CHALMERS
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Designing an accessible indoor navigation application

Guidelines of how to apply universal design when designing an indoor navigation application to help users with wayfinding

Master's thesis in Interaction Design and Technology

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Gothenburg, Sweden 2021

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Cover: Illustration of a person using a wayfinding application standing outside the main entrance of a hospital.

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Abstract

Navigating within large buildings, such as a hospital, can be stressful and time-consuming, leading to a bad user experience, causing anxiety and frustration due to missed appointments. Therefore, applications for indoor navigation have recently been catching attention. In the designing of a wayfinding system for a hospital environment it is important that the application is easy to use, effective, accessible, and intuitive as the ambition is to simplify the wayfinding to allow the user to access information and help individual navigation. This thesis explores how to develop an accessible design supporting wayfinding within a complex environment, such as a hospital. With the purpose to investigate how an indoor wayfinding application can be designed to be accessible, with all users in mind, with the aim to fill the gap of the existing research regarding this subject.

To attempt this, a pre-study was conducted to research previous literature within the subject of accessible and universal design, and by designing and testing an indoor navigation application for Danderyds hospital with users, with and without disabilities. Through an iterative design process, the application explored key factors and solutions to support for indoor navigation. The conducted usability testings involved both remote asynchronous and synchronous usability testing online, and synchronous usability testing on smartphones. The outcome of this thesis resulted in nine guidelines of how to design for an indoor navigation application with a universal design approach.

Keywords: accessibility, universal design, inclusive design, indoor navigation, graphical user interface, complex environments, interaction design, usability test, prototyping.

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Linnea Palmgren Söderström & Molly Zelmerlöw Sigander, Gothenburg, May 2021

Contents

List of Figures

List of Tables

1

Introduction

The growth of digital technology creates new opportunities of how to interact with the physical environment. As digital devices such as smartphones, tablets and others have become more popular it has helped to improve how people interact and exchange information (De Lima Salgado & Freire, 2014). Mobile applications can serve as a bridge between the digital and physical world, to help optimize the real-life experience. Applications for indoor navigation have recently been catching attention (Diakité & Zlatanova, 2018), optimizing the real-life experience with the possibility to individually navigate within buildings. Navigating within a large building, such as a hospital, can be stressful and time-consuming (Marshall, 2017) leading to a bad user experience, causing anxiety and frustration due to missed appointments or stress (Hughes, Pinchin, Brown & Shaw, 2015). Therefore, in the designing of a wayfinding system for a hospital environments it is important that the application is easy to use, effective, accessible, and intuitive as the ambition is to simplify the wayfinding to allow the user to access information and help to individual navigation (Harper, Duke, Crosser, Avera & Jefferies, 2020).

To design a seamless user interaction for indoor wayfinding systems that is invariable regarding who the user is and that will not cause stress, anxiety or frustration, is a challenge. To be able to individually navigate within a new building it is of importance that the indoor navigation application involves a graphical interface that supports an enjoyable user experience without any barriers, despite language, age or disability. Universal design is an approach in design that incorporates products or systems, as extensively as possible, that can be used by everyone (Lenker, Nasarwanji, Paquet & Feathers, 2009), regardless of age or ability, and without any need for adaptation (Silva, 2011). To make an application that is designed for everyone also makes it accessible for everyone (O'Briant, 1999).

1.1 Project background

This master thesis is in collaboration with Locum AB, a Stockholm based company that manages, builds and develops healthcare properties for Region Stockholm. Locum strives to provide an attractive and sustainable healthcare environment through commitment and innovation and has begun to explore the possibilities of developing an application to help visitors navigate within the hospital environment, as well as their way to the hospital. Locum has observed that hospital visitors struggle with navigating within the hospital to find the right department or destination. Therefore, Locum intends with a pilot project to investigate the possibilities to help visitors to easier find their way and navigate to their booked appointments at the hospital, with the use of a wayfinding application. This project is named “Lätt att hitta rätt” and the application that will be developed in this thesis will therefore be referred to as “Easy Wayfinding”. To help with the present project Locum has hired Axel Health, a company that specializes in developing human technology for healthcare and provides tools for managing patient flows, to support the development of the application. This thesis project will help and assist Locum and Axel Health with the user experience design by investigating, discovering, designing, and testing an application for indoor navigation and wayfinding within the hospital environment, between buildings and outdoor transportation.

To develop an indoor navigation application that will be functional and usable at Danderyds hospital, Axel Health decided to use the system provided by MapsIndoors as the foundation for the maps and the navigation system. Since MapsIndoors provides a solution that can be integrated with the hospital’s floor plan, and provide a seamless transition to Google Maps outdoors (MapsPeople, n.d.) it was chosen by Axel Health as a proper fit for this project. Further, an additional prototype called Easy Wayfinding will be designed by us, the researchers, that will serve as a future option for the applications interface where the approach is to design an universal interface that is accessible for all users. The ambition is to combine user research for both the MapsIndoors design and the new interface of the Easy Wayfinding prototype to investigate the best solution for a universal design for indoor navigation in hospital environments. This will be done by evaluating the interface of MapsIndoors and designing for a future implementation of the interface of the Easy Wayfinding design. The planned result of the application for this project will be either a native application or a web based solution for a mobile device that provides navigation guidance based on a preset starting point from the user’s position to their booked appointment at the hospital. This is planned to be done by either the user opening the application with help of a QR code, provided in the invitation for the booked appointment at the hospital or through a link sent in a text message to the patient.

The purpose of this project is to design an application with a universal design approach that is accessible for all users, regardless of disability, age or language. As Marshall (2017) states, it has been discovered that healthcare facilities often are intimidating and overwhelming and that directional signage is insufficient for visitors in order to find their destination. Signage generally includes unfamiliar terminology which makes it ineffective and causes confusion. For a wayfinder to get lost when navigating within a hospital is often caused by a poor design, and not the person. Therefore, it is important that, when in the process of designing a wayfinding system for hospitals, focus should be on the impact of the users on one hand, and the hospital on the other. When a user can navigate and understand the environment it provides a feeling of natural movement due to the good design. With a poor design, it can be costly for the hospital due to lost staff time and also patients leaving as a result of bad user experience (Morag & Pintelon, 2021). Therefore, this project strives to design a graphical interface for an indoor wayfinding application for a hospital environment, with an interaction based on universal design and usability testing, that hopefully will create a pleasant user experience for all users. The purpose is to investigate and examine what design solutions are important and what functionalities should be implemented in the design to make it as accessible as possible.

1.2 Research Problem

As the digital wayfinding system increases, there are still issues yet to be addressed, such as the system's ability to support people with disabilities (Marshall, 2017; Morag & Pintelon, 2021). Previous research exists on universal design, of how products should be designed to suit everyone regardless of disability or not (Singh & Tandon, 2018), and further research examines wayfinding for specific types of users with different disabilities (Huang, 2018). However, there is a gap in the research of how to combine these and design a wayfinding system that supports all users. The use of a universal design approach helps to develop products that are beneficial for everyone in a society, and facilitates the use for all users, and not only for individuals with disabilities. There are some well known applications for outside navigation, which has had a major impact on wayfinding. However, outside navigation profoundly differs from indoor navigation, as for example, an indoor navigation must operate navigation of different floors and efficiently communicate this to the user. This project aims to investigate how an indoor wayfinding application can be developed to be as accessible as possible, with all users in mind, with the purpose to fill the gap in the existing research, and develop an application that can help visitors navigate when arriving at a new location where assistance and guidance are needed. For this project the application will be developed for Danderyds hospital in Stockholm.

1.2.1 Research Question

The objective for this project is to gather information on how people with different types of disabilities handle digital applications and their specific needs, requirements and desires, to compile these to create and design an accessible product for indoor wayfinding. This will be investigated with the research question stated below:

What design solutions are important to consider when designing a universal accessible application for indoor wayfinding?

1.3 Constraints

Since this master thesis was collaborating with a pilot project that was developing a prototype of a wayfinding application there were some existing and possible constraints within the project. Something that needed to be addressed quite early in the process was trying to include a broad variety of disabilities as possible, and to balance several aspects regarding availability, and to have them working together in one application. It could be argued that separate applications supporting specific types of disabilities would offer the best solutions in order to support the users needs. However, for this project only one application was developed, with the aim to support as many types of disabilities as possible. To succeed in this, a lot of focus was addressed on performing user tests and continuously having dialogues with a focus group and including them throughout the design process. Thus, it was not possible to implement all desires and requests provided by the users of the project, and some features had to be disregarded. However, all desires and findings of this project will be considered for future improvements of the application, which was clearly communicated to all participants involved in the project.

Another limitation regarding the scope of this project that had to be addressed was the area of navigation. This project was limited in the number of functions to implement in order to test different features and settings on a small scale, to then develop it further when a working prototype was created. The aim for the final product beyond this project was for the application to provide visitors with wayfinding guidance within and between buildings, as well as navigational guidance to the hospital. However, the scope of the application created for this project was much smaller, and was limited to three pre-selected routes at Danderyds Hospital.

Furthermore, an additional limitation for the pilot project was trying to develop a digital solution for indoor wayfinding, as positioning is an important part of navigational applications, but the problem arises where GPS signals can not be used inside a building as it can not provide a sufficiently accurate positioning. This is a rather new area of research that does not have a conventional solution and there are many different ways with various technologies to provide for indoor positioning. However, all solutions require a network involving digital devices to be installed in the physical environment within the buildings, where these devices support different methods to calculate the position of the user. To do this, these devices require access to data provided by the operational system of the device running the application, and therefore, an installed application must be used and not a web application since this does not allow access to the required data. Another concern about the application providing for positioning was the budget of this project. An accurate positioning requires these devices to be installed in the environment which is expensive and could therefore result in the solution providing for positioning becomes too costly to implement in the pilot project.

1.4 Ethical issues

This project does not approach all different disabilities as it was not possible to investigate or involve all different types for this project. The specific traits for the target disabilities for this project was based on literature about the disabilities along with feedback from the user testings. However, results based on this study claims to create guidelines to support universal design, even if users in this study only refer to a small part of all types of disabilities. This project has made a generalization of these disabilities with awareness that it does not reflect or regard everyone living with these specific disabilities, and that disabilities can vary between individuals and therefore be experienced differently.

Designing a digital application for wayfinding to be used during navigation requires the user to have a portable device to run the application on. To use this product as intended, the user also needs to carry out some steps such as opening the application provided in a link assigned by a text message and approving location sharing, which requires technical knowledge. Elderly people or users with cognitive disabilities might not know how to perform theses tasks in order to access the navigational descriptions and therefore can not use the application. Also, there are people in the society who do not use a smartphone at all, where this application will exclude these people from the design completely.

During the time of this thesis with the ongoing COVID-19 pandemic almost all interviews and user tests were done remotely and therefore there was no risk of infection that could be caused by this project. A few usability tests were conducted in a synchronous setting, but these were performed with near friends and family and during controlled circumstances, with no risk of spreading the virus. Therefore, this project did not violate restrictions and regulations due to the Coronavirus.

During usability testing screen and audio recordings were collected where all data is anonymous, and no personal data was recorded. In the analysis it was not possible to deduce any information to a specific participant. Only us, the researchers for this project, have had access to the data. When the project is completed, and the thesis is approved, all data will be deleted. This will be at the latest in December 2021.

1.5 Stakeholders

Locum AB – One of the main stakeholders for this master thesis was Locum, which is a company that manages, builds and develops healthcare properties for the Stockholm Region. This thesis was a part of the project “Lätt att hitta rätt”, with the aim to create an application for wayfinding within hospital environments. Our expertise of user experience design was requested to help evaluate the application, understand the end users requirements and to help design a user interface that was accessible to all users.

Chalmers University of Technology – The other main stakeholder was Chalmers University of Technology where the students conduct this research. They conduct research and provide education in technology and natural science, and promote knowledge and technical solutions for a sustainable world.

Axel Health – Locum performed this project in collaboration with Axel health, a company that specifies on developing human technology for healthcare. Axel Health was hired to manage this project and develop the application led by Locum.

Healthcare properties – Locum manages several healthcare properties in the Stockholm Region and provides their service to some of Sweden's biggest hospitals; Danderyd Hospital, Södersjukhuset, Karolinska university hospital, etcetera. In this specific project the application was developed and designed for Danderyd Hospital.

End users – The main target group and the end users for this project were hospital visitors and patients. Everyone is a potential hospital user and therefore, the aim was to design the application based on universal design.

