure A3: Set of questions for drivers from the qualitative interview study

List of Questions (Drivers)

1. Name:
2. Age/Age Group:
3. Gender:
4. Nationality:
5. Bus/Taxi Driver:
6. Years of Experience as a Driver:
7. How often have you travelled with a passenger with disabilities?
8. Have you very recently driven someone with any kind of disabilities during your work hours, especially someone who is deaf, blind or deaf-blind?
   a. Can you brief us on the overall journey you had with that passenger?
      (If the subject needs a set of questions to answer the above one, ask them questions from b, c)
   b. What kind of disability did the passenger had?
   c. Did you converse with the passenger during the journey? How did you communicate with the passenger (if he could not see, or talk, hear you)?
      i. Was there any special help they needed while entering the vehicle?
      ii. Was there any special request or doubts they had before entering?
      iii. Did they ask anything or communicate with you during the journey?
      iv. Did you feel any need to communicate with them throughout the journey? If yes, what and why?
      v. Did you help them or communicate with them while they were getting off the vehicle?
9. Can you give us a scenario where you had to help one of these passengers?
10. How did you support/help them? What role do you consider having in the interaction with a passenger with disabilities?
11. Is there any special assistance that these passengers require when compared to other passengers on your vehicle? What does typically change when you have passenger with disabilities compared to other people?
12. What are the common or frequently asked doubts or questions, or actions expected from you during the journey (from the perspective of a passenger with disabilities)?
13. What do they typically ask you to do for them? What do they request from you?
14. What do you inform the passenger? Does it change or remains the same for all the passengers?
15. What are the main differences when you are driving with a passenger with disabilities?
16. What are the main similarities you notice between these passengers?
17. What according to you, is the major challenge when driving a passenger that are blind, deaf, blinddeaf?
18. How do you see your function/role as a driver of passengers with disabilities?
19. Email ID (for a Thank you note):

Figure A4: *Set of questions for the target users from the qualitative interview study*

Interview Transcripts

The interview transcripts from the participants were documented on an excel sheet for analysis.

Table A6: Transcripts from the interview of the drivers.

# Interviewie Number	D001	D002	D003	D004	D005 (Field)	D006 (Field)
Questions	**Answers**	**Answers**	**Answers**	**Answers**	**Answers**	**Answers**
Age/Age Group	53	56	56	61	37	49
Gender	Male	Male	Male	Male	Male	Male
Nationality	British	Swedish	Swedish	Swedish	Afganistan	Lebanese
Bus/Taxi Driver	Taxi	Both Bus and Taxi, currently a taxi driver	Taxi	Taxi driver	Bus and Taxi	Taxi and Bus
Years of Experience as a Driver	20 years (stopped driving 3 years ago)	36 years	Since 92 as taxi driver (26-27 years)	Around 40 years	3 years	10 months in Taxi (5 years all together)
1) How often have you travelled with a passenger with disabilities?	Quiet often, more experience with handicapped kids	Earlier, nearly 100% of the passengers were disabled. Now, it is more into a mix of passengers, only nearly 10%	Not so much, because of the size of the taxi (8-seater van type) Wheelchair mainly.	15-20 years	Everyday	Almost everyday
2) Have you very recently driven someone with any kind of disabilities during your work hours, especially someone who is deaf, blind or deaf-blind?	Yes, very often	Not very recently, a month ago	Not very recently.	Everyday	Yes	Yes
· Can you brief us on the overall journey you had with that passenger?	Driver gets all inputs on their screen. They behave accordingly, even pick-up and drop-off indoor. Help with bags, wheelchairs. Blind: Guide them using voice and navigate them. Where to sit?	-	-	-	-	-
· What kind of disability did the passenger had?	Wheel chaired, Blind	-	-	-	-	-
· Did you converse with the passenger during the journey? How did you communicate with the passenger (if he could not see, or talk, hear you)?	Where to sit? Front or Back Deaf: Communicate using mobile texts Blind: Through voice Deaf-blind: Always accompanied by someone	-	-	-	-	-
· Was there any special help they needed while entering the vehicle?	Pick-up and Drop-off Help with bags and wheel-chairs.	-	-	-	-	-
· Was there any special request or doubts they had before entering?	-	-	-	-	-	-
· Did they ask anything or communicate with you during the journey?	Blind: want to go to multiple destinations (only on community service) They ask help with shopping. Check about the driver	-	-	-	-	-
· Did you feel any need to communicate with them throughout the journey? If yes, what and why?	Inform them about the route he is planning to take. Most of them know each movement of the vehicles.	-	-	-	-	-
· Did you help them or communicate with them while they were getting off the vehicle?	Same as before	-	-	-	-	-
3) Can you give us a scenario where you had to help one of these passengers?	Deaf: Everything is visual Sign language is a good way of communicating.	Either computer or telephone get information on their disability Vehicles are already equipped for disabled users Not too low or high	Read the order carefully, to know what to expect. Follow instructions Make particular notice of their requirements Use mobile for finding the address.	-	-	-
4) How did you support/help them? What role do you consider having in the interaction with a passenger with disabilities?	Same as before.	All the information and requirements are on the Assistance requirements are already mentioned	Go to their door, with stick or not (blind). Very important to listen to them, they know what they need. Will do what they need help. Guide them to the vehicle and also to their destination place. Take extra care, make them feel comfortable. Being polite, listen to them.	Depends on what needs they have. Ask and notice and act accordingly. Good seating.	Pick from home, door. Always give information. Talk always. Tell them where exactly they are currently. Talk to them. Always give information. They want to knoe which route the vehicle is taking, are they going through highway or city roads.	Show responsibility in traffic. More careful, Choice of seat is always a high priority for them. Even the choice of music.
5) Is there any special assistance that these passengers require when compared to other passengers on your vehicle? What does typically change when you have passenger with disabilities compared to other people?	Some people ask for no help. Talked about the structure of the car, is it an easy way to sit, help with roof handles and all.	Blind: Always lead them Always talk to them And communicate with them Bus: Ask them about special help	Being social is a good experience in treating people according to their situations. Apologise for any delays or for any inconveniences caused. Humour is a very good instrument to use. It melts the situation around.	Assistance in getting in and getting out of the car.	They need too much. Have to be taken care of. Newly disabled: they are not used to this, so they need more help.	

6) What are the common or frequently asked doubts or questions, or actions expected from you during the journey (from the perspective of a passenger with disabilities)?	Opening doors Help them board and de-board the vehicle Help with luggage	Recently handicapped ask lot of questions Questions about the car, type of car.	Anything! They have any luggage, I help them, without even them asking. Small things also matter.	Directions Assistance in boarding and deboarding vehicle. Experienced and inexperienced disabled passengers. Which direction of the building are they at? (Orientation?)		
7) What do they typically ask you to do for them? What do they request from you?			They are more grateful and understanding.	No		
8) What do you inform the passenger? Does it change or remains the same for all the passengers?	Route Weather Blind: Unless they know, he keeps updating them on the recent location of the vehicle		Any situation comes up, traffic stuck, or accident come up, I talk and explain the situation. Always keep them informed. Do it in a natural way, do it automatically.	Blind: Talk and say what's happening on the road.		Responsibility
9) What are the main differences when you are driving with a passenger with disabilities?	Normal: Less help from the driver	Less conversation without disability More conversation	More careful with disabled Its almost the same. They don't want to be treated differently.	Not much difference. It's always up to the individual. Treat according to individual needs.		Door-to-door service. Bur responsibilty is high for the disabled users. Just try to do everything they want.
10) What are the main similarities you notice between these passengers?	Same help with opening and help with	Not much difference Very similar	Not big difference.	Everyone have special needs. Adapt to it.	Safety is always more of a caution.	
11) What according to you, is the major challenge when driving a passenger that are blind, deaf, blinddeaf?	Blind: Not much of a big deal. Pick and Drop at the door. Deaf: Use print out of address to show him. Check for hearing aid. Mobility: They are way ahead of you. They already know work arounds. They find a way to communicate with you.	Deaf: Basic Sign languages	Making them feel like any other passenger. Making sure that they don't feel like I am being pitiful at them.	Description of what's happening in front of you. Traffic or what's happening around. Need to be descriptive to the passenger.	It is not difficult at all. Maybe finding the exact destination/pick-up location. Difficult to talk to them to fing the right location.	Its kind of the same as driving any other passenger. It is kind of easier to drive with disabled users since they dont say much. But it depends on each passengers individually.
12) How do you see your function/role as a driver of passengers with disabilities?	Main issue with mobility users. Blind person on wheelchair.	Leading them Door to door service	Make the trip as easy as possible. Safe, Funny Music Rememberable journey	Stop for mail. Shopping. Act according to the request.	Being Helpful. Door-to-door dervice. Go in and help them to reach the destination. Act fast and quick and efficient in case of emergency.	Just do everything for them. Help in boarding and de-boarding. Always give information. Especially on the waiting time informations for bridge open, train crossings, traffic, stop signals and so on. Just do everything to make them as comfortable as possible.