Linnea Palmgren Söderström & Molly Zelmerlöw Sigander – The two interaction design students at Chalmers University conducting this master's thesis. The purpose with this thesis was to contribute to research within the field of interaction design by gaining knowledge of universal design and using this in designing a high-fidelity application for navigation.

2
Theory & Background

In this chapter the theoretical background for this project will be covered, such as frameworks, and relevant concepts. Included in this chapter is digital design, universal design and designing for disabilities. The material presented in this chapter will be the foundation for the work in the design process.

2.1 Digital Design

Cooper, Reimann, Cronin and Noessel (2014) state that digital products should be designed in order for users to use them and easily achieve their goals, to be efficient, satisfied and happy. Approaching a human-oriented design means designing with the user in focus. This involves understanding the user's needs, motivations, desires and context. To achieve a good design, the designer also needs to understand the business, technology, requirements and constraints. This knowledge should be used as a foundation for the design in the development of a product in order to create products whose behavior, form, and content are useful, usable, and desirable, as well as technically feasible and economically viable. To make the user experience seamless and comfortable, consistency and coherence should be used in the design along with using standard solutions that allow for the opportunity for the user to quickly learn the interface reducing the risk of errors (Cooper et al., 2014).

Web Content Accessibility Guidelines (WCAG) have developed internationally established recommendations and guidelines for accessible content on the web, for designers and developers to follow when designing websites and applications to be as accessible and useful as possible to include people with different disabilities (DIGG, 2018). There are three levels that WCAG are divided into; A, AA, and AAA. The level A criteria, the lowest level of ambition, must be met for all websites in order not to exclude any user. The next level, level AA is the base level that needs to be met by websites and mobile applications within the EU. When referring to level AA, both criteria at level A and at level AA are included. Level AAA is the highest level of ambition. By using these guidelines, a website becomes more accessible and increases the opportunity for everyone to participate in society on equal terms.

2.1.1 Designing for mobile interface

Mobile applications usually have basic UI elements and layout patterns such as *lists, grids, bars* and *drawers*. Grids for example, are used to organize content and functions into regular rows and columns to give an aesthetic and pleasing appearance. For navigation in a mobile interface, menu bars are the most commonly used mechanism. They are placed at the button or at the top of the interface as narrowed horisontal regions consisting of tab-like or button-like control labeled in text or icons (Cooper et al., 2014). Cooper et al. (2014) propose different options on how to integrate a menu on a small screen such as drawers, or *hamburger menu* as it also is called. Further, the authors claim that the most important activity on mobile applications is searching. However, the challenge for searching within a mobile interface is to allow sufficient expression of search terms that requires a minimum of data entry for the user. Some examples to solve this problem is by having *voice search* allowing the user to search by audio input. Other suggestions that decrease the keyboard time for the user are *auto-complete* that provides the user with a list of popular options matching the user's input as they are writing and *tap-ahead* that allow the user to select from the auto-complete option and use that as a search. *Auto-suggest* is a further improvement that allows for misspellings, and provides correctly spelled options and synonyms. Building on auto-suggest, to suggest options within a category, *categorized suggestions* can be provided. Moreover, a search function should remember the user's past searches and allow for *recent/frequent searches. Filtering* and *sorting* can also be used and due to the limited screen size on mobile interfaces, sorting and filtering are often merged and have a similar function.

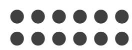
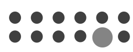
Cooper et al. (2014) write that as the interaction on a mobile is multi-touch, it requires the onscreen objects to be big enough and easy to activate with the fingers without accidentally triggering another interaction. Cooper et al. (2014) claim that multi-touch gestures are the heart of the mobile experience but the number of core gestures is small and the users usually do not need a large amount of different gestures to be satisfied, it is just important that the gestures are simple, intuitive, and easy to learn and discover. Some of the most frequently used gestures are tap to select, activate or toggle, *tap-and-hold* for contextual pop-up menus, *drag to scroll, drag to move, drag to control* knobs, switches and sliders, *swipe up/down* for scrolling, *swipe left or right* for horizontal scroll or open drawers, *pinch in/out* to shrink or zoom, rotate by twisting the thumb and forefinger and *multi finger swipes* to switch between screens (Cooper et al., 2014).

2.1.2 Design principles

Design principles are principles used as guidance for designers to be able to create designs that are pleasurable and user friendly (Interaction Design Foundation, n.d.-a). Design principles are generalizable guidelines that intend to guide designers to think about different aspects of their design (Sharp, Rogers & Preece, 2019). The Interaction Design Foundation (n.d.-a) writes that the principles represent gathered wisdom of researchers and practitioners in design and related fields, and Sharp et al., (2019) refer to design principles as derived knowledge, experience and common sense.

The principles are applicable rules, laws, guidelines, biases and design considerations that a designer should apply by selecting and organizing features and elements in the design (Interaction Design Foundation, n.d.-a). With the use of principles a designer can predict how a user is expected to behave while interacting with the design. The principles improve the usability by reducing the cognitive load and decision making time during the user experience, and it increases the appeal of the design. For designers it helps to make effective design decisions in a project. To be able to use and apply the principles it is important to understand the user's problems and how the user will understand the design solutions. Therefore, the principles should be adapted to each case and design based on the situation to build a solid user experience (Interaction Design Foundation, n.d.-a). However, design principles should only act as guidelines or triggers for a designer to ensure a feature is provided in the interface, but the principles should not tell the designer of how to design a certain element (Sharp et al., 2019). Examples of design principles can be found in Table 2.1.

Table 2.1: Example of design principles (Interaction Design Foundation, n.d.-a).

Design principle		
Balance	Equal weight of objects	
Repetition	Leads to the eye following elements and are used to attract the user to a part of the design	
Contrast	Can be used subtly in a design and can also be used to draw attention to an object	
Proximity	According to the Gestalt psychology elements that are near each other are being perceived as one group	
Hierarchy	Elements arranged in order of importance	
Emphasis	A strategy to draw the user's attention to a specific element in the design that distinctly stands out from the rest of the elements	

2.1.2.1 Human interface guidelines

Apple has developed the Human Interface Guidelines (Apple Developer, 2020) to guide designers to create more compelling, intuitive and beautiful experiences resulting in better designed applications. It offers designers and developers a comprehensive perspective of the key user interface elements and how to best implement the features in the design. Apple Developer (2020) has developed guidelines for each of their platforms of macOS, iOS, watchOS and tvOS and each has multiple sections that regard fields like application architecture, interaction, views, control and system capabilities.

2.1.2.2 Material Design

One adaptable system of design guidelines, components and tools is Material Design (n.d.). It is a design system created by Google to help designers and developers build digital experience for Android, iOS, Flutter and the web. The principles are inspired by the physical word material and used to be able to create hierarchy, meaning and immerse the user experience. The principles are guided by print design methods such as typography, grids, space, scale, color and imagery (Material Design, n.d.).

2.2 Universal design

Universal design, or design for all (Stephanidis, Akoumianakis & Savidis, 2001), refers to the design of systems, products and services that are usable, accessible and functional without need for any adaptation to the greatest extent possible, regardless of age or ability (Silva, 2011). The motivation for universal design comes from exclusionary design, occurring when a design is directed for the "fully able people" (Singh & Tandon, 2018), which does not provide the needs for the biggest range of people (Stephanidis et al., 2001). As universal design targets a broader perspective it has a positive effect on the society as a whole, since it is designed for everyone, not only the "average" person or a person with a disability. Since it meets the needs of people with different abilities, it is still accessible for the "average" person and is therefore beneficial and offers better conditions for everyone (Silva, 2011).

The Center for Universal Design developed a research project to establish guidelines for universal design, and developed 7 principles of Universal design; *equitable use, flexibility in use, simple and intuitive use, perceptible information, tolerance for error, low physical effort, and size and space for approach and use* (Preiser & Ostroff, 2001). The purpose of the principles is to guide the design process, allow for systematic evaluation of design and to educate both designers and consumers about more usable design solutions. The principles still serve as important and useful guidelines while designing, however, they only offer a starting point for the universal design process, and to select the most appropriate design solution requires understanding and negotiation among accessibility and usability. This demands for a user's input in the design process to help evaluate the design during the development phase, to ensure that the needs of the full diversity of users have been met. The main purpose of the principles is to guide others in their process of designing inclusive design, and has proven to be useful all over the world (Preiser & Ostroff, 2001).

2.2.1 Universal design - accessible, usable and inclusive

Accessible, usable and inclusive design are terms commonly associated with universal design. The terms have the same approach to design products that are suitable for everyone, however they slightly differ (DO-IT, 2019), and can vary across the design space (McAdams & Kostovich, 2011). *Accessible design* refers to designing specific for people with disabilities, such as adding a ramp to every entry of a building. *Adaptable design* is further an approach where the design modifies to be easier to use (McAdams & Kostovich, 2011). *Usable design* indicates the usability of a product, the ease, satisfaction and efficiency of using it. However, usable design does not invariably consider individuals with disabilities, which can lead to products that perform well in usability tests but are not accessible for everyone (DO-IT, 2019). *Universal design* is the broadest concept but cannot be seen as a substitute for accessible design, since the goal with universal design extends further than eliminating discrimination for people with disabilities. The purpose with universal design is to be beneficial for everyone (Steinfeld & Maisel, 2012). *Inclusive design* can be seen as equivalent to universal design as universal design is design that can be coequally used by people of any ability with no discrimination against users based on their abilities (McAdams & Kostovich, 2011). Burgstahler (2020) presents a framework to illustrate the relationship of these terms (Figure 2.1).

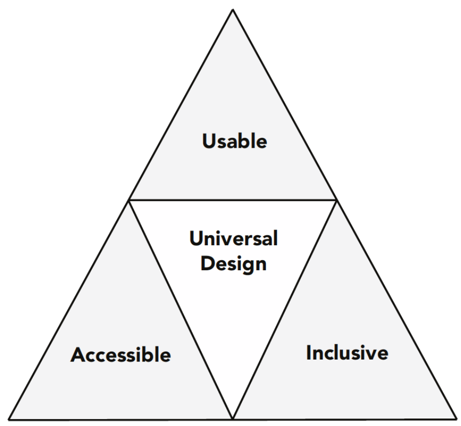


Figure 2.1: Universal Design of Instruction (UDI) framework (Burgstahler, 2020).

2.2.2 Conceptual framework for universal design

Singh and Tandon (2018) introduced a framework that identifies four key elements of universal design that are important to make a product more accessible; *functionality, usability, performance* and *product attachment*. Singh and Tandon (2018) claim that for designers to understand all user's needs and aspirations, people are divided into three user groups that are important to understand and develop universal products that will work best for people with and without disabilities. To achieve true universal products, the designers need to classify the users in a hierarchical manner, to identify their needs based on some priorities. The first group of their pyramid is Fully Able People (FAP), that are people that will have no difficulties while using the product

(Figure 2.2). The second group of people is people who have some special needs or temporary disability, and is called Specially Abled People (SAP). The last group is the Differently Abled People (DAP), that consist of people with severe permanent physical or mental disability.

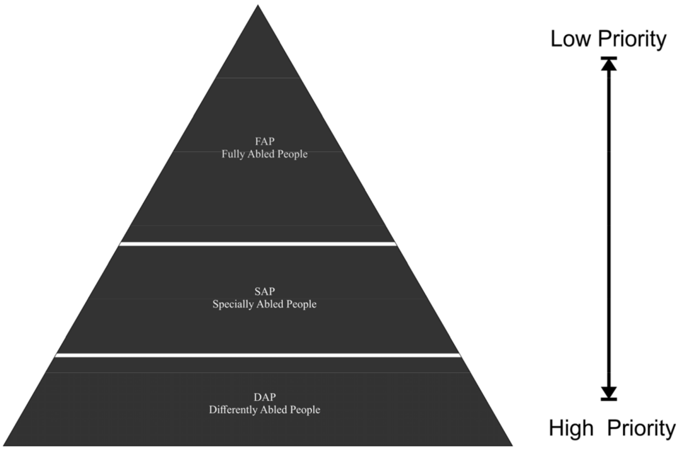


Figure 2.2: Universal Design of Instruction (UDI) framework (Burgstahler, 2020).

Singh and Tandon (2018) write that to identify the key elements of universal design involves three stages; identify words that represent product attributes in a value database, clean and filter the database and lastly identify a few important elements that are responsible for the issues related to the design of a universal design product. Singh and Tandon (2018) identified four elements:

1. Functionality: The quality of being suited to serve a purpose well
2. Usability: Ease of use and learnability of human-made objects
3. Performance: The action or process of performing a task or function
4. Product attachment: Procut attachment is the emotional bond consumer experience with a product

Further, Singh and Tandon (2018) claim that if all these four elements are being satisfied in a design, the possibility of the product to be accepted as a universal product will significantly improve. Based on this, the authors designed a conceptual framework model (Figure 2.3), that describes the effect of the four elements of universal design. According to their study functionality, usability, performance, and product attachment are important contributors to universal design (Singh & Tandon, 2018).

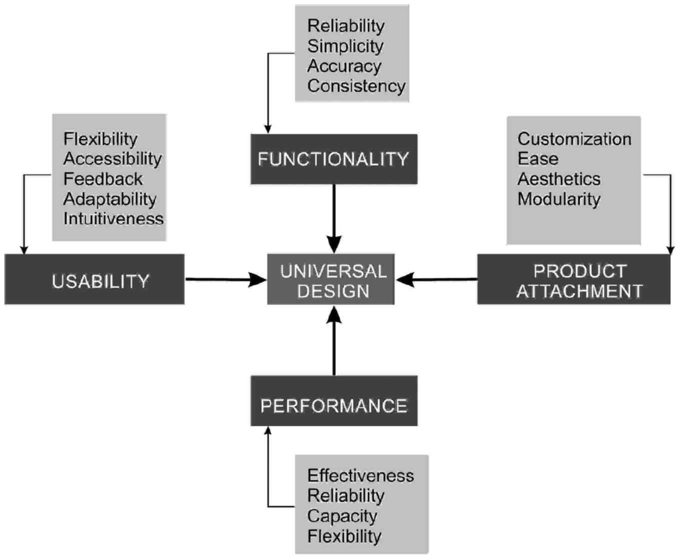


Figure 2.3: Universal Design of Instruction (UDI) framework (Burgstahler, 2020).

2.3 Disabilities

A disability applies to individuals with a long-term physical, mental, intellectual or sensory impairment that might hinder an individual's full and effective participation in society when interacting with different attentional or environmental barriers (United Nations, n.d.). This refers to people with *perceptual disabilities*, such as hearing and visual impairments, *motor disabilities*, such as limited or no use of hands, arms, legs, mouth and *cognitive/intellectual disabilities*, such as lifelong impairments as down syndrome or autism or impairments that develop over time such as dementia or Alzheimer's disease or event-based impairment such as aphasia (Lazar, Feng & Hochhesiser, 2010). Lazar et al. (2010) write about the importance of involving users with disabilities in research to avoid researchers making assumptions based on stereotypes.

2.4 Designing for disabilities

To avoid exclusionary design (Singh & Tandon, 2018), and to approach universal design that will make the use of digital devices similar for everyone there is a need to understand all the various users and their needs. It is important to have a diverse awareness of different disabilities and the critical features that are important to be able to interact with an interface. Therefore, in this section focus has been to understand the needs of people with dyslexia, visual impairments, cognitive disabilities, elderly people and children. These disabilities were chosen to cover a wide variety of different disabilities to include a diversity of people in the research for this project.

2.4.1 Dyslexia

Dyslexia is a cognitive learning disorder regarding reading, spelling and written language but can also affect number work (Vangeli & Stage, 2018). It can take different forms and can manage differently depending on which age a person is diagnosed (Habib & Giraud, 2013). Habib and Giraud (2013) state that dyslexia affects the acquisition and development of written language, and a person with dyslexia has a poorer reading performance with a greater deviation compared to others of the same age. A person with this learning disability cannot write or read, understand and interpret texts in the same way as a person without dyslexia can and therefore, dyslectics often experience difficulties in their daily life (Habib & Giraud, 2013).

Vangeli and Stage (2018) have in their research found common dimensions and elements among interaction design parameters which support and improve users in their reading skills. Technology is a helpful tool that can contribute to the improvement of dyslectics' cognitive skills. In their study of interaction design and dyslexia, the focus was on functionality and user interface, leading them to establish some guidelines and parameters focusing on helping dyslectics to improve their reading skills. The three factors that facilitate dyslectics to improve their reading performance are: *font size, colors* and *layouts* (Table 2.2).

Table 2.2: Factors to support for dyslectic users.

Font	Color	Layout
Size 12-14	Avoiding bright colors	Simple and clear
Sans Serif fonts	Light grey as font color, or have a light contrast between background and fonts' colors	Large letter spacing
Text should be enriched with pictures and audio elements	Have clear differences among text and background	Lines of 60 to 70 characters
		Line spacing: 1.3, 1.4, 1.5, 1.5–2
		Narrow columns should be avoided

2.4.2 Visual impairments

People who are visually impaired use touchscreen devices differently than fully sighted users do. Fleizach and Seymour (2013) claim that digital products are increasing and touchscreen interfaces are becoming more common. Huang (2018) has explored factors of accessibility of touchscreen interfaces for people who are visually impaired. Touchscreen has become a standard feature of smart mobile devices and provides an easy-to-use interface and smart devices can provide different assisting tools supporting people with disabilities. Smartphones are equipped with many accessibility functions such as VoiceOver, text-to-speech functions, inverted screen color and larger font size, which enables visually impaired users to use these devices. However, these functions are only basic and insufficient where visually impaired users still face difficulties using touchscreen interfaces. This is mainly due to the fact that a touchscreen does not offer any tactile feedback (Huang, 2018).

Furthermore, Huang (2018) describes a smartphone wayfinding system for visually impaired people. This system used auditory and tactile feedback to compensate for the visual information on the screen, and the result showed that visually impaired and blind users effectively could use the application without assistance. Huang (2018) outlines several functions that can improve accessibility on mobile devices for people with visual and motor disabilities, such as screen readers, voice input, large buttons, screen magnification and high-contrast screens. Including a bold border around an object to induce that it has been pressed which would enable for visually impaired users to locate and track clues on the screen. Sound feedback or auditory clues, that describes the current object that has been touched enhances the input. Also, the interface should provide tactile and vibration corresponding to the signals. Voice control functions such as Siri (iOS) and Google Now (Android) are included in smartphones and can assist users to operate and control their phones through their voice. Also, touchscreen interfaces include lots of 'multipoint gestures' to operate different functions, for example zoom in and out with the pinch gesture. However, these systems are provided with an assisting tool so that the same function can be performed with one finger as well. Huang (2018) states that the content in an interface should be read aloud using voice control when users touch the screen interacting with text or objects in the interface. Furthermore, even non-textual objects should have auditory information and 'speak out'. It is also of importance that when an interaction with the interface has been made, the interface should announce the action. Lastly, contrast of the interface should be high because it makes text and objects easier to perceive for visually impaired users, and a function to invert the colors on the screen can be used to achieve high contrast.

2.4.3 Elderly people

Mobile phones are an essential gadget in ederly people's life, and have become a great necessity for them (Al-Razgan, Al-Khalifa, Al-Shahrani & AlAjmi, 2012). However, the graphical interface of the mobile phone has become more complicated (Al-Razgan et al., 2012), and with a growing elderly population, the technological innovations need to support the growing population in their need of help to manage their everyday life (Endter, 2016). To design for eldery people is a challenge as ageing is a life-long process that differs between individuals (Endter, 2016). However, with a growing age the physical health and cognition is declining, elderly people can suffer from gradual deterioration in their hearing, visual and cognitive abilities (Sugam & Wong, 2019).

For devices to have an age-friendly design it should be adaptive, usabel, affordable, discreet and intuitive, and also allow elderly to be independent in their numerous areas in their life, especially regarding health, house, mobility, security and communication (Endter, 2016). To design for elderly the graphical interface needs to require minimal physical, visual or cognitive operational stress (Sugam & Wong, 2019). Further, Al-Razgan et al. (2012) present a set of guidelines and design recommendations for touch based mobile phones interfaces that are targeted towards elderly people (Table 2.3).

Table 2.3: Factors to support for elderly users.

Functionality	Look and feel	Interaction
Functionality of the same type should be grouped together	Three-dimensional appearance button for touch-screens	Easy to zoom in and out and pinching
Main navigation placed identically on all the "pages"	Separate keypads for numbers and letters	Tapping with audio confirmation
Critical functions should never disappear	Good spacing between buttons	Tap action and not drag and drop
Important functions placed at the top of the screen to avoid mistake touches	Larger font for text and labeled icons	The interface needs to clearly express where the user is, and which "task" is active
Buttons for specific actions, e.g. a single button to return to the home state	The most important feature available directly via a labeled button and not via menu navigation	Avoid slide-out keyboard
Naming programs and commands		
Not to have too many or too few features		

2.4.4 Cognitive disabilities

A cognitive challenge or disability can take different forms and vary within individuals. Cognitive disabilities are generally considered to include learning disabilities, autism, traumatic brain injury, aphasia, attention deficit disorder (ADD), attention deficit hyperactivity disorder (ADHD), alzheimet's disease etc (Friedman & Bryen, 2007). Some cognitive capabilities will never change, some might change over time if an individual has had a concussion or a stroke and some people might experience gradual degradation in mental capabilities over time (Bessa, 2012). Many of these disabilities include deficits in memory, perception, problem-solving, conceptualization and attention. This creates innumerous accessibility barriers in use of web applications and individuals with cognitive disability can experience difficulty using the web due to limited reading comprehension, complexity, slower learning, limited fine motor control, reduced spatial perception, lowered visual acuity, less hand/eye coordination, finger dexterity and lowered information overload thresholds. Problems can occur when a user have to control the mouse, click and locating on small items, read the text, navigate the screen, distinguish foreground images and text from background material or have to choose between many different options as it can be hard to recognize the most appropriate choice (Friedman & Bryen, 2007).

Friedman and Bryen (2007) conducted 22 web design recommendations that focused on addressing cognitive disabilities, cognitive impairments, learning disabilities, dyslexia, aphasia and intellectual disabilities. The recommendations as follows regard these addressed disabilities shown in Table 2.4.

Table 2.4: Factors to support for users with cognitive disabilities.

Cognitive disabilities
Use pictures, icons and symbols along with text
Use clear and simple text
Consistent navigation and design on every page
Use headings, titles and prompts
Support screen readers. Use alternate text tags
Use larger fonts, fonts in minimum 12pt or 14pt
Uncluttered, simple screen layout
Maintain white space: Use wide margins
Website customizable, control of: type size, placement of navigation (right, left side) contrast, large print, sound
Use exit, home, help, next page buttons on every page
Use with sans serif fonts, such as Arial, Verdana, Helvetica, Tahoma
Navigation buttons should be clear, large, and consistent
Use numbered lists rather than bullets
Support font enlargement for Web browsers
Use color for contrast
Check reading level with automated tools
Don't right justify text; use ragged edge right hand margins
Use lower case, no all in caps
Provide voice captions (audio files) for text
Provide audio/voice-overs where the words are read aloud
Use navigation methods, i.e. 'undo' or 'back button' to help users recover when lost
Give feedback on a user's actions (e.g. confirm correct choices, alert users to errors or possible errors)

2.4.5 Designing for children

Adults and children have different information-seeking behaviours as children are more effective, efficient and provide more quality in their searches and web navigation than adults. Children like to play games and lack reading fluency, and they are curious. Therefore, the conventional interfaces that are rigid, text-based and task-oriented are inconvenient for children in their information-seeking. This means that information-searching interfaces that are designed for adults might not be as effective for children. As children have limited information seeking capabilities they need an interface that helps them with their information searching barriers. One way to do this is to have icons in the interface that are simple with a clear meaning (Wu, Tang & Tsai, 2014).

Kamaruzaman, Rani, Nor and Azahari (2016) designed a touchscreen mobile application to assist the teaching and learning of numeracy and basic calculation for children with autism. The authors mention the importance of using both pictures and words next to each other where the pictures should be big and easy to understand, there should be short sentences and if difficult words are used they should be explained. Additional recommendations that the authors describe are to keep sentences together in one page to not fill it with too much information, illustrations should be in sharp focus, never to use inverted printing and never use roman numerals.