Table A8: *Transcripts from the interview of the target users.*

# Interviewie Number	TU001	TU002	TU003	TU004	TU005	TU006	TU007
Questions	Answers	Answers	Answers	Answers	Answers	Answers	Answers
Age/Age Group	28	63	70 (1948)	30	33	soon 70	
Gender	Male	Female	Female	Male	Male	male	female
Nationality	Sweden	Swedish	Swedish	Swedish	Swedish	swedish	swedish
Occupation	-	Social leader	Availability Questions in the city, Small Publishing house (books for children)	Employed	Ezecutive and Mediator on SRF Göteborg	active pensioner, do volontary work in different associations- goes to meetings. important to be on time	office worker
Type of Disability	Deaf	Visually impaired Blind	Injury in eye, nearly 16 years, low vision, foggy vision	Visually Impaired	Visually impaired	blind- since birth	blind-illness 13 years ago
1) How often have you travelled in a public transportation (bus/taxi)?	Often	5 times a week, nearly everyday	Almost every other day	Almost everyday	By bus or tram about 4 times a week and by taxi (Färdtjänst) twice a month.	several times a week	twice every day
2) Preferred or Most commonly used mode of transportation:	Bus	Tram and busses	Tram or bus Taxi	BUS Bus, Tram and Train Taxi at times	Tram or train because of the predictability.	taxi-färdtjänst- he prefer färdtjänst as the bus service is to seldom, he live at a rural place and the bus is to far away and he said that he never can take it even if he would like to. when living in gothenburg he always took the public transport bus.	buss- she prefer bus as she has a dog and the taxi does not always has the nessiary stuff to make the trip safe for the dog. they show no understanding in taking down the "grid" at the back, and they have a lot of random stuff at the back which makes it difficult to fit the dog
· Can you brief us on the overall journey you had recently in a public transportation?	Normally bus 2-3 times / week. Taxi 4 times/year. I use metro every day though.		Yes. Been there many times Know how to go to the right place, familiar location Can't see what number, which tram is coming.	**Announcement doesn't work Ask driver or other passenger for checking the right bus**	A few days ago I traveled by taxi (Färdtjänst - Arbetsresa) from my home to work on a meeting in a totally new location for me. I used an app to order the trip. A few minutes before the car arrived I followed it´s location through the app, to make sure, when to put on outware and leave. When the taxi arrived the driver opened the door and shouted out my name, wile getting out and opening the back door of the cab. Getting seated I hade to repeat the address to where I was traveling and than just smalltalking. After about fifteen minutes the driver asked me if I recognized the building of which I was going to, but because of my	he had to go to a meeting in one if the associations he is active in.	he use public transport to get to work

					visually impairedment I couldn´t and also because of the fact it was my first visit. A few minutes later we´ve found the place and I got out of the taxi wile getting the question if I needed help to the door.		
· What mode of transportation was it?	Bus	Tram	Tram	Bus	Taxi (Färdtjänst – Arbetsresa)	taxi färdtjänst	bus
· Did you converse with the driver during the journey?	No, only "hello".	Yes, in the back. Couldn't hear the outside announcement. Asked the driver Prefer the main entrance talk to the driver	Checked if it is the correct tram. Monitors: Letters written, no audio, can't read, anything out of schedule.	Announcement Traffic, Route changes,	Yes, a few times.	sometimes he make conversation if he likes to. sometimes he tells them to be quite as he does not want to listen to their life story	she says hi to the driver. they usually respnd back. she regularly take the bus so the drivers have gotten to know her by now. they make special anouncement if the info system is broken. they sometimes make special anouncement for her even if she have not asked for it or need it .
· Was there any special help you needed while entering the vehicle from the driver?	No.	He conformed the trams destination.	Phone before travel, call vastrafik and get help from them to know the exact timing and plan before going to the station.	No	Not really, more than to get confirmed it was my car.	they locate the door, and then sometimes provide help in geting the seat belt on, but he can do it himself.	no. she ask the dog to find her a set. if you go with taxi they locate the door and then maybe help with seat belt. it is important the the bus stops at the front of the bus stop, at the same place every tome, so that she can locate it, she know where that spot is so iti s easy to get into the bus. she then always passes the bus driver on the way in.
· Was there any special request or doubts you had before entering the vehicle from the driver?	No.	No	If no announcement, can't see which tram, have to ask people around me or even ask people inside the tram or the driver.	No	Maybe about if it was the right car or not, but that was assured by his shout out for me.	"samåking"- taking färdtjänst means that you pick up several passangers along the way, and as he is blind he cannot see if there are people in the vehicle, sometimes he hear someone talking and realise that there is someone sitting there.	
· Did you ask or communicate with the driver during the journey?	No.	No	Loud speaking is functioning, so that you know where to get off. Loud enough to hear in the crowd.	No	Yes.	before entering the vehicle he asked if there are several people or only him this time. he prefers going by himself, as it is more relable. with more people in the vehicle timing is unpredictable. he book with much time in advance if he has a meeting to attend.	
· Did you feel any need to communicate with the driver throughout the journey? If yes, what and why?	BUS: No, but if I´m not sure where I should get off, I usually ask the driver with my phone. TAXI: no.	No, I could hear the announcements	If there is any delays or problem with the roads, not aware about them. There are big signs which can't be read by the subject. Ask others what is written on the signs.	Taxi: Payment conversation	Not before there was any doubt about where we were going.		
· Did you get any help or communicate with the driver while you were getting off the vehicle?	No.	Special seat: sometimes occupied. They move for me. If not, I stand there. No	No, sometimes. When there is good signs and announcements, you don't need any help.	Correct destination Guide assistance from the vehicle to the destination.	No but I got the offer.	he wants help to locate the final destination when he is in new places. like please guide me to the reception if they have a meeting at a hotel for instance. known places he does not need help at	she has a dog so she does not need help that much, she knows where to go. sometimes she ask someone to confirm where she is.
3) Can you give us a scenario where you had to get help from one of the drivers?	BUS: Only when I need help to know where I should get off. Happened maybe 2-3 times in my lifetime. Now they have signs in the bus telling me when the next stop is, after that I never ask the driver.	Announcement is low or doesn't function inside the vehicle. Ask someone on where we are or help her in talking to the driver in helping her turn on the announcement Blind Square: Talking GPS. Listen to different streets, just for curiosity.	Taxi: Multiple destinations, different routes. Emergency, security		I think help is mostly about confirming information for me in different steps. Confirming for me if it´s the right cab, the right tram och the right destination or platform etc. If I travel to a new destination with different entrydoors I tend to ask for help to the right door and maybe help with the "intercom"...	if the driver goes a de tour, or something happen along the way he want information about it	she had not experienced any situaiton which there had been any disruption to the ride. one time she missed getting of, she was doingsometing on the phone. she realise and got of a station further away. she asked the dog to find a bus stop at the other side. the dog found the bus stop and she took the bus back again.
4) Do you expect support/help from the drivers? What role do you consider drivers have in the interaction during the travel?	No, I don´t expect anything from the driver.	Announcement Information: if the tram goes in a different way. Help in getting the right precision (orientation) to take the next tram. People in the tram is also helpful.	Be good drivers, expect them to put on the loud speaking, both outside and inside the tram, don't take it away, keep it on always. Audio Description: Climate, detailed journey description.		Confirming to make me calm and feeling in control over the travel or my way from A to B.		
5) How would you like to be approached by the driver?	Like a human, as all other people.	I prefer to approach them.	If I ask them, I want them to be friendly and nice.		Hard question, but I would like to have the possibility to talk and ask how mouch I need, even if it´s not as needed.	they should listen in more	