Shneiderman (2004) writes that children expect to have fun while they are using technology and that children often link the idea of fun to challenges, social interaction and control over their world. He recommends designers to address three goals that contribute to make the interface fun, which are providing the right functions so that users can accomplish their goals, offer usability plus reliability to prevent frustration from undermining the fun and engage users with fun-features. To reach the second goal he lists eight golden rules for designing a user interface; *strive for consistency, cater to universal usability, offer informative feedback, design dialogs to yield closure, prevent errors, permit easy reversal of actions, support internal locus of control and reduce short-term memory load.*

2.5 Designing with icons

Huang, Shieh and Chi (2002) describe that icons are commonly being used as a communication tool in an interface, since icons can be easy to recognize, remember, and have more universal recognition than text as icons interfaces confront fewer obstacles than language, and offer a perception of affordance. However, there are two common problems regarding icon designs. One of them is that icons often have language barriers that do not guarantee an instant comprehension within or across cultures. The other problem refers to the fact that people cannot quickly locate the icons they need. Previous studies indicate that factors that affect the quality of the icon are that they need to be identifiable, meaningful, concise, associable, and memorable (Huang et al., 2002).

2.5.1 Pictogram design

Pictograms are symbol-based icons that represent an object or concept through a simplified illustration. Pictograms are specific for being an image-like graphic symbol that is illustrated in white on a black background and every symbol stands for a word or a concept. These are used to communicate at a simple linguistic level, to be an alternative to the written language and can serve as a support for time, structure, memory and location. Pictograms can also be used as signage in public environments, and since they are clear and quick to read, it can provide a better understanding of written signs (Specialpedagogiska skolmyndigheten, 2020). Pictogram is a quick reading visual language that is designed for people with difficulties in reading, and has been shown to improve communication for many disabled people. Each Pictogram image has a universal meaning that makes it work in several similar contexts which provide the user with abstract thinking and give each Pictogram image a general meaning (Specialpedagogiska skolmyndigheten, 2010). Lidén (1999) suggests that Pictograms should be low iconic images, which are a combination of very simple silhouettes and pictures with some reproduction of details, structures and simple perspectives. They should be designed with the highest contrast possible, such as white silhouette figures with black background to help to perceive the images quickly (Lidén, 1999).

2.5.2 Pictogram on signage

Siti and Swasty (2017) write that the importance of signage is not only to steer the place or location but also to inform visitors about rules that exist inside or outside of a building. Having a presence of pictograms makes an easier identification and understanding of the scheme and can communicate information to visitors briefly and effectively. Many pictograms may be used in different domains without problems concerning the graphic representation and meaning of them, such as men/women toilets, lift, escalator, stairs, parking area, which is usually understood by everyone, as it has a simple graphic drawing using a very familiar representation. Symbols can overcome a language barrier and can therefore be useful on signage in public facilities where visitors might come from different cultures or speak different languages, as in hospitals, hotels or airports. Some symbols can be understood all over the world, such as arrows, and the most common one used in signage is a map. A map can be necessary when communicating the position of places and spaces, as it is a visual replacement for complex direction and is often additional information content for signage (Siti & Swastys, 2017). Further, pictogram is an informative signage element that is important to clarify information that does not require reading the text and are useful in signage for three reasons: to save space of sign, that the meaning of a symbol can overcome the language barrier, and it can help communicate more clearly than words. Pictograms communicate visually rather than verbally, and to convey good communication without words it is needed to have a good representation because a graphic and visual language is above the written language. Therefore, pictograms on signage should be standardized and informative (Siti & Swasty, 2017).

3
Related Work

This chapter will describe some of the previous work related to this field of research. The topics of this chapter concerns the meaning of wayfinding, wayfinding in indoor and hospital environments, and previous and existing wayfinding systems for indoor navigation. Further, the chapter touches upon the challenge of live positioning for indoor navigation.

3.1 Wayfinding

The process of determining where to go, how to best navigate and understand one's location in an unknown environment, is called wayfinding. Wayfinding facilitates navigation in large complex buildings and environments, such as hospitals (Harper, Duke, Crosser, Avera & Jefferies, 2020). It has been shown that it is commonly difficult to navigate at places like hospitals, and that poor signage and architectural planning makes it inefficient to navigate (Smolenaers, Chestney, Walsh, Mathieson, Thompson, Gurkan & Marshall, 2019). Traditional wayfinding systems are often based on static signage, such as text signs, arrows, color and numeric coding. However, it can cause confusion for the wayfinder when an excessive number of signs are presented and can lead to information overload. Therefore, hospital environments are usually too complex to explain with signs (Morag & Pintelon, 2021).

Smolenaers et al. (2019) explain existing wayfinding strategies and present some potential solutions to the problem of wayfinding in complex environments. Signage is the most obvious method of wayfinding in public spaces, but unfortunately it often involves complexity and difficulty. Morag and Pintelon (2021) claim that signs do not convey cues that are simple enough and it does not provide natural movements. Smolenaers et al. (2019) write that a solution could be to use icons and symbols in order to make the signage more effective and universal, maps are another common method to use for indoor navigation. However, many hospital maps lack accessibility where it uses exaggerated acronyms, nomenclature, lack of details, and are out of date. Signage and maps could also differ in their designs, which can make it inconsistent and confusing for the users. Additionally, visual landmarks and motifs can be built in the environment and work as a help for orientation and navigation within a space. Some hospitals make use of a concierge system to offer help with wayfinding where visitors can seek wayfinding assistance either by getting directions to their destination, or by getting help by a concierge accompanying them to their destinations (Smolenaers et al., 2019).

Traditional wayfinding using environmental cues and signs, has advanced by the use of technology such as interactive displays, kiosks and mobile applications. The purpose with using an application is to simplify the wayfinding as it allows the user to access the essential information about their whereabouts and helps them navigate individually in the complex environment (Harper et al., 2020). Morag and Pintelon (2021) describe digital wayfinding to be beneficial for the user since it helps them find the simplest route to their destination or the possibility to adjust the displayed information to fit their needs and preferences. Therefore, in the designing of such wayfinding applications it is of importance that the application is easy to use, effective, accessible, and intuitive (Harper et al., 2020). According to Marshall (2017), there are many advantages and possibilities with a wayfinding application. However, it cannot constitute as the sole source of wayfinding in healthcare facilities. There is a risk that wayfinding technology would be highly favored by younger visitors and patients, but might not be utilized or even understood by the older adult population. Additionally, a population of users with various types of disabilities such as blindness, hearing loss, or cognitive impairments, may be excluded from using the application because their needs have not been taken into account. Even language barriers and cultural barriers may exist (Marshall, 2017).

3.2 Wayfinding in hospitals

Hughes et al. (2015) argue that many people, both visitors and staff, experience issues navigating in hospitals and that there were concerns about not arriving at appointments in time, and having to plan for the total travel time to the destination. Other barriers that affected navigation involved security and limitations to access where some sites might be isolated or closed, which can prevent both staff and visitors taking the optimal route. Barriers to navigation is also about cognitive limitations and the mental state of the person in need of navigation. Stress, sickness, confidence and mobility can have a large impact on their attempt to navigate and people having different needs require help in various ways (Hughes et al., 2015).

Hughes et al. (2015) have listed different types of navigation aids that involve the interaction between the hospital and its users, where the first interaction often involves textual information. Verbal directions is another navigation aid often used to seek guidance and was also found to be the most popular form of navigation aid in their study. Other examples of navigation aids mentioned are different types of maps, labeling systems, physical landmarks and external information such as GPS applications and websites. Further, it was found that participants valued clear, consistent and comprehensible information that were delivered verbally, through signage or with the use of colour.

3.3 Wayfinding and indoor maps

Indoor navigation is not as developed as outdoor navigation, but in recent years it has gained much more attention (Diakité & Zlatanova, 2018). Indoor maps differ from outside maps where there are pavement and roads to help organize the navigation. Diakité and Zlatanova (2018) describe the importance of having a non-trivial navigation system to support guidance and possible evacuations from a building. The authors present a framework that considers the complexity of an indoor environment and provides a spatial partitioning scheme. It mainly presents three different types of objects that can be found in different buildings and indoor environments, which should determine the map's planned route. These objects will be distinguished on the basis of their mobility, where static, semi-mobile and mobile objects can occur. What kind of object it is depends on their ability to independently change their position. This classification of objects can facilitate the design and production of an indoor map.

Another study performed by Ponchillia, Song-Jae, Kim and Harding (2020), investigated the needs and preferences of users who are visually impaired. The participants in the study stated that the most important type of indoor information was points of interest, e.g., elevators, bathrooms, cafeterias. Further, the most important feature of an application was the ability to know one's location at any time. When it came to finding the best output mode, verbal output and vibrational cues were the most suitable. The result from the study showed that airports and bus or rail transit facilities were buildings where it was most important to have navigation systems, and sports arenas and airports were buildings where it was generally most difficult to navigate.

3.3.1 Positioning for indoor navigation

The field of indoor navigation, and more specifically indoor positioning, is a fairly new subject and has not yet achieved the same success as outdoor positioning. Indoor positioning systems (IPS) are used in different ways to locate objects in an environment where GPS and other satellite technologies lack precision and can not be used indoors because of disturbed reception of signals (Santosh, Kwon, Shin, Hwang & Pyun, 2016). Locating an object with GPS signals requires undisturbed reception of signals from at least four satellites, and therefore other technology to facilitate indoor positioning is needed (Santosh et al., 2016). Bluetooth Low Energy (BLE) beaconing technology, trilateration, triangulation, and geomagnetic field fingerprinting are some options that can be used for indoor positioning (MazeMap, 2021; Bekkelien, 2012).

A BLE beacon is a small wireless transmitter that sends signals to other devices nearby (WordStream, 2020), where these signals can be picked up by a compatible application or operating system to determine its physical location (Wang, Yang, Zhang & Zhang, 2015). Wang et al. (2015) describe this technique having high potential when it comes to indoor positioning as it has both low energy consumption and low cost and can cover up to 100 square meters depending on the signal power. By using BLE beacons it is possible to set up a network inside a building to support indoor positioning by detecting objects within its range that are receiving the signals and with an algorithm calculating its physical location. However, these transmitters need to be installed in the physical environment to communicate to other devices, such as a smartphone, to send and receive signals form.

3.4 Previous wayfinding systems in complex environments

Morag, Heylighen and Pintelon (2016) argue that wayfinding with poor design might cause the user stress, anxiety and can also be costly due to lost time. While wayfinding with good design can reduce stress and give people a sense of control and empowerment. When it comes to large complex buildings such as hospitals, that might be growing and expanding, a need for a good wayfinding system becomes more critical and acute. To design a good wayfinding system Morag et al. (2016) claim that the system should communicate to the broadest target group possible, hence taking into account the different sensory, physical, language, intellectual needs, and social and cultural backgrounds that people might have. In the study of Morag et al. (2016) it was found that a diversity of hospital user's face difficulties at the entrance, and that directional signs were difficult to understand if the icons and symbols were color coded with different colors. Several participants also reported that they did not receive enough satisfying feedback when they had arrived at their final destination and therefore needed to ask to be sure. All participants managed to reach one destination but when they needed to reach several destinations in a sequence, it was even more complicated and time-consuming to understand the colored signs and symbols (Morag et al., 2016).

Harper et al. (2020) examined what aid is the most efficient for wayfinding systems in complex environments and discovered usability issues that impact the effectiveness of a mobile wayfinding application used by large complex hospitals providing information recommendation used to enhance the user's navigation. The research conducted by Harper et al. (2020) examined the usability of an interactive wayfinding on a touchscreen kiosk and of an interactive wayfinding mobile application. The results indicate that the mobile application solved the problem of cognitive load as the participants were able to bring the instructions with them. Another problem discovered in the kiosk but solved in the mobile application was an accessibility issue of being able to reach and use the kiosk from a wheelchair. The mobile application provides a more accessible option for everyone, including people with disabilities, since it is possible to be used remotely and therefore presents the possibility to bring the instructions. Further, the information provided by the application complemented other wayfinding aids used in the physical environment, such as landmarks, signage and color. Therefore it is beneficial if the application and the environment match as it is more efficient for wayfinders to be able to identify their position using cues in the surroundings. The mobile application solved several problems that existed with the kiosk, however it did not include a universal search feature, providing instructions on how to access help from a human, or provide location-based navigation.

Harper et al. (2020) describe three recommendations designing for mobile applications to be used in a hospital. The first recommendation is that the system should provide a search function that will allow the participants to search for a diversity of data, where it is of importance that the search function is easy to discover and that it will be easy to use. The other recommendation is an option to locate a help desk. If participants did not feel that they got the assistant they needed from the system, they would ask a staff member to help. Even if the system aims to work without any need for external help, it is beneficial to provide that option which would increase the effectiveness of the system. The third recommendation is that the system should provide a map for visual aid with appropriate orientation. The system should therefore be designed to provide a list of instructions for navigation with symbols, buttons and icons matching the environment.

Morag et al. (2016) discuss the development of different technologies that can assist people in their wayfinding since it is complex to navigate in hospitals even with the use of signage, spatial cues such as arrows, numeric encoding, color coding, guidance from staff, etc. The implementation of customized and adaptive technologies produces a personal wayfinding guidance that is tailored to meet the users personal needs. They mention examples of a system having arrows presented on the floor to direct a person or have dynamic displays along the route to present relevant information based on the people's specific needs, such as large fonts for visually impaired users, or English for them who do not speak the local language (Morag et al., 2016).

Morag and Pintelon (2021) carried out an interview study in twenty hospitals to evaluate digital wayfinding systems, to find the challenges and the benefits associated with these systems and to help understand why these systems are widely used in commercial environments but not as common in hospital environments. Despite the benefits that digital wayfinding systems offer for the hospital wayfinders the actual presence of them in hospitals are low even if the system offers a considerable potential to assist elderly or people with disabilities. As these digital wayfinding systems increase there are important issues that have not yet been shown in the literature about this subject. This includes user responsiveness in operating the systems, which particularly applies to elderly people, an evaluation of the benefits that a system would provide for hospitals, and the system's ability to support people with disabilities. When wayfinders navigate inside a complex environment such as hospitals, individuals usually use the information of an available wayfinding system with information provided in the buildings architecture, landmarks, and interior design. Therefore, when the hospital grows and changes it becomes even more complex as a wayfinder to navigate having to adapt to new routes. This is especially challenging for the growing number of elderly people who usually visit hospitals more often than the young population (Morag & Pintelon, 2021).

The result from Morag and Pintelon (2021) study indicates a consensus that digital wayfinding systems bring a significant value both for the hospital and its users and believe it will become more common with these systems at hospitals in the future. First the authors apply to the individual trust in the technology. If some information does not provide the users' needs, they will want to speak to someone and this worry will increase if there is any communication lost or delay in receiving information, especially for elderly and people with impairments. Further, the authors refer to the reduced task complexity and the overall user stress and anxiety as the systems simplify the wayfinding complexity, users can more easily navigate from one department to another, and it also makes the movement between floors easier. As the users are able to see the duration to their destination it also reduces the stress level. Further, the authors refer to the parallel or substitute use of static and digital systems. Elderly users are especially familiar with the signage system and might prefer using it, therefore there should be an overlap between the systems. The signage system should also back-up the new digital system based on the reliability issues users might have. Lastly, regarding the individual user's perspective, the system supports people with diverse needs and abilities. For example, people with reduced movement could find the shortest route and the people with vision impairment could adapt the information in the system based on their needs (Morag & Pintelon, 2021).

Outdoor wayfinding applications of different kinds are common to use on smartphones, but limitations with electronics and the ability to accurately position location and tracking of movement is a reason why indoor navigation is not as widespread. Indoor maps must also be adapted in such a way that they are suitable for use in a navigation application (Smolenaers et al., 2019). Smolenaers et al. (2019) describe three phases of where a navigation application has been developed, tested and evaluated. During user testing some confusions were discovered regarding the map. Some users found it confusing when the map and symbols rotated on the map, and the level of detail was agreed to be too complex. Further, some problems with the tracking of the user in outdoor areas between buildings and parking areas were discovered. A suggestion to solve this was to add color to the application to distinguish inside rooms from outdoor areas. The evaluation and usertesting led to some additional improvements such as icons to mark points of interests on the map. Additionally, to improve the design of the map, the path was highlighted in blue in front of the user with a blue arrow pointing in the right direction, where the path then changed to white behind the user to convey a clear difference between forward and backward on the path. Another feature that was added was "favourites" and "recent destinations" so that users could easily save and find previous locations. To facilitate for the user to pre-program their destination a QR code is included in the clinic appointment letters that can be scanned within the application. A development of this feature could also include guidance to the hospital from the user's home. Lastly, Smolenaers et al. (2019) describe some improvements for future development of the application which involve accessibility features for users who are visually impaired, but also support of additional languages.

3.4.1 Existing indoor navigation applications

A study conducted by Marshall (2017) explored the possibility to assist visitors with smart phone navigation. The purpose of this study was to develop a wayfinding smartphone application, Navihealth, for a large healthcare facility to help visitors navigate in the buildings, which would decrease visitor stress and improve overall patient satisfaction. NaviHelath gives real-time navigation with step-by-step instructions and offers navigation for indoor facilities, between multiple buildings, through parking areas but also to locate the hospital itself (Marshall, 2017). An advantage of the application was that it could be updated and suggest alternative routes, if any part of the building would be closed or if an elevator would be broken, compared to signage in hospitals. Apart from patient satisfaction and reduced stress, the application could also entail improved staff workflow due to a reduction of staff having to provide directions to visitors or patients. Marshall (2017) also describes some weaknesses of the application where the absence of owning a smartphone or not using navigational services, which makes the application less accessible. The result of the study showed that participants expressed a strong interest in the application and that it would likely have a positive impact on helping visitors and staff (Marshall, 2017).

Norwegian University of Science and Technology together with Wireless Trondheim developed the application MazeMap, a wayfinding application for indoor and outdoor navigation (Biczok, Diez Martinez, Jelle Krogstie, 2014). The application allows the user to navigate with an accuracy of 5-10 meters, see buildings on the map, locate one's position within a building and search for rooms and other objects such as toilets and parking lots. The users are also being presented with step-by-step directions of where the user is and where they are going. The aim with MazeMap is to help the user to navigate with the use of smartphones, tables and laptops.

The MapsIndoor navigation system was developed in 2014 by Mapspeople and was first designed for indoor navigation for the University of Copenhagen (MapsPeople, n.d.). MapsIndoor is designed to make wayfinding in indoor complex areas easier as the platform is built on Google Maps, which is supposed to create a smooth transition between indoor and outdoor navigation. The purpose is to have the opportunity for users to navigate from one's home to a specific point of interest (POI) inside a building. The system can be integrated into mobile applications, kiosks and websites which provide the users with a digital navigation tool to help them navigate within a large indoor facility with only the usage of a smartphone. Since GPS doesn't work inside buildings, MapsIndoors native application can be integrated to either Blutethoos beacons, WiFI positioning, positioning via magnetic fields or via lighting. Indoor spaces can occasionally change, and with an Indoor Navigation Content Management System allows developers to add, edit and delete points of interest. With the system it is possible to see the users exact location (MapsPeople, n.d.)

4 Methodology

This chapter will explain various kinds of research methodologies that can be applied during the research and design process. All methods contribute to different solutions and are being used for different purposes depending on the design being developed. Therefore, this section will describe the aim of each method and how they are applied in practice, and not the actual application of the method for this project. A detailed description of the chosen methods applied during this project will follow in chapter *6. Execution and Process.*

4.1 Design thinking

Booth, Colomb, Williams, Bizup and FitzGerald (2016) write about the importance of asking why the performed research is important. The aim with the research question *"to find design solutions that are important when designing a universal accessible application for indoor navigation in a hospital environment"* is to investigate how to design a product that can be useful for everyone. The objective with this project is to find guidelines of what to consider when designing an accessible application for indoor navigation for future designers and developers to pursue, to be able to create designs that everyone can use.

Booth et al. (2016) further mention the importance of having a plan when a research question is set. A plan to test the gathered data for the research question and perform research. In order to do so, the ambition with this project is to perform user research to gather insights and needs from people with various disabilities of what is important for them along with support from literature about design for disabilities, as the primary sources for this project. Further, the secondary source will be peer-reviewed literature of existing, tested and planned navigation systems for indoor hospital environments. The intention with this project is to make claims and arguments of how to design an accessible application for an indoor navigation system for hospital environments based on acknowledgement and responses from user research, literature and usability testing (Booth et al., 2016).

Graver (2012) writes that over the last year it has become more common to perform research through design (RTD), and mentions that there have been opinions about it lacking clear expectations and standards of what is good design research. However, Graver (2012) reasons that standards might be too restrictive and that RTD should be exploring, speculating, particularising and diversifying rather than being scientific. The methodology plan for this project was to perform research through design, by the designing of an indoor navigation application, to envision design solutions that are important when designing a universal accessible application for indoor navigation in a hospital environment. This was planned to be done by first gathering insights and opinions based on literature and conducting user tests, to then analyse the result and use it as a foundation in the iterations of the designing of the interface to lastly perform iterative usability testings to evaluate and test the product. The aim with the project was exploring, speculating and finding new insights of how to behave when designing an accessible indoor navigation application for hospital environments.

4.2 The design process

Hartson and Pyla (2012) write that building usability into a system requires an interaction design process to help guide the designers with a structure to deal with the complexities in a project. The guidance from a design process ensures that important phases in a development of a product will be present. The double diamond design process (Design Council, 2021) will be used as the foundation for the design process for this project. The process is divided into two diamonds with four phases; *discover, define, develop*, and *deliver*, as presented in Figure 4.1.

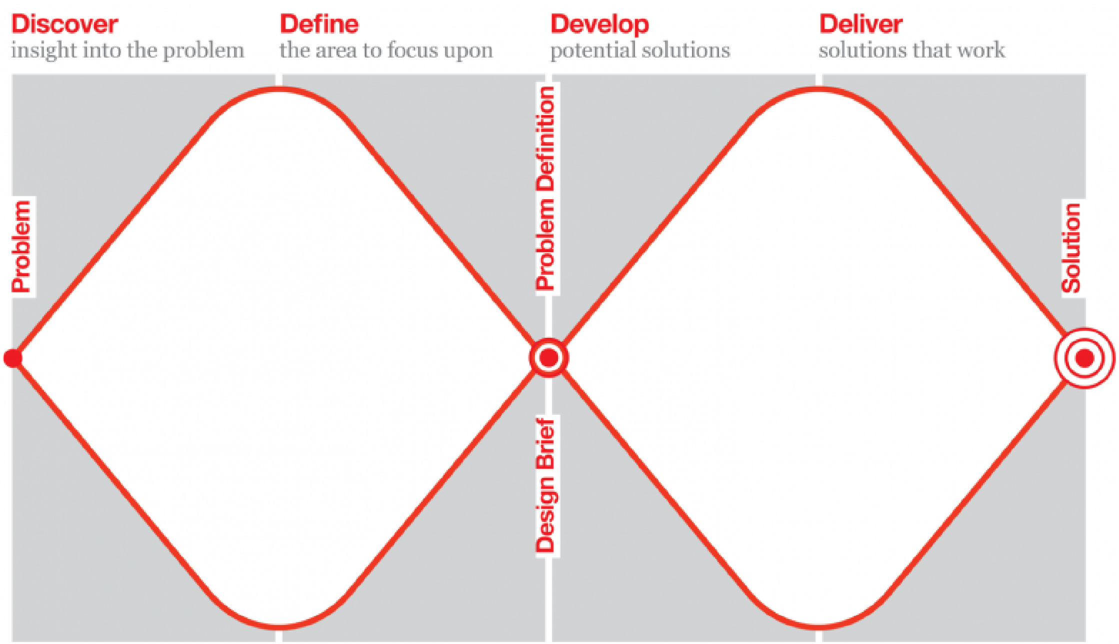


Figure 4.1: The double diamond of design (Sharp et al., 2019).

4.3 Discover

The first phase of the diamond, the discover phase, is to help understand the problem and the users to be able to design based on gathered insights and findings, rather than assume what the problem is or what the users needs are. This phase includes doing research of the problem and involves users that are affected by the problem (Design Council, 2021).

Literature review

A literature review establishes the context of the study and gains insights for the researchers about the subject, to help understand gaps in the field, unresolved issues and new perspectives (Turner, 2018).

Focus group

Focus groups are interviews held in group sessions and are beneficial since they allow for perspectives that might not have been raised without a group. The method captures shared experience and enables individuals to put forward their opinions and insights. The sessions should be guided by facilitators but allow for flexibility to let the discussion steer and follow unanticipated problems and issues that are being mentioned (Sharp et al., 2019).

Brainstorm

Brainstorming (BS) is a technique that can be used to reach solutions to practical problems and fosters group creativity where ideas and thoughts are shared among members spontaneously (Al-Samarraie & Hurmuzan, 2018), but it is beneficial if BS sessions are planned for in advance (Bonnardel & Didier, 2020). Positive feedback is important to increase a group's creativity (Lu, Qiao & Hao, 2019) and there are several ways to reduce performance anxiety or stress by tackling the problem from different perspectives, such as having a BS session to consider the worst possible idea (Interaction Design Foundation, n.d.-c).