6) Is there any special assistance you require when travelling? What does the driver help you with?	No.	Bus: Pay. Doesn't know how to pay using the digital interface. So ask help from the driver.	Card, paying with the card, is it the right card, error message issue?		Not really, but if traveling by train the conductur might be able to help with information about changes to other trains etc.	find the door, seat belt if needed, locate the final destination	if i were in a taxi, i do not want them to let the dog out unitl i stand next to the vehicle trunk due to safety, so the dog does not run away
7) What are the common or frequently asked doubts or questions, or actions that comes to your mind during the journey?	They never ask us. When they realize we´re deaf, often they keep quiet during the entire ride.	If the tram is taking another route, would like to be informed. Traffic issues. Anything that influence the travelling. Delays or if tram needs to be changed, would like to be informed. Same all information: must be properly informed (only via speakers) (must use all kinds of method of information(	Lot of changes in the roads, busses and trams are stopping and have to get on other tram, impossible to do themselves. Know the reason for stopping and get information on how to catch the connecting trams. Maybe guiding people, using hand gestures and voice according to their needs. Good information or some person helping me.		Will I make it in time? Is this really the fastest/best way? Wonder if Ill find the right location wile I´ll get there?	if the trip takes long time he wants to know, he want to know if there are only him or other people to pick up on the way, if they take a de-tour,	if the anouncement does not work, i ask him to indicate when i reach my destination
8) What do you typically ask the drivers to do for you? What do you request them?	Nothing.	Announcement	Announcement		Maybe to change ending destination wile in a cab, or to help me getting to the right door wile getting off. On busses of trains or trams I might ask about delays or other routes.	seatbelt and indentify the door, find the end destination	
9) How do drivers differ in their interaction? How do you prefer drivers to interact?	The foreign drivers tend to be more open using body language while Swedish drivers remain silent.	Just talk to me. Common message for everyone, it's the speaker. Personal information.	Ready to give information in nice cordial manner, badly educated to address all kinds of users.	Some doesn't speak at all, use body language to show something, doesn't work for you. Like communicating using assistive technology products.	I prefer if they answer to my questions or makes me feel calm by confirming the relevant travel information.	there is a different how they talk, some are chatty, some are mody, but all aske if i need any special help, some are better in taking my bags	
10) What do the drivers inform you during the journey? Are you expecting any kind of extra information from the drivers?	Nothing and I don´t expect any information.	Common messages to be said personally. extra services: not asked. Information: more information than less information Not specially treated	No, announce or inform about the situation outside the tram and on the roads.	Traffic jams, changes in route, expect driver to inform without asking	Maybe if they recommend me to change route, transportation or else because of problems in the traffic.	the driver talks about their life sometimes, if it takes long time i can ask them stuff- like why are we stoping	
11) What is most difficult action/task when you have to travel using public transport?	If it happens my transportation card doesn't work for any reason, then it´s a big problem communicating with the driver trying to explain my situation.	Find a seat, where to sit. Some places, you can't even stand Sit closest to the driver, easy to move and communicate with driver while the bus is moving.	Going on the right tram or the right bus.	Get on the right vehicle Announcement works Getting off at the right station	Changing transportation. The changes makes it hard to find the fast changing information and that creates stress.		
12) What is most problematic with the drivers?	Their attitude when they realize we´re deaf and not trying to communicate with us if it happens something.	If they don't understand what she is asking	Putting off or taking down the announcement.	Some are great, some aren't Speak to you, answer to questions and doesn't ignore you. Using of body language.	The fact that the driver works and often seeks socialization, wile my goal is to get fram a to b.		
13) How do you see the function/role of a driver while you travel with them?	Just transport me from A to B.	They should be able to effectively give information that is asked for.	Right tram Announcement Good information	Support when needed For assistance and guidance	As the one providing me with the possibility to get from a to b. 😊		
Other Remarks	Do not misunderstand me, I would love if all the drivers could sign language. That´s our dream. But unfortunately, it isn't possible, so we instead remain silent during the rides.						

A4. Field observation and Qualitative interview

Selection Criteria

- They must be available for the study physically.
- They must have the ability to sense these vibrations.
- They must be part of one of the mentioned categories of disability: Deafness, Blindness or Deaf-Blindness.
- They must not have any cognitive disability, since for the test, the participants need to learn the coded vibrations.
- They have the ability to travel (wheel-chair is not a problem).

Recruitment Process

- The project description was advertised on Facebook and many people contacted the company from those.
- The advertisement was also put up on the university site (https://www.oru.se/nyheter/nyhetsarkiv/nyhetsarkiv-2018/enklare-att-resa-for-manniskor-som-ar-dova-och-blinda/)
- The project was also presented at multiple events to recruit participants (SRF in Stockholm/Orebro, FSDB in Stockholm/Orebro, Audiologiska kliniken, synsentralen, ögonkliniken Orebro).

Questionnaires

Table A9: *Background data collection Interview Questions asked by the test leader before the study.*

Questions		Answers
Birth Year		
Gender		
Type of functional impairment		
How long have you had functional impairment (years)?		
Language (Speech, Sign Language, Tactile / Visual)		
Personal assistant/companion (how many hours)		
Vision and Hearing function	**a. Essentially normal vision and hearing**	
	b. Severe vision and hearing (Deafblind)	
	c. Severe hearing loss or completely deaf but essentially normal vision	
	d. Severe visual impairment or completely blind but essentially normal hearing.	
	e. Mild vision and / or Mild hearing function	
	f. Known diagnosis of hearing / vision loss, etc.	
Description of the activity performed at the tests and the tactile aid used for guiding the subject:		

Table A10: Initial Interview Questions asked by the test leader before the first ride.

Questions (survey of travel habits and area of usual traveling for choice of route when testing)	Answers
What trips do you usually make?	
What needs for travel do you have?	
What are your difficulties and limitations when traveling? Elaborate your answer!	
What help do you need or want when traveling? Elaborate your answer!	
What tools do you have and what good qualities and deficiencies do they have? Elaborate your answer!	

Table A11: Interview Questions asked by the test leader after the first ride (without tactile guidance).

Questions (after travel without the tactile communication tool)	Answers
How do you know that the vehicle has arrived / arrived? What is difficult? Elaborate your answer!	
How do you find the way to the vehicle? What is difficult? Elaborate your answer!	
How do you locate the vehicle at the pickup point? What is difficult? Elaborate your answer!	
How do you know it's the right vehicle? What is difficult? Elaborate your answer!	
How do you know if there are other people in the vehicle and where they are? What is difficult? Elaborate your answer!	
How do you know that the vehicle is on its way to the right destination and which road it intends to take? What is difficult? Elaborate your answer!	
How do you get information about disturbances / delays along the way? What is difficult? Elaborate your answer!	
How do you know that the destination has been reached? What is difficult? Elaborate your answer!	

How do you find your way from the vehicle to your final destination? What is difficult? Elaborate your answer!	

Table A12: Interview Questions asked by the test leader after the second ride (with tactile guidance).