Al-Samarraie and Hurmuzan (2018) write about three different brainstorming techniques, where the performance of these techniques is highly dependent on the context. In verbal/traditional brainstorming (TBS) group members actively participate in a dialogue and verbally share their ideas one at a time. This helps group members to combine ideas, however, it can be discussed that individuals working alone produce more ideas, and therefore nominal brainstorming (NBS) promotes group members to generate ideas individually and no communication with other group members takes place. Electronic brainstorming (EBS) facilitates simultaneously idea generation with the use of online resources. The discussion process can be supported by chat, e-mail or other resources to enhance a group discussion.

Kunz et al. (2014) write that challenges can occur when sighted and blind people collaborate as it can be difficult to overcome the different ways of perception and expression. A BS session mixed with both sighted and blind people could lead blind people into an unintended and unconscious exclusion. Screen readers and Braille can be used to access the same digital information for a sighted and for a blind person. However, accessing and processing the information will be different since visual channels allow for fast and parallel perception of information while Braille or audio is not comparable to a serial perception. Therefore, blind people will need more time to process the content of the information. Non-verbally communication such as gestures, postures, facial expression provide a large amount of information that is only processed visually. These non-verbal expressions are also used when conducting a BS session for coordinating the discussions and turn taking. To engage blind people for these coordinations is by verbalizing it which evokes new problems as non-verbal communication is parallel and unconscious and thus have to be made conscious to be able to translate it to verbal information. This can slow down the BS session.

Exploratory research

Exploratory research is the preliminary research to define and analyze the nature of the problem to be solved (Doyle, 2016). Exploratory research is research that helps gain familiarity with a phenomenon to achieve new insights and understanding of it, it can also be called formulative research and refers to developing a hypothesis rather than testing it (Kothari, 2004).

4.4 Define

In the define phase, gathered findings from the disover phase are supposed to be organized, structured and then analyzed to be able to define the challenge and make conclusions regarding what to implement in the design (Design Council, 2021). This section will describe some methods that can be used for this purpose.

Affinity diagram

To understand collected data it needs to be explored and organized to be able to visualize and analyze the overall structure of data. Affinity diagram is a method to sort and organize the ideas produced during a brainstorming session (Widjaja & Takahashi, 2016). It allows for exploring the data by identifying themes and searching for an overall narrative in the data. By organizing the individual ideas and insights into a hierarchy it will show the most common structures and themes, and it is done by grouping together elements that have a common factor. The groups are not predefined as they are dependent and emerge from the data. The process of the grouping is a gradual process, as the notes are put up one by one, and with every new note a search will be done to see if it relates to any other note to be grouped together with (Sharp et al., 2019).

The Golden Path

Using the golden path method is a way for designers to identify the ideal way of interacting with a product. This method investigates the key steps a user takes to achieve the product's main goal, which should be easy and effortless. The method can reveal alternative paths additional to the central flow, which are optional routes and should be seen as secondary experiences. These can be outlined outside of the main route but focus should be on the golden scenario (Design Sprint, n.d.).

Extreme Characters

Djajadiningrat, Gaver and Fres (2000) founded the method extreme character which is the use of fictional users with exaggerated emotional attitudes and personalities. The extreme characters with their specific attitudes and needs will be used to design for users that are extremes and expose traits that might have been hidden when only designing for a specific target group. To not only design for one specific target group will explore the interaction and understand other design possibilities. The use of extreme characters will help to consider the interaction but also the sociocultural role of a product (Djajadiningrat et al., 2000).

Journey mapping

A *User journey map* is used to visualize the experience a user will have while interacting with a product or a service. The visualization shows the user's story of actions, feelings and perceptions while interacting with the product over a period of time. Usually a user journey map is used with personas or scenarios to help to understand the user that will use the product (Martin & Hanington, 2012). A *journey map* is used for discovery to create a holistic view of the user's experience to create a narrative that will help to uncover both positive and negative moments while interacting with a product (Gibbons, 2018). Gibbons (2018) writes that the key components of a journey map is to have an *actor* - usually a persona or a user who experiences the journey, *scenarios and expectations* - that describe the situation that the journey map addresses, *journey phases* - different levels of the journey, *action, mindset and emotions* - the behaviours thoughts and a feelings that the actor have and *opportunities* - the insights that the mapping gathers.

Benchmarking

Benchmarking is a method that involves making comparisons of products, processes or performance used to improve processes or create a new standard (Value Based Management, 2021). Benchmarking for UX design is used to evaluate the user experience of a product (Moran, 2020), to help the designer to create a clear reference point for designing and redesigning to make improvements. UX benchmarking is a way to evaluate the user experience by a comparison to a meaningful standard, which is often done by tracking the process of the product or service, to then compare to similar ones (Joyce, 2020).

4.5 Development

The development phase involves finding solutions for the defined problem (Design Council, 2021). It is an iterative process of designing with repeated usability testing and redesigning.

Prototype

A prototype is a simple version of the product. It can indicate the appearance of the final design, how it will work or what functions it will involve. Creating prototypes allows designers, stakeholders and users to interact with the product, and to explore its intended design and functionalities. Prototypes can vary in fidelity, and it is common to create rapid and low fidelity prototypes in the beginning of a design process, while creating high-fidelity prototypes later in the process (Sharp et al., 2019).

Sketch
Sketching is a low fidelity prototype that consists of easy drawings, which are often hand-drawn. Sketches are usually drawn to communicate the preliminary design ideas and the focus should be on the design concept, not details (Sharp et al., 2019; Hartson & Pardha, 2012).

Storyboard
Storyboard is a low fidelity prototype that is often used to show scenarios of an intended interaction or performance of a task using the product. A storyboard can be constructed of a series of sketches or scenarios to display its intended usage (Sharp et al., 2019).

Wireframes
Wireframes represent the layout of a design. It shows interactive objects and focuses on the screen content and its behaviour. A wireframe often includes menus, buttons, dialogue boxes, tabs, and navigational elements as it is supposed to convey a visual schematic of the interface (Hartson & Pardha, 2012).

Mock Up
A mock up can be used both early and late in the design process. Early in the process it can be used with low-fidelity prototypes to gather valuable feedback of functionality, usability and understanding (Interaction Design Foundation, n.d.-b). It can also be a simulation of a final product to be able to advertise to stakeholders (Doyle, 2016; Hartson & Pardha, 2012). Late in the process a high fidelity mock up can be used to demonstrate interaction to use for usability testing or as a communication tool (Hartson & Pardha, 2012).

4.6 Delivery

In this phase of the design process the product should be tested with potential users to evaluate its usability and gather insights of the applications implemented features and functionalities and the perceived user experience. Findings and usability problems will be analyzed to make further refinements and improvements to the design by rejecting design solutions that do not work and improving the ones that will (Design Council, 2021).

Heuristic Evaluation
A heuristic evaluation is executed by investigating an interface, and finding opinions of what is good and bad about it (Nielsen & Molich, 1990). It is a usability engineering method to find usability problems in a user interface design by examining

and judging the interface with usability principles called "heuristics", to then attend to these problems as a part of an iterative design process. The ten most important heuristics are; *visibility of system status, match between system and real world, user control and freedom, consistency and standards, error prevention, recognition rather than recall, flexibility and efficiency, aesthetic and minimalist design, help users recognize, diagnose, and recover from errors,* and *help and documentation* (Nielsen, 1994). The heuristics are general rules that describe common properties of a usable interface, to be used as a checklist of the evaluator. (Nielsen, 1995).

Performing a heuristic evaluation is done by evaluators individually, going through and inspecting the interface several times to compare them with the heuristics (Nielsen, 1995). The output of the method is a list of usability problems in the interface with references to the heuristics that were violated in the design. Botella, Gallud, and Tesoreiro (2011) write that heuristic evaluation should end with a set of recommendations or advice that requires experiences from the usability evaluations and propose the idea of using interaction patterns that can offer a solution to concrete problems, in the use of heuristic evaluation. Botella et al. (2011) assigned interaction patterns based on the context of use of the pattern to a heuristic (Figure 4.2), the relationships are based on how relevant the interaction patterns are to solve a usability issue derived from a heuristic. The author's claim that this correlation offers designers and developers a starting point of how to solve a usability problem that was detected in heuristics.

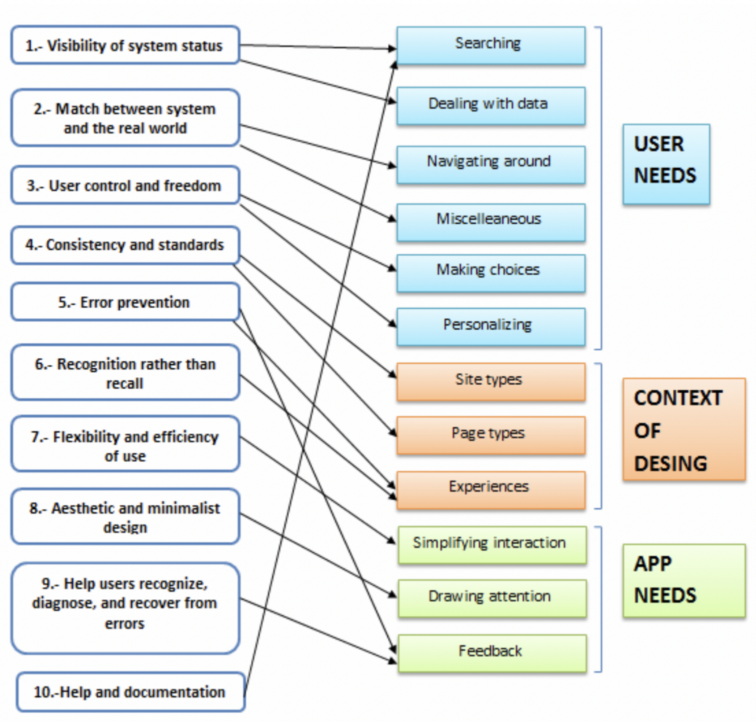


Figure 4.2: Correlation between heuristics and interaction design patterns (Botella et al., 2011).

RITE

RITE is an empirical rapid evaluation method that stands for "rapid iterative testing and evaluation". It is used as a formative usability inspection method to early in the process identify and change problems in the design. RITE engages user-based UX testing with a rapid "test-and-fix" approach by selecting some specific features from the design to evaluate in a quick and easy action, with the intention of quickly iterating and fixing problems. The method is usually tested on team members or participants without following specific protocols or writing reports. Instantly after testing the problems will be evaluated to immediately implement the required changes. Additionally RITE testing can be conducted to investigate the new changes to determine its effectiveness. To attend to a problem immediately helps move on with the design without having any problem blocking the process (Martin & Hanington, 2012; Hartson & Pyla, 2012).

Cognitive Walkthrough

Cognitive walkthrough is a usability method to inspect and evaluate how easy a system is to use (Martin & Hanington, 2012). It provides a cognitive perspective as it simulates how a user will be solving problems in each step while interacting with a system (Sharp et al., 2019). When preparatory instruction of the system is unlikely to occur, and the user needs to engage in the interface to know what to do next, the user takes steps to move closer or further from their goal. The method is used to identify usability problems during the interaction to evaluate each of these further (Martin & Hanington, 2012).

Additionally, a *pluralistic walkthrough* can be conducted where usability researchers, users and developers together work through a scenario with tasks in the interface. When completing the tasks and performing the scenario the usability issues will be discussed, where researchers also bring the advantage of expertise and knowledge to interpret each step of the interaction. Performing a pluralistic walkthrough, each person assumes the role of a typical user which includes a strong focus on users' tasks and experience at every level throughout the process. During the walkthrough each person should write down their thoughts and expected action when working through the scenario, without conferring with other participants. After performing the task a discussion can be held to share insights and opinions about the prototype (Shart et al., 2019).

Usability Testing

To ensure meeting the needs of a full diversity in a design, users have to be involved in the design process (Preiser & Ostroff, 2001), as an application's value is determined by the need or willingness to use it and its functionalities, along with its usability. The usability of an application is examined by usability testing (Sharp et al., 2019), using methods with involvement of people (Borys & Milozs, 2018). Usability testing is a process of revealing errors in the design during the design process (Qian & Zhongsheng, 2010), with the goal of detecting these errors of usability problems in the user interface and documenting them to later be able to correct them in future versions of the design. Another goal is to evaluate whether the product is usable and if the intended user can achieve the task for which it was designed for, and if the user is satisfied with their experience (Sharp et al., 2019). According to Nielsen (2012) five participants is enough in a usability study, where testing five people can discover the same amount of usability problems as testing with more participants.

Conducting usability testing is important since it provides insights of a user's mind-set and how a real user works through the interface (Nielsen & Landauer, 1993). Yudhoatmojo and Sutendi (2019) write about two types of usability methods, remote methods and conventional methods. Performing usability testing remotely allows researchers to evaluate the usability testing and to gather information from users, without having to be present at the same location as the users (Baravalle & Lanfranchi, 2003). According to Baravalle and Lanfranchi (2003) conventional usability methods are performed in a controlled laboratory environment where the test subject individually executes tasks under supervision of the researcher. The main advantages of performing usability tests in a laboratory is that the researcher can control the environment and the circumstances that can occur during the test. However, it can be more difficult to recruit participants to participate in a test when it is performed in a laboratory, and some people cannot participate due to its being time consuming, illness or disabilities. Usability testing can also be performed in a temporarily assigned controlled environment by temporarily setting up equipment to convert the space into a usability laboratory (Sharp et al., 2019). This enables participants to perform the test in a less artificial setting compared to a laboratory space, but still in a controlled setting where the researcher can manage the environment that might impact participants' experience, also participants may have it easier to engage in the usability test, because they do not have to go to any specific place, but can for example perform the test in their home or work environment.

Remote Usability Testing in Field

The biggest advantage of remote usability testing is the number of users who can participate and the low cost it entails the researcher. However, remote usability testings does not offer the same possibility to perform direct observations (Baravalle & Lanfranchi, 2003). Yudhoatmojo and Sutendi (2019) mention two types of remote usability tests, *remote synchronous usability testing* and *remote asynchronous usability testing*. The former separates the evaluator and the test subject by location, but not time. In the latter, the test subject and the evaluator are separated by both time and location, and the test subject performs the tasks without any assistance from the evaluator. Methods for remote synchronous usability testing are best suited for complex tasks, where the steps on how to perform the test are unstructured. Remote asynchronous usability testing is the opposite and is best suited for simple tasks where there are specific execution steps.

Studies have been made to compare results from conventional laboratory tests and remote usability testing (Baravalle & Lanfranchi, 2003; Andreasen, Nielsen, Schrøder & Stage, 2007; Tullis et al., 2002). Baravalle and Lanfranchi (2003) performed both laboratory and remote usability tests to compare the results. This showed that both methods revealed the same core problems and consisted of similar task time and success measures. Laboratory testing proved to be able to identify user motivations and usability issues better, and remote testing proved to be more advantageous for understanding problems that were unique to specific types of environments and users, due to the number and diversity of users (Baravalle & Lanfranchi, 2003). A great advantage that the remote method showed was the diversity among users, which increases the possibility to uncover problems that are unique to specific types of users but also problems that are unique to specific environments due to them using their own computers all in separate environments (Tullis et al., 2002).

Use Case

By performing use cases it is possible to capture the users interactions and requirements about a product. Use cases is a specific process performed by following step-by-step descriptions while capturing the detail of the interaction. The use case involves a normal course which is a set of actions most commonly performed, together with alternative courses that covers additional possible sequences of interactions. This is a useful method being able to discover and enhance usability problems and errors in the design, but also to capture the user's choice of interactions and goals when using the product (Sharp et al., 2019).

Observation

Observations can provide important information about activities and the context of the situation. Observations allow researchers to gather details about users' behaviour and how they use the technology, which is information that cannot be provided with only interviews or questionnaires (Sharp et al., 2019). Generally, the researchers directly observe the test users as they interact with a product, however remote observation can involve users in different locations (Thompson, 2003). With remote observation the researcher does not observe the user directly and rather observe the gathered data, since the researchers and the users can be separate both in time and space. Conducting an observation at the same time but at a separate location means that the researcher observes the user as they perform a test and can remotely communicate with the user. To perform an observation at both different time and place means that the researchers observe the users actions after, commonly with help from a recorded video or audio (Thompson, 2003).

Think Aloud

Hammontree, Weiler and Nayak (1994) explain *think aloud* as one conventional method that is commonly used for usability testing. Using the think aloud technique, the participants verbally describe their thoughts and experience while interacting with a product. By constantly encouraging the participant to talk about their experience gives the evaluator valuable access to their intuitive opinions and their understanding of the design (Hartson & Pardha, 2012). Performing the think aloud method remotely requires the prototype to be accessible and controllable by the remote user, but also that the user's interaction with the prototype will be visible even for the observer together with an audio record of the user's comments. This can be set up using a sharing window tool on the device, and a telephone call.

Rating Scales

To gather demographic data and users' opinions and subjective satisfaction, rating scales can be used. Two common scales are semantic differential scale and likert scale, both good for making judgements of how easy, hard, usable etc. a task was. The likert scale is mainly used to measure opinions and beliefs and the semantic differential scale explores the users attitudes (Sharp et al., 2019). The scales present a value with different levels of an attribute that is divided in equal divisions with the most extreme value in one direction with points in between the two anchors of both ends of the scales (Hartson & Pardha, 2012). There are benefits and disadvantages with both of the scales, the likert scale is more commonly used and can be easier to understand since the statements are provided for the user, however a semantic differential scale is easier to compare and there is less risk that the wording does not limit or bias the users (Schibeci, 1982).

Questionnaire

Questionnaires are a well-established technique used to collect users' opinions which is often sent electronically to potential participants. Questionnaires can include closed or open-ended questions, as the participants can answer using a scale or describe using their own words. One advantage using this method is that it can be distributed to a large number of participants since it is more flexible than participating in an interview (Sharp et al., 2019).

Interview

Open-ended interviews questions allow for the participant to be exploratory during the interview and to have a conversation about the design. With open-ended interviews it is possible to go into depth about specific topics that occur in the conversation of the interview. Structured interviews questions are more commonly used when specific feedback is required about particular design features or such (Sharp et al., 2019).

Thematic Analysis

Thematic analysis is a flexible method used to analyse data for qualitative research (Norris, White & Moules, 2017) as it provides an accessible and systematic procedure to generate codes and themes from qualitative data (Clarke & Braun, 2017). It is a method to structure data based on themes, which could be either determined before the analysis (*deductive*) or arised on the basis of the collected data (*inductive*) (Langemar, 2008). The intention with performing qualitative research is to generate knowledge that is grounded in the human experience (Norris et al., 2017), by identifying patterns regarding participants' lived experience, behavior, views and perspectives (Clarke & Braun, 2017). Thematic analysis helps the researcher to take a well-structured approach on how to handle the data, which is especially beneficial when summarizing and identifying key features of a large data set (Norris et al., 2017). Further, it is a useful method to identify, organize, analyse, describe, and interpret different patterns that appear within the data set (Clarke & Braun, 2017), to examine various perspectives of different participants and gather unanticipated insights (Norris et al., 2017). Clarke and Braun (2017) describe thematic analysis with the aim to, based on the research question, identify and interpret key elements that appear in the data set. In this way, thematic analysis can provide a rigorous and trustworthy result with many insightful findings. Clarke and Braun (2017) describe thematic analysis as codes and themes that are identified in the qualitative data, where codes are the smallest units of the analysis, and themes consist of a collection of codes. Codes can capture various types of information, such as interesting features that are relevant to the research question. Codes then work as building blocks to create themes, which constitute patterns of meaning and become a central organized concept. According to Sharp et al. (2019), thematic analysis is often used in combination with affinity diagrams to identify themes and show common structures.

5
Planning

This project was planned to consist of four phases similar to the double diamond process (Sharp et al., 2019): *discover, define, development*, and *delivery*. In this section an elaboration of each phase will be outlined including the methods and how they were planned to be used.

5.1 Discover

As the project is initiated by Locum, there are some guidelines and criterias to the end product for this project to adhere to. Therefore, the purpose of the first phase is to conduct background research about the subject and hence perform a *literature review*. One criteria from Locum is to make the application accessible to all users, and meet the needs of people with different types of disabilities, the plan is to create a *focus group* that will be involved through the project and evaluate the design. An initial meeting with the focus group is planned to involve a *brainstorm session* to gather insights, and to understand the user's needs and challenges interacting with an application for wayfinding, as a foundation for the development of the graphical interface of the application. Also, *exploratory research* at Danderyds Hospital will be performed to examine the environment of where the application will be used and to determine the specific route for the application in this project.

5.2 Define

Results from the brainstorming session will be analyzed using *affinity diagram* and *thematic analysis* to identify common patterns and useful insights. The purpose of this analysis will be to summarize all data to create design guidelines to consider during the development phase. In this phase the goal is to define how the product should work and what functions it should involve. To illuminate the intended interaction and performance of the application *the golden path* will be conducted as a method to investigate the product's main goal and identify the ideal way of interacting with it (Design Sprint, n.d.).

5.3 Development

Starting the development phase sketches and easy *wireframes* will be created to explore the layout of the application. This will be combined with methods of *storyboard* to lay out different scenarios and to explore user interaction. Based on this, a *high fidelity prototype* will be created in Figma, including color, buttons, and text and will eventually become an interactive prototype. The prototype will be created in collaboration with Axel Health to integrate the user experience research with their expertise of how to technically implement a working product. The Figma prototype will be continuously redefined and developed based on user feedback.

5.4 Delivery

To find usability problems within the interface *heuristic evaluations* will be conducted based on Nielsen's (1994) ten most important heuristics, which will be used as a checklist to evaluate the interface and if additional usability issues appear they will be noted as well. The aim for this study is to perform various forms of *usability testing*, using different techniques and methods such as *observations* and *think aloud technique* to gather the most insights and usability problems (Tullis et al., 2002). For the first step involving users, a remote synchronous usability testing (Yudhoatmojo & Sutendi, 2019) will be performed with the focus group to ensure that the design fulfills the requirements of the different user groups. Later in the process, *asynchronous usability testing* (Yudhoatmojo & Sutendi, 2019) will be performed involving test subjects who have an appointment at the hospital, where they will answer questions about the product using both *likert scale* and *semantic differential scale*. Also, *interviews* will be conducted after each test to understand and gain insights of the users impressions about the product. Data will be analyzed using *thematic analysis* along with *affinity diagrams*.

6
Execution & Process

In this section, a sequential summary of the design process with its accompanying methods and design iterations will be described. The project includes four iterations where each iteration was considered to end whenever there was a need for redesigning of the prototype. This section will focus on presenting the outcome and the events that occurred in the actual execution along with the different design methods.

6.1 Design process

This project followed an iterative design process based on the double diamond approach as seen in Figure 6.1, including a variety of methods presented in Table 6.2. This section will further describe the design process and the focus of each phase.

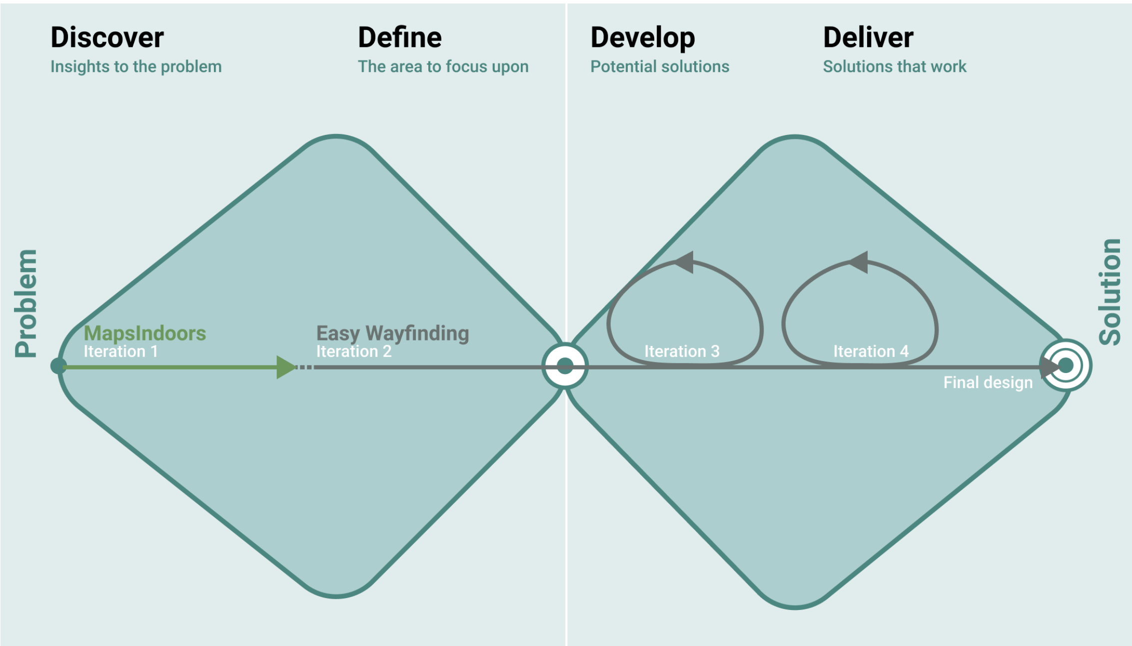


Figure 6.1: The design process executed for this project.