Questions (after travel with the tactile communication tool)		Answers
How do you know that the vehicle has arrived / arrived? What is difficult? Elaborate your answer!		
How do you find the way to the vehicle? What is difficult? Elaborate your answer!		
How do you locate the vehicle at the pickup point? What is difficult? Elaborate your answer!		
How do you know it's the right vehicle? What is difficult? Elaborate your answer!		
How do you know if there are other people in the vehicle and where they are? What is difficult? Elaborate your answer!		
How do you know that the vehicle is on its way to the right destination and which road it intends to take? What is difficult? Elaborate your answer!		
How do you get information about disturbances / delays along the way? What is difficult? Elaborate your answer!		
How do you know that the destination has been reached? What is difficult? Elaborate your answer!		
How do you find your way from the vehicle to your final destination? What is difficult? Elaborate your answer!		
How much help do you need from the tactile communication tool when performing the current activity? **Elaborate your answer!**	**Not at all**	
	A little	
	Pretty Big	
	Very Large	

How much has communication aids helped you perceive the right command during the journey? **Elaborate your answer!**	**Not at all**	
	Somewhat	
	Pretty Much	
	Highly	
Is the communication aid easy to understand (Are the vibrations clear)? **Elaborate your answer!**	**Not at all**	
	Somewhat	
	Pretty Much	
	Highly	
Is the tactile communication aid easy to use? **Elaborate your answer!**	**Not at all**	
	Somewhat	
	Pretty Much	
	Highly	
Does communication aids feel reliable (don't miss, don't disconnect)? **Elaborate your answer!**	**Not at all reliable**	
	To some extent reliable	
	Pretty reliable	
	Highly reliable	
Will you want to use communication tools in other	**Not at all**	

activities? **Elaborate your answer!**	**Perhaps**	
	Probably	
	Surely	
Do you have any suggestions on how communication tools can be improved.		
How do you want new aids for self-driving cars to work? Elaborate your answer!		

Interview Transcripts

Table A13: Transcripts from the interview of the participants from the vibro-tactile field observation study.

Test Date	20190225	20190520	20190530	20190607	20190610	20190611	20190617	20190618
Background Data	IH	TV	RA	SS	ML	AH	AJ	MW
Birth Year	1983	1976	1977	1960	1992	1998	1986	1979
Sex (Male/Female/Other)	Other	Male	Male	Female	Female	Female	Male	Female
Type of Functional Impairment	Visually impairment, Completely blind	Blind	Visually impairment, completely blind	Dövblindhet, Usher syndrom Typ I	Deafblind, Usher typ 1	Deaf and severe vision impaired	Blind	Deaf-blind
Functional Impairment since Year	Birth	Birth	Birth	Birth	Birth	deaf from birth and we recognized that I am vision impaired in Sweden	Birth	Birth
Language (Speech, Sign Language, Tactile / Visual):	Speech	Computer: Braille, Speech. Other: Speech	Speech, Braille	Sign language, visual	Visually sign language, written Swedish	Sign language, Arabic, lip reading visually	Speech, Braille	Sign language
Personal assistant / companion, how many hours?	No	No, When signing documents: get help from people he knows	No	Personal assistant, 325 h per month. Right now I have no one and my husband helps me. It is difficult to find assistants who know sign language.	No	No	No, A companion for 5 hours in a week	No
Vision and Hearing Function								
a. Essentially normal vision and hearing								
b. Severe vision and hearing (Deafblind)				x	x	deaf + Severe hearing impaired		x
c. Severe hearing loss or completely deaf but essentially normal vision								
d. Severe visual impairment or completely blind but essentially normal hearing.	x	x	x				x	
e. Mild vision and / or Mild hearing function								
f. Known diagnosis of hearing / vision loss, etc.							Usher Type 1	
Description of the activity performed at the tests and the tactile aid used for guiding the subject:	Traveled private car from Poesigatan 23. below the stairs to the gym actic, Slottsgatan 17, parked at the disabled parking on nearest street, at the crossing olaigatan klostergatan.	Travelled in private car from Vastrabangatan 27 to University Hospital, Orebro, Ahuset, 1.6 km.	Traveled private car from Idrotsvägen 20, to Melleringe, approx. 4 km.	Traveled private car from Kyrkbacken 32C, Grängesberg to ICA Gränges (?) library close to Coop,	Travelled private car from Rudbeck to Östävägen 2		Travelled from subject's home at Kilsgatan 5B to Ostavagen 2; the participant sat at the back, it took 10 mins of travel. Participant needed help to find the car since it was parked at the parking lot 3 mins away from the participants front door.	Subjects home to Rastatuga
Initial interview (survey of travel habits and area of usual traveling for choice of route when testing)								
What trips do you usually make?	To the job, the gym, friends, Gothenburg, Stockholm, Stallet, Stan, the train station, the studio	Frequently: Express bus with friends (Fairchanst), Walk or go by bus, unfamiliar locations	Every where, to the work and around in the region.	My sambo drives me, to shop. We moved to here newly nad I have a nes assistant which I will use to take bus so my sambo can relax. Go to my daughter, Sambos douther who is living here. Go to Falun, Leksan and Hospital, eye clinic which is in Falun. Smedja backen, where there are nice shops, boat harbor. I go also to Kumla and Örebro by car. We took the train to Borlinge, Arlanda and flied to Oslo, Trondheim with my assistant. I wouldn't make it without assistant. It was a research project.	Its to ways to walk to my work. When I Vinrginska I have to take taxi because of many cross overs. I both walk and take färdtjänst. If I need to go to airport then I take the bus to the airport from Örebro.	Go by buss, walk. I can sit and stay on the buss. I can travel by train. I go to school, to riding school. Last year I was at Härnösand on DBU meeting. The purpose was to learn to go by train. I want to try and learn to travel by train or flight my self.	To the university, dad at Vingåoker, friend Erik at Katrinaholm, companion Garner.	I go to work, Shopping center, one or two times a year to the hospital, I drive car to buy grocerries from the super market. I also go to friends. I also go for Horse-riding.

What needs for travel do you have?	Do not understand the question	visit friends, go to healthacre facilities, specific shoppings, fetch packages	Via the work I travel to Karlskoga, Kumla, Hallsberg, Lekeberg, Nora and Lindesberg by färdtjänst. To visit the friends in Stockholm, Göteborg and Motala by train. At home city I walk to the town.	I cannot see so good and I need an assisten who can translate visually. I traveled to Barcelona with group of persons with deafblindness. I had two assistents who coul guid and interpret visually. It was very good. I would like to do more travels specially in Sweden. I have no good economi to do these travels. My husband works as assistent for me and can follow me.		I need to go to other sities. I am curies to see other culters and not be at the home all the time. To test different foods.	I go to Katrinahom and not any places, since fardtjanst is limited to the locality of Orebro. I need to change if I need to go any further and it costs me. I was in Nora for playing music at a restaurant last Friday (Fardtjanst). I go to Stockholm in trains. I meet my friends in Katrinaholm and Vingaoker. My sister in Orebro as well (fardtjanst).	I have to go to work, different activities, I work during evenings, since its dark, I need to go by car. I have to take my daughter to school, also my daughters riding school, also grocerry shopping.
What are your difficulties and limitations when traveling? Elaborate your answer!	Just go public transport. What is tricky is to find where I am going to for example the gym or where I have not been. If it is a place that usually goes then I find it. (Maria asks) Has anyone shown you the first time? Just like me. By training in the road. Then there may be things in the way for example excavator that digs in the middle of the road then I have to ask someone else to help me. (How do you know that something is in the way?) If it is blocked off then chase may pop in through the barrier. Most often, I find that it is scanty that is scary. I am attentive and careless but then I have to ask someone for help or take another road. If it is not a known place, then it is difficult. then I take the travel service or get shot by my partner. The orientation is difficult.	If he know where to go, the trip is not problematic. Problem starts when he doesn't know the way and the route. He asks help from others. Run into: Signs on the roads, people on the road, road works, alterations on the roads. Finding the bus: bus doesn't stop at the exact locations, always listen out for the bus.	If I go home the most difficult part is when the correct bus is arriving. From home to the work there is only one buss going which makes it easier to take the correct bus and travel. When I travel by train there might be changes in where the train departes from. It.s very short noties when you get notified when the changes is made.	If it is a new environment then I need an assistent o translate visually. I need to use my vision (blir spänt) and I get head ache. The assistent can tell me what there are around. I am dependent on an assistent to guide me. If I drop something I can not find it and an assistens has to help me to find it. If I will go out with my dog in the morning I can use my white can and it is ok. But other times and in in unkown environments I donot dare to go out because dangerous and crasy persons who cane hit me or rape me. I can not go long distnce with my dog I get tired and I have to peak up pee (bajs) and it becomes heavy.	If it happens something or there are a lot of people or if there is problem with trafik ligt, sign, I do not no which train I have to take and where I should sitt. The inform often late and I don find out at time the changes. If it is sunny, light than it is difficult to see the display. Train and buss is difficult because of the changes, light, a lot of people, no information,... Therefore I prefere taxi which takes me from point A to B. The cab i more time flexible than train and buss which don wait for me. If I stand and wait for the cab than the driver sees me looking aroun d and tells me that it has arrived but not buss or train.	In train or if I travel, because I have not going by my self I have to go by my mum and therefore havent learned to travel by my self. I have seen that other deaf people travel by themselves. I will do the same.	The taxi doesn't come in time. Sometimes the drivers are not swedish and they speak bad swedish, so difficult to understand them. Sometimes Fardtjanst can be delayed even for more than 40 mins, which is too much of a delay. I think fardtjanst have become really worse from earlier times, mainly because of the delays and drivers not being able to communicate in proper swedish. Sometimes they even ask me to direct them to the location, instead of searching at the navigation in their phone. One thing that is better is that we can pay now with card instead of cash.	I have to ask for help! When the taxi (fardjanst) comes, maybe its wrong or late. I have to wait a long time. If I go myself, new places are hard, especially if it is dark. In bus, difficult to find the place outside when it is dark, so don't know when to push the stop button. Dark everywhere. There should be street light everywhere so that we can see properly. It is dark inside the bus as well. Different busses have different lightings. If it is dark, difficult for me to see. Sometimes i use my phone torch to see the stop button on the bus if it is dark inside the bus. They turn on the lights only when the bus stops, then I realise that the stop has arrived and i need to rush and pick up my stuffs and hurry to get off. I cant get ready early since its dark and i cant see if we are arriving. Some of them turns on the light early, but not all.
What help do you need or want when traveling? Elaborate your answer!	Help with the above difficulties. I use a guide dog that makes it go faster. If there is some obstacle on the road then she stops and then barks, I find out on the way it is. GPS can do a lot. Just like when driving a car on a GPS. Now I have the gps app that doesn't work that well. However, it tells what is around. Should I go to the employment office and it starts talking about AF then I know that I am on the right track at least. Then it can be difficult to know where the door is, for example.	Seats booked: need help in finding the right seat from the driver or the co passengers. Help in knowing if they reached the destination.	It depends on where I´m going and if I go by train there might be some difficulties when I need to change the train.	I have my white can and I have to have it. I need my phone and my assistent. I can not do anything whithout my assistent. Today there are many stupid persons i the society and I dont dare go out. The assisten must know sign language, social hapti and must guide me.	MAYBE WHITE CANE AND. In Örebro I dont think that I need help. When I am in Stockholm than I use my white can so people sees me. The white stake is kind of giving information so people see that I am blind.	If I go by train or fly I dont know. Maybe an assisten or a person who can teach me.I will learn how to travel. I know nothing and will improve. I can do it anyway. The posibility is there. I friend of me who has bad balance and is visually impaired travels.	I need help if I have luggage and need to find a good place to put them, driver can guide me to the correct door of the car and also to the door of the destination. If I go to a house, or a restaurant, need help from the driver to guide me to the door.	I need Fardjanst to go to work. I need to ask for help help help. Fardjanst is good. Because they can wait. Busses have specific time, so they cant wait, they will hurry. A car/taxi is better. Because I can decide when to go, they adapt the timing as per my needs. Taxi takes different routes, by Fardjanst take the longest way and stops everywhere.
What tools do you have and what good qualities and deficiencies do they have? Elaborate your answer!	Blind square, Ledarhund, technic toe (if I do not lead the dog with me, do not touch the ground), white stick that marks for others and shows that I am blind, Computer with Braille display. Uses leader dog and then it goes faster. If it is an obstacle in the way then the dog stops and I find out what it is. GPS can do a lot of good in the same way you drive. Computer with point display. Iphone that is best tool and dog. Iphone has Voice over already installed so no hassle. The dog is alive as a partner. Blind square, an app that is GPS. Talk about what's nearby. The subject's home is	White cane, mobility cane: feel hinders or obstacles, others can see he is blind and will help without asking. Not a wide range. Only close proximity obstacles. GPS navigation: makes me more independent. They are not very accurate.	I use google map in my smart phone, white can, smart whatch to navigate when I go.	I have whithe can, cell phne, eye glasses, sun glasses which are also importent, the assistent, hearing aid which helps me a lite bit with sound. I hear that it is speech but not what they say. I can hear the dog (murrar, då är den arg och vaktar) då går jag och tittar vad det är. I use my cell phone to send sms, use messenger, facebook, look at the news, warnings (we deafblinds help each other)., Whatsapp, video translating where I cal to get translated.	Different type of apps, app for localtrafic in Örebro stockholm. They help med to know if it is delayed or if I have to change. There are apps like Skånetrafiken or Reseplaneraren... which tells me in detail,...... I use them together. It depends where I am. I find them very usefull.	I have my computer which can help you to visualise, soom it, write on it. I use the application zoom. I cann ot use zoom in my cell phone. White can. I have my cell phone and use it to have contact with my mother, and other persons. I use the map on the cell phone to find the way to go.	I have a white cane and smart phone (iPhone 8), Braille Display, Computer (Jaws: Screen Reader). Many apps: BlindSquare (GPS)	Yes, i use GPS in my phone. I dont use white cane, i have the Bell that vibrations, every deaf person uses that. Nothing else.

	added as a point in the map. That information is good because it helps me find a point for example my home that I have put in. it says directions, poesigatan 200 m at 9 o'clock, then it is a point. You know how you keep going, but it does not work in detail. The iPhone is good because it has Voice Over.							
Interviews after travel without the tactile communication tool	She sat behind for the test leader to say. Otherwise she would have been in front of the habit. If I had been alone, I would have asked the chaufen about where we are. Otherwise, I usually sit in front of habit. She finds her belt herself, no help is needed. Chaufören usually helps with the belt without asking what she doesn't like and feels humiliated.		He sat infront of the car with Hamid as driver and Parivash, Pournami behind. The camera was on dashbord					
How do you know that the vehicle has arrived / arrived? What is difficult? Elaborate your answer!	I hear the car / bus and if it is taxi driver / friend then they come out or weave the rhythm and say I am here. If the car / bus is standing there without giving notice becomes difficult	By using my ears. Engine sound. Car stopping sound. Then I approach the vehicle. Try to contact the driver or the driver contacts me to confirm its my vehicle.	The reason R could find the car is because PR was out side of the car and called on R The car is silent therefore it is difficult to know if it is PR or other one. It is common problem when there are heavy trafic and you dont no which car you will go. In the train station the noise from trains can mask other sounds and noises like information from speakers. The sound from trafic crossing can be masked and R doesnt know if it is red or green.	If it is an unknow environment then I do not know. If my husband will drive then I know. If there is a similar car then I do not know and I can take a wrong car. Therefore I don travel whithout assistent. I had a translator who said theat. I got information from the translator otherwise I had to ask you everything.	Sometimes it is difficult for example when they are many taxi cars. If I am at Virginska then I see that the taxis and ask if the taxi is mine. The driver doesnt come to me, I go and ask.	Yesterday we had text message. I wrote you and explained the adress. I didnt know. You come home to me and rang on the door, the lamp was blinking, I openede the door and it was you. I knew that you will come at 9 oclock.	Sometimes I can hear the engine/motor, and sometimes the driver gets out of the car and comes to me.	I know the time they should pick car up, I always lookout and look through the window or go out the door and check. It would be great to have a signal or something on my phone, so that I don't have to wait and check.
How do you find the way to the vehicle? What is difficult? Elaborate your answer!	If the bus stops further away then you tell the dog to search the door. If I go with the stick myself then I ask because I may not have time for the bus	Multiple vehicles: try my luck at all of them to find the right one. Feel the edge of the street with the cane, feel the metal of the vehicle without scratching.	R was specting that the car was on the short end of the building or on the other side of the street. The driver had the exact adress and was spected to stay there. R chanced and went the way where it common thar the cars stay and wait and it was corret.	I know Ithat the car was somewhere there. My husband usually park there. Today I had translator who could help me.The translator	Today, I followed you. I you had explained where you were staying I would look and come to you. I order the cars to an special place for examp,le come to this adress and stay at corner on the left. At virginska the is a Taxi Plol, Taxi stand where the taxuí stand. In stockholm There are Taxi pols.	I am living in Enrisvägen and I know where the cars park. I was obvius for me where the way to the car was.	If the vehicle is in front of the garden, I know the way from my home, if the vehicle is parked elsewhere, then I need help from the driver.	It depends on where or which environment. At home, easy and I know. New place, bit difficult, look out and also check for stairs. Depends on the environment
How do you locate the vehicle at the pickup point? What is difficult? Elaborate your answer!	If the bus stops further away then you tell the dog to search the door. If I go with the stick myself then I ask because I may not have time for the bus	Ask around and feel around. When driver doesn't know where I am standing, will try to find me. Sometimes the driver calls and ask or sometimes waits and sometimes even drives off.	PR guided R to the car. The pick up location was a parking and there were other cars which makes it difficult to find.	The translator informed me.	I see. It depends on where I am. If it is familiar place, it is easy to find. If it is unfamiliar place, I need to make some effort effort to look for it, If there is an address or description from the taxi driver, then I can find it. Otherwise I use map apps.	I knew where you had parked the car. If for exampel will go by a car and I knoe that it is gray and where it is parked than I see it and find it. If there where many cars, I can go close to them and go slowly and find them. The cars has number and I can check. I knew that you have a red car.	I listen and I can hear the sound of the fardtjanst cars motor sound and also the footsteps of the driver. If there are lot of cars, the driver helps me.	If its at my working place or home, there is only one car coming, its easy. New place or other crowded place, it is difficult. I use my phone and text to check with the driver and ask if its her car. Sometimes there are delays and I need to know if I was late, or if the car already left.
How do you know it's the right vehicle? What is difficult? Elaborate your answer!	It's just question. It has happened that I have jerked the wrong car. It is the chaufa that helps me.	Ask the driver, or wait for the driver to confirm.	Someone has to inform.	The translator informed me. Otherwise I would have no chance to find the car. If I had no translator than I have to sta and wait to someone who can help me to find the correct car.	I go and ask the driver. It can be difficult if it is dark and I donot know If it is a provate car or Taxi. Taxis har often a sign. I can see that the train comes, bus comes. I know the time they srrive. I look at the time table. I can look at the people and follow them. If I am in another country of course it is difficult. When people are standing, I do no know if the train or bus has come or left. To communicate I use my cell phone. I write the text and sho them or I point with body language and use body language.	I know where your red car is and I just go and sitt on it.	Sometimes it is difficult, then the driver comes out and says my name, then I know its my car.	I show the driver my phone and ask him if its my car and then I sit down. Yes, I see the car. Only thing is to find which one is my car and then I ask them.

Question	Answer 1	Answer 2	Answer 3	Answer 4	Answer 5	Answer 6	Answer 7	Answer 8
How do you know if there are other people in the vehicle and where they are? What is difficult? Elaborate your answer!	If I open the front door then I see, On the bus I know the backrest, do not touch the people but feel on the shoulder. In a bus, it is important to know where a vacant place is or a standing place where there is no vacancy.	Politely. Sometimes driver assigns a seat. Tentatively feel and sit. Mostly driver assigns. I don't have any preference.	Some times I know because people are talking. Other wise I need to ask some one if there as free sits. Most of the time I stand in the bus and when it stops in front of the school the bus becomes empty and I can find free sit. I have to ask.	The translater is translating all the time visually and informing me about people, where they are and what they do.	If there is good lighting, I can see through the window some shadows and can guess if there are any one inside. At night, it is difficult to see, unless there is a strong light inside the car.	I could be my mother or my brother. Today I knew that you two are in the car and the interpreter is in the car. I saw you.	Always the driver says, there is one person on the back side, so the driver asks if he wants to sits in the front or beside the co-passenger.	I can see them, I can see if there are other people on the car. If it is darker shaded window, it is difficult, then I need to open the door and see.
How do you know that the vehicle is on its way to the right destination and which road it intends to take? What is difficult? Elaborate your answer!	Communication. On a bus if the speaker exclamation works then I can sit and watch facebook or stuff with the phone. If the loudspeaker call does not work, I sit completely tense.	Driver usually asks and confirms the location given to them on the system. Driver usually tells them about each passengers destinations when its shared cab. They announces the next drop off is.	That is interesting. Today I gave the direction and could easily follow the route because it is the route that I take often. Othervisw I use accessable application on my phone which tells me for instance which street I am now.	When the driver asked me where we should go. The translateor said to me and I could say that we will go to library and what way he should take. I asked the translator where we were and because I knew the environment when he drive wrong I asked the translator where we were and then said that he has to turn around. I felt that he drive wrong. When we come to the cross I felt that it was wrong. It is the same when I go by färdtjänst. It is not nice to go wrong. I have stop them.	Sometimes I use the map to see where I am going and if I reached or not, especially if it dark outside and if I am unsure about the route. If there is good lighting, I can see and recognize the location.	I trust to the driver. If you drive wrong than you think you will go back again. If I know you than it is no danger, but there is an unknown person it can be dangerous. If I need some an unknown person I dont go with them bu I learn them and Go with them. I look at the road. I have been traveling there many times. I see if ther turn on left or right I can see. If the car goes quicly to pass the car que then I know.	I use my GPS Blind Square on my phone, so I can see if they are on the right route. Google Maps as well. I use navigation for all kinds of travels, train, bus and all. Google settings can be changed to tell me when I have reached the destination, they can be changed to even tell me about Supermarkets, parks, restaurants, streets. All as per my need.	I can see the road and the way we are riding. I can see through the window. If I know the way, I can recognize. I just have to trust the driver of it's a new place. Just like everyone else, I can see. Difficult is if its an unknown location. Sometimes I dont know if i have got off at the right entrance of any big buildings.
How do you get information about disturbances / delays along the way? What is difficult? Elaborate your answer!	From the chaufen. Is it big saying the one you go with or the chauffer says.	Ride is too long, checks with the driver about the locations.	I have to rely on my application on the phone and find the alternatiove routs. It there are any constractions and the route is changed then it makes it difficult.	The translator informed that the translator drive to fron and I told him to turn around. The translator use to say everything. I ask them what do you see, tell me. If there is something unusual then I ask the translator to describe or they can say that.	It is difficult if it is fardtjanst, driver doesn't say much since they can't sign language. And they can't write on their phones as they are driving. I notice when it takes longer time. The driver tries to use gestures to help me understand or share the information.	If there are buldings, car tracks than I see and know that it can be delayed. I have experienced it for several times.	I don't get any. The driver tells me if there is any. Sometimes they get angry because of the problem and they tell me or I even ask them.	I don't. That's really bad bcoz fardjanst doesn't inform if they are delayed. They can't communicate with me, hope they can do some small sign language. If I am with friends, I can contact with them and they can tell me why we are delayed. But with drivers, hard to communicate. If i can see on the roads, why there is a delay. That is enough for me to see why the delay. If it is dark, cant see, then i need to patiently wait.
How do you know that the destination has been reached? What is difficult? Elaborate your answer!	In a car, the car says the car. If it only stops, you ask if you are there. In a bus that does not have a working loudspeaker call then it is tricky. It has happened that I have missed to get off.	The driver signals about the destination. Ask with the fellow passengers. Sometimes just have a guts feeling and get off.	Since it is destinaction that I have traveled at least the last two years, I know. Other visw I need to use google maps to get some sort of information or I have to ask the driver what is around me. The answer to the question is thart I ask the driver.	I had to ask the translator if there was any sign of the library and then I knew that we were in right destination. The car stopped and the motor stopped. Old cars are easy to feel their motors are easy to sense. The new cars are to silent and diffucult to sense. If there are several stops as in bus then the assistent tells me not go down and wait untill next stop.	If there is light and if I know the area, it is easy for me to see and recognize. At night, if it is still an area I know, I can reognize. Otherwise, I usually check the map to confirm. I use google map or apple's imap.	In Brickebacken, or if I go to the castle I can see the library and buss stops. I can see where I am. I could see that you stopped over there and other persons, interpreter go of and I go of too.	Often the driver informs me. When I hear that the cars engine is stopped I can understand that the car is stopped. But the fardtjanst drivers never do that or it can be confusing because sometimes they stop the engine if there is a long queue on the traffic signals.	I can see, so I know we have arrived.

How do you find your way from the vehicle to your final destination? What is difficult? Elaborate your answer!	If the car / bus stops where it is then it is easy. Once, the bus had stopped earlier because of the rocky road and the chauffeur informed about it. Had he not said so, I would have thought I was in the wrong place.	Cicking noise at the entrance. Echo sound from the cane. Cane shows the hindrances. Search for the door handle and follow the wall. If wrong, go backwards, and try to find the right way.	This time it was easy because there was a guiding noise. Otherwise I am depended on some assistent from the driver.	The translator guided me. Whothout translator it is not possible. There may be other cars, children who are runing to their mum and I can not see them so that I can wait untill the can pass. The translator said that there was another car going out, back which I couldnt see. I could not see it and may be ran over.		Today we go to wrong entrence and I saw that, then somebody told us and We go to the correct entrence. If it is known than I find by my selv. Otherwise I get help. Here in Örebro I know only half of the places. If I know the adress then I look and find. I try to learn the places in the Örebro. If I will go to a church where I have never been. My teacher sends me the adress and I use the google map to find the adress. If I have been there and know the adress than I do not use my cell phone again.	The driver usually guides me to the door of the destination. They have to lead me, its part of their job description. So, they do it all the time for me.	It depends on the light, daytime I can see. If its dark and if its new place, it is difficult. I look around and try to find the right way. Tollanskoolen? If drivers are confused about which door to drop for buildings with multiple entrances, I have to tell them which door they have to drop me off. For people with severe eyesight this could be a huge problem.
Interviews after traveling with tactile communication aid								
How do you know that the vehicle has arrived / arrived? What is difficult? Elaborate your answer!	Feel the vibrations. Two vibes vibrated simultaneously.	I didn't hear the vehicle arrive, since we were inside the building. Due to the vibration, I came to know that the vehicle has arrived.	The test leader send signals via the vibrators, both vibrating long vibrations at the same time.	I got two long vibrations pulses on left aothing was difficult. I was just unused to the tactile aid. I felt me as a robot and had to follow the signals.	I got the vibrating signal. Someone informed me using the signals.	It was different vibrations to the left, right, start. It was an vibration and you had told me when to stop, go right or the left. There were log vibations from both of vibrators meaing that the car has arrived.	Because I received the vibration signal where both the vibrators gave long signals. So i knew that it was for the arrival of the vehicle	I got a signal that the vehicle was here. 2 long signals
How do you find the way to the vehicle? What is difficult? Elaborate your answer!	Was guided via the vibrations, Right, left.	Quick and painless navigation using the left and right codes, reach the car without any problem.	The test leader send signales via the vibrators,to turn to the left or to the right.	I felt in the vibrations, When it vibrated at left I knew that I have to go to left side. It told me what side I have to go. I was guided via vibrations. When I was close to the car it vibrated that I have arrived.	Using the vibrations	You did some vibrations to me, left, right then I found your car.	I got the vibrations for left and right signals and I was led to the door of the vehicle using the aid.	It wasn't much difficult. Could imagine it would be difficult if it was dark. I follow the directions left and right.
How do you locate the vehicle at the pickup point? What is difficult? Elaborate your answer!	Was guided. The stick helped find the car.	Using the same navigation guidance, vibrations, felt it with the cane.	I heard that the vehicle was parked in front of me. I would need a signal to stop if there were other vehicles at the same place.	I was guided via vibrations. It was strange feelings. Yiu have to use and get used stepvise.	Using the vibrations. If the car is close to me, then it is easy to find. If there are many cars near me, it is difficult to find and I don't know. This time the car was closer and the vibrations was signalling. So I knew	I knew. I saw your red car at the pick up point.	I could hear the car, even if the engine was turned off? Its hard to explain, can hear the sound of the car wall using the white cane. The vibrations also guided me to the car.	I can see. I looked around and saw there was the car. Now I knew, so I could see it.
How do you know it's the right vehicle? What is difficult? Elaborate your answer!	Taken on the guidance, you might have a signal that informs you that it is the right car.	I didn't ask or anything. Since the vibrations guided me to that vehicle, I assumed that was the right vehicle.	I was guided by the test leader to the right car. If there were several other vehicles, it would be more dependent on the guiding.	I was guided via vibrations until the car. When I was beside the car I recognised it. If I had a blindfolder I wouldnt be able to recognize it.	I have already answered. Using the vibrations.	I know you have a red car and knew where it was parked there. You were guiding me to the car and I saw it.	I need the guidance to find the car. I wont be able to find it without the help, the guidance helped me	The signal told me where to go and then I arrived at the vehicle.
How do you know if there are other people in the vehicle and where they are? What is difficult? Elaborate your answer!	There I had no help from the aid. I just stepped in and sat down. There you have more benefit from human or dog.	That wasn't something I didn't think about. I just assumed it was the right door, vibration told me to go left and stopped when I reached the door handle. Gave the hint that I should take that seat/door.	I was sitting in the front where it was empity. If the fron seat was occupied I needed guidence to a free seat.	I feel the smell. If the car had roof it would smell more. It was light and I could look so that there were no other persons. If it was dark and would sense with my hands.	It was difficult to see since the window was not transparent. It was difficult to know via the signals, if I had to sit in the front or back of the car. It is easier for left and reft signals.	We did went with same car before I knew that. When I going by buss and all sits are busy I stand. If there is an empty chair than I sit there.	I wouldn't know if no one said anything. I just took the seat where the door was. First I got confused and was about to sit on the driver seat and was guided to the back seat. If no one says anything I sense the seats with my hands.	For me, I can see. I open the door and saw it empty and I sit down
How do you know that the vehicle is on its way to the right destination and which road it intends to take? What is difficult? Elaborate your answer!	Now you called out the intersections, which is important.	Don't care about the route, I assumed we were on the right track.	It was a familier route for me ' and I have memorised the stops, turns, therefore there was no need to use the application EYE-D which I usually use to identify where I am going.	I se a litle bit. If I have interpreter I can ask. I have good locale position sense and know where I am. If I talk to someone than I can loose the position.	I trusted the vehicle. We had agreed to where to go. And when we arrived and there was light, so I could see that the destination was correct. At the end of the journey, I used the map to quickly check the location. When I saw the bus station, I knew that we were near to the destination.	If I am going to the library I know the way and can see if it drives wrong way. I knew the way to the library and I know the different roads leading to the library.	I trust it to the driver and wouldn't think that she would kidnap me. I knew the driver today, so I wasnt worried. The vibrations helped me to know the right and left. If I knew the way 100%, I would recognize the route with the directions given by the vibrations.	I got signals from the aid about turning left and right. When we were getting closer to my area, I recognised that we are on the right way. Then I realised that we were taking detours as well. I could see it.
How do you get information about disturbances/delays along the way? What is difficult? Elaborate your answer!	When driving on GPS, it tells and redirects. When that should be done.	I didn't care that much for any disturbances or traffic waits, felt like we werent at home, assumptions	There were no disturbences in the rout. If there was some disturbencies I would need information about what has happened which is important to med to find out. It is important to get information about what is going on the road. The	If there are staircases I can not see them. The interpreter tells me.	It was via signals, when the car stopped at the signals and all I was given vibrations.	If it is delayed, car que, a lot of people in the way, some problem, accident, bulding then I know that. If there are a car in front of me and they are informing in the radio than I dont know. May be in future the can find a new way, for example they can	I got information about the red light, waiting at car lanes from the vibrations.	Yeah, it was a disturbance when we had a speed trouble, but I didn't get any signal from the aid, but it was okay for me. Since I can see, then I informed you about the missed turn.

	R1	R2	R3	R4	R5	R6	R7	R8
			information makes me accept the situation easier.			have a display in the car with text information or sign language informing what has ahppened.		
How do you know that the destination has been reached? What is difficult? Elaborate your answer!	You said through vibrations.	Through the vibration (long) signal, vibration gave a signal to go ahead, move out of the vehicle.	When we reached the street where I live, it became easy to feel how the road was going and I could fell the speed obstacle close to the parking.	the were vibrations informing me that the destination was reached (two long vibrations on left and right side)	Via signals.	We just drov. Today we drove to my home, other we drive to school. I can see where I am. I felt also vibrations, both vibrators vibrated long.	We parked a bit far from the destination, the car stopped and I got the vibrations and also the engine stopped. So I knew we reached. I expected the car to stop at the garage, but the car stopped at the parking area.	The signals told me that the car has arrived. And also I could see that we have arrived.
How do you find your way from the vehicle to your final destination? What is difficult? Elaborate your answer!	The car stopped where it was and I knew where I was. If the car stops further away then you have to get information.	I actually felt at home and felt the stretch of grass that felt home, vibrations confirmed the route or the correct path for me.	The car was parked on the opposit side of the street and I knew that therefore I could find home. Othervise I needed guidence.	I can see and got help from the vibrations. I just followed the vibrations.	With help from the vibrations: left and right guiding signals.	From the parking to my home, I live here and I know the way. You parked there and I knew where to go. I got also help from the vibrations. Anyway I knew the way to home.	The vibrations guided me to the way to my home door, with right and left signals of the vibrations.	I know the place and the aid also gave me signals
How much help do you need from the tactile communication tool when performing the current activity?								
Not at all						x		
A little	x	x	x	x			x	x
Pretty Big								
Very Large					x			
Elaborate your answer!		I didn't need much guidance. Had it been a different setting or a different location or maybe during winter time (difference between ground and grass is not evident). It would have been off much greater help.	I was in familier surrounding where I am almost every day.	If I see than litle help if I dont see than very large.	I will get to know Where I am, whats going on, while focusing on my phone. Since my hands were free, I could do other things on my phone while the vibrations gave me information about the travel.	I can see the way. When I was sitting in the car I could see the way and I had no need on the vibrations.	I couldn't find the way from the car to the home door, so I needed this guidance.	Since I can see, it will be a little use for me. I can use my eyesight for most of the things. Everything is different for me if it is dark outside. I will need more guidance during dark.
How much has communication aids helped you perceive the right command during the journey?								
Not at all								
Somewhat				x				x
Pretty Much					x			
Highly	x	x	x			x	x	
Elaborate your answer!		High degree understandable. One command for the cars arrival and when I should exit, there were 2 commands, one command to get moving is enough.		If I see than litle help if I dont see than very large.	Because it was my first time and I had learned those commands in short time.	I already knew and can see, I did not need this aid. But I really want to go by car in the feature.	I got good help from them.	Since it was during the daytime.
Is the communication aid easy to understand (Are the vibrations clear)?								
Not at all								
Somewhat								
Pretty Much					x			x
Highly	x	x	x	x		x	x	
Elaborate your answer!	They are easy to feel.	No problem detecting the vibrations			Simple and easy and small		It was easy to understand the vibrations, especially when there were 2. It would be difficult if it was 4 or more.	
Is the tactile communication aid easy to use?								
Not at all								
Somewhat								
Pretty Much					x		x	
Highly	x	x	x	x		x		x
Elaborate your answer!		None at all	Simpler to use, more user friendly.	I could underständ the information only after 15-20 minutes training.	Simple and easy and small			Very easy
Does communication aids feel reliable (don't miss, don't disconnect)?								
Not at all reliable								
To some extent reliable	x							
Pretty reliable				x	x	x	x	x
Highly reliable		x	x					
Elaborate your answer!	The trip was short and can't say much.	No glitches, nothing he felt		In the staircases which I could not see. There was a lock to the well and I had to go around it. I could not get help for	Sometimes I forget that I am carrying it, when it is vibrating, I became aware and I may miss out the command by the time I focus on the vibration.		I trust the aids, but not 100%, because now it depends on the person/computer guiding also. So, I can't rely 100% and it	Some commands were missing. But it was okay.

					that. It worked all the time.			specially depends on who is guiding me.
Will you want to use communication tools in other activities ,?								
Not at all								
Perhaps	x	x						x
Probably			x	x				
Surely					x	x	x	
Elaborate your answer!		maybe during mobility training, its more talk oriented, they describe everything via speech. During later stage, you might want to consider using this.	It can be good to use in combination with other accessible aids like phone applican. Instead of listening to how to go using GPS, I would like to use Ready-Move and get the information directly in the hand. When it is hogh trafic the noise from trafic can make it difficult to yo to listen to gps instructions. I will use my hearing to hear other things in the surrounding. I need my hearing to use it to find out what is going on and not just to listen to instructions from GPS.	Persons who have an active free time may can use it in the activities. For one sitting at home all the time can not use it so much.	I think this can be used for many other innovative things like Travelling in trains, walking. While walking this can help in locating hurdles or things passing near me.		For example while riding horses, go karting (a person sitting behind can guide me).	If I need it on other activities, I would use it. Maybe when I horese-ride. Maybe at work. I don't know really. Maybe while walking.
Do you have any suggestions on how communication tools can be improved.	It must be complementary to other things. Should be a speech function that communicates with me. Communication is not detailed and must be supplemented. If I use Ready-Move and it says stop. Then I want to know why.	Well it was good and simple.	It is good as it is. It would be a good idea if the same possibilities were for cross plattform.	No. I am not updated when about aids. I saw there are taxi cars without any drivers. Persons with blindness can sit in the car and give order where they will go. You can collaborat with them	It would be great to get information about things happening inside and outside the vehicle. I am I would also like to know about traffic jams, if the vehicle is stopped at these signals and if the driver is bringing more passengers.	I think it works very well with horse riding.	those wireless ones are the best when compared to Ready-Ride. They are easy to use.	Maybe need a signal to let me know if there is any hindrance in front of me. Like when I have reached the door of the car.
How do you want new aids for self-driving cars to work? Elaborate your answer!	There should be speech function that communicates with me and that I should be able to set up how detailed information I want. I want to be able to choose what I need for information. I want to know every cross or not. I think if it is self-sufficient how does the car know where to go? I have to be able to communicate and say that now I want to slottsgatan 17. I may want to stay in the middle of the road and buy protein drink and then I have to be able to control the itinerary to the extent I need.	It's a complimentary. To be able to communicate with the car using voice. This is more useful when people can't hear. Being blind, I prefer more of speech and voice.	There should be a functioning system that informed when the right vehicle has arrived and it should also notify where there are empty seats. All information should be accessable to any one, tactually for persons with blindness or deafblindness specially information about the security and skape routes.	I will write the adress to the destination so they can drive me there. It would be a dream to not be dependent on the assistent. I am thinking, from my door, in some way I have to contact the car and I can be guided by the vibrations so I can also take with me my dog to go and shop. I will be available to do all without any help from my assistent. I would be more independent and feel free. I will go and cut my dog, buy flowers without any help from someone.		I want self driving cars of course. I want to have a stron lamp in the car both at the exit and in the back sit and I need also a bright display so I can read it. I want a display with sign language or text to tell me what the hearing people say.	The cars should have sensors which can easily synchronize with the wrist band on my hands, so that the car can guide me to or from the destination. They should be constructed with a system comfortable for ready-move.	Its really difficult. Maybe they should be connected to the cell phone somehow. Some type of communication, connected to some kind of agency to let me know that if am going the wrong way or someone to turn to. There must be some kind of button to make sure that i can communicate in case the car is going in the wrong way or something. More spontaneous thing to change the route if i can. Like going shopping in between. Maybe i pass by a shop and i want to go back. Some way to communicate with the car's computer somehow.

Figure A5: Set of pictures from the AD guidance study