6.1.1 Discover

In this phase focus was to explore the problem space and gather insights about the problem, to later be able to make design decisions in the next phase. It was important to discover requirements for the interactive product and understand the problem. This project had a user-centered approach as it was of importance to involve real users and their goals in the design process to ensure that the product would be usable and satisfy the users (Sharp et al., 2019). Since this application will be used in such a complex environment as a hospital by a variety of people, the application must be designed to be usable for everyone.

6.1.2 Define

According to Sharp et al. (2019) this phase frames the design challenge by discovering the problem space and collecting insights from literature and users. This is done by analysing and interpreting previous discoveries to define what will be developed and the scope of the project. In this phase the basis of the product's requirements will be formed which will be used to underpin the subsequent design and development in later phases.

6.1.3 Development

The development phase focuses on designing solutions for the product and proposing ideas that meet the defined requirements. The core is to design alternatives by creating prototypes, but also to consider the details such as colors, menu design and icon design. Interacting with the product is the most effective way to evaluate a design, which makes prototyping a huge part of the development phase, to design for the behaviour of the interactive product and their look and feel (Sharp et al., 2019).

All prototypes in this project were created in the vector graphics editor and prototyping tool, Figma. Figma is used to design user interfaces and user experience for real-time collaboration (Figma, n.d.). Designing and creating prototypes in Figma was done throughout the design process to be able to communicate low- and high fidelity prototypes within the design team and also to present interactive high fidelity prototypes to the users and stakeholders.

6.1.4 Delivery

During this phase the product will be evaluated and tested to be able to reject solutions in the design that do not fulfill the requirements, where improvements will be made to enhance the product (Design Council, 2021). At the end of this phase the product will be finalized and launched. However, evaluating and testing the product can be done using different methods and involve users at different degrees (Sharp et al., 2019), as for this study several methods of usability testing were performed involving users where each method focused on different perspectives of the design principles to discover as many usability problems as possible.

By performing different types of usability tests, focus could be aimed to investigate the different design principles and how users experience the design in different settings. By highlighting which aspects and design principles that were to be examined in each test, the execution could be shaped accordingly and also involving different users. Table 6.1 outline the different aims for the usability tests performed in this study, where some design principles were uniquely examined in every usability test, while some principles could be evaluated in all of them. More details about each test will be described later in the process.

Table 6.1: Design principles that were examined during usability testings.

Maze usability testing	**Usability testing on smartphone**	**Workshop/Focus group**
Flow of interaction	Flow of interaction	Accessibility
Expectations of interaction	Placement of buttons and functions	Universal Design
Descriptive navigation instructions	Descriptive navigation instructions	Descriptive navigation instructions
Time to execute a task	Hit areas	Layout
Errors	Feedback of actions	
Insights of their experience	Emphasis	
Emphasis	Errors	
	Hit areas	

Table 6.2: The executed methods performed in the design process.

Phase	**Method**				
Discover	Literature Review	Focus Group	Brainstorm	Exploratory Research	
Define	Affinity Diagram	Golden Path	Extreme Characters	Journey Mapping · Patient Mapping	Benchmarking
Develop	Prototype	Wireframes	Mock Ups	RITE	
Deliver	Heuristic Evaluation	Online Survey · Use Cases · Likert Scale · Questionnaire	Usability Testing · Think Aloud · Observation · Interview · Focus Group	Thematic Analysis	Affinity Diagram

6.2 Pre-study

The pre-study involves the phases of discover and define of the design process. In the discover phase a literature review, interviews, focus group sessions with brainstorming, and exploratory research was performed. In the define phase affinity diagram, golden path, extreme characters, journey mappings, and benchmarking were used to be able to support design decisions and set design principles.

6.2.1 Discover

In the following section the discover phase will be further explained with its associated methods. At this point it was of importance to understand potential users' needs and requirements of the application, and therefore brainstorming sessions with a focus group were put together to be involved throughout this project.

6.2.1.1 Literature Review

In the beginning of this project a literature review was performed to gain insights about this specific field of research and to understand gaps in the research. This was done by reading literature about previous research relevant to the project, to evaluate what sources to use, to understand the gaps in the research and to learn about important concepts for this project, regarding areas such as design for accessibility, design for disabilities and indoor navigation.

6.2.1.2 Interviews

To gather first hand insights of how visual impairments affect the usage of navigation systems and how help tools can be used on digital devices, two interviews were conducted interviewing three people with visual impairments. The first interview was with one participant with congenital visual impairments, and has no vision at all. The other interview was performed with two participants, one with severe visual impairments and the other one was slightly visually impaired. The conducted interviews were performed with open ended questions to let the participants share their knowledge unimpeded. At first, general questions about how to navigate on computers and phones with the use of different help tools were asked and then questions about navigating using applications in the physical environment.

The interviews revealed that common help tools provided in phones are *VoiceOver, Text-To-Speech* (TST) programs installed on the computer or phone and a *braille display* that is an external device. The VoiceOver is a gesture-based screen reader that gives audio descriptions of what is on the screen. TST also reads digital text and converts it into speech, and is often controlled by use of keys on a keyboard. Braille display is used for people with no sight for displaying braille characters. Which aid that is being used depends on the purpose and content of the device and page, but mostly a braille display will be used while using a computer for a person with no sight and the other two participants stated that they use VoiceOvers or TST along with other preinstalled functions in their devices such as inverted colors, zoom functions and bigger font size. The most common problem when navigating on a website or in an application is that buttons and links do not have any accessible text that can be converted to speech, which makes it impossible to know its function. The lack of this is especially common in mobile applications.

To move around in a physical environment, the participants use a white cane, a guide dog and different kinds of GPS applications, such as Google maps, Apple maps or Blindsquare. When navigating to a specific goal, Google and Apple maps are being used. When using those navigation applications the integrated VoiceOver was used and the participants mentioned the importance of the navigation description providing one step at a time. Further, the navigation descriptions should contain both the name of the street and the travel of direction. To have a *points of interests* (POI) in the navigation descriptions was claimed to be of importance too, since it helps to have elements in the surroundings that can be used to locate one's position. The application Blindsquare is a navigation application that is developed for people with impaired vision that describes where the user currently is located, and does not tell the user where to go as in other navigation applications. The most important feature of Blindsquare is that it tells which streets the user is walking past and uses other elements in the environment such as stores and crossings to help the user to understand its location. To navigate inside a building the participants only use the white cane as aid, apart from asking for help. However, in the use of a potential indoor navigation application, if a live position cannot be used, it was mentioned that providing POI:s on the map are of extra importance since it can be used to determine the user's location where it for example can be used to smell coffee close to a cafe.

During the interviews some especially important insights were mentioned regarding creating a design for people who are visually impaired. First, all functions and features implemented on a website or in an application must work with a text-to-speech function. Second, it is important that there always is descriptive information that explains the function of the different objects or buttons that a text-to-speech aid can read aloud. In this way the website or application can be understood and managed without seeing icons, buttons, and objects. Lastly, for people with severe or slightly visual impairments colors are important, and therefore, the contrast needs to be high and the font sizes need to be big.

6.2.1.3 Focus Group

The focus group that was put together for this project involved members of Locums collaboration council for accessibility. The focus group was recruited to participate in group discussions and usability tests during the whole project. The participants in the focus group had different disabilities, such as visually impaired, rheumatism, mobility impairments, etc. The user classification of the participants were mainly DAP and some SAP, however none of the participants were FAP (Singh Tandon, 2018).

6.2.1.4 Brainstorm

To gather insights and to understand the user's needs and challenges while interacting with an application for wayfinding, brainstorming sessions were conducted with the focus group at two separate occasions, constructed remotely online using Microsoft Teams. The purpose with these sessions was to gather insights from users with different disabilities to have as a foundation for the development of the graphical interface of the wayfinding application. The two sessions were 1,5 hours long, with a 10 minute break in the middle. The first session included four participants and the second session included seven participants. Along with the participants of the focus group, developers and project management of the project were also present. By involving both the stakeholders and the users in these sessions gave further insights and a deeper understanding of important features to consider in the design.

Each session with the participants consisted of two sets of brainstorming sessions. Both of these had premade clear problem statements to facilitate reaching the aim of the session. A warm up presentation was held in the beginning of the meeting, as the participants presented themselves to place the participant in a more outgoing mode to enhance creativity. In the first brainstorm of each meeting, the participants were asked to generate ideas of an application for wayfinding at a hospital that would be the worst possible application ever. For the second brainstorm the participants were asked to consider what features would be included in an application for wayfinding at a hospital that would make it the best application ever. The purpose of considering both the worst and the best idea was to force the participant to acknowledge both good and bad ideas, and to decrease the feeling of performance anxiety. Using these methods would gather insight of what is important to both include and to exclude in a design for such an application. For each brainstorm the participants were asked to first think for themselves for four minutes and make a numbered list of their ideas. After the four minutes had passed the participants one at a time presented their ideas to the group. Letting all participants share their ideas to the group and to have two separate brainstorms at each meeting refers to Kelley and Littman's (2000) brainstorming secret number four, allowing the participants to *"build and jump"*, that in the second brainstorm the participants could build on others' ideas, or to continue on their own.

Most of the participants had visual impairments and due to the fact that the meeting was held online it was not possible to present the ideas to each other visually. Therefore, the participants needed to conduct a verbal brainstorming by listening to each other's ideas and could not read anything written or see any body language. The two brainstorming sessions were a combination of verbal/traditional brainstorming (TBS), nominal brainstorming (NBS), and electronic brainstorming (EBS). It was a TBS session as the participants shared their ideas verbally one at a time. However, since the participants first had to develop their ideas on their own with no communication and then share them to each other it was also a NBS. Further, it was also an EBS as it needed to be performed online. The reason why a verbal brainstorming session where held is that everyone would process the information the same way, even if they were sighted or not. Screen readers and braille can be used when blinded and sighted people conduct a brainstorming together, however that means that the information will be processed differently. Therefore it was important that everyone conducted a TBS to process the information the same and the reason why no visual graphic elements were included in any of the sessions.

6.2.1.5 Exploratory Research

To gain more familiarity of the problem of missed appointments due to getting lost at the hospital and to examine the environment of where the application was going to be used, exploratory research was performed at Danderyds hospital in Stockholm. Due to the current circumstances of COVID-19 and the restriction at the hospitals, this exploratory research was conducted remotely with a few people from Locum and Axel Health on site, using a video call to livestream to be able to investigate the environment. The visit at the hospital revealed that wayfinding at the hospital could be difficult with only the help of signage based on contradictory information or lack of signs and therefore it can cause much confusion. The placement of guidance information varied from being placed in the ceiling, in the elevator or on the floor. This in combination to the various possible routes to take to specific destinations made the wayfinding at the hospital somewhat complicated.

The exploratory research was also conducted to determine the specific routes for the pilot and test version of the application at the hospital as not all buildings or departments would be involved at the start. The visit at Danderyd led to the decision to include three departments in the pilot version of the application, with routes of possible ways to navigate to them. These three departments involved the x-ray, orthopedic and the emergency room. The reason for this was to test the application in a small version at first, to investigate electronics and implementations and evaluate the result, before expanding the application for the whole hospital. Further, some additional POI were decided to be marked on the map. These were locations such as restaurants, elevators, toilets, and shops on the floors affected by the routes.

Creating maps to provide an overview of the hospital

After conducting the exploratory research it was necessary to further understand the layout of the hospital and all options to transfer in the buildings, and therefore overview maps of each floor were created by a compilation of all blueprints of the concerned buildings, with the routes and POI's pointed out (Appendix A). The first route extends from the entrance of the emergency room at the first floor, going up to the second floor to the department of emergency. This route differs from the other two where patients arrive without any invitation. The second route extends from the main entrance located on the third floor up to the X-ray on the fourth floor. The third route goes from the main entrance up to the fourth floor to the orthopedic cashier, then back to the third floor to the reception of the orthopedic. In addition to these routes, different kinds of POI's were marked on the map as for example toilets, restaurants, ATM and elevators.

6.2.2 Define

Based on the background research done in the discover phase the next step in the process was to analyze and interpret the insights and findings to define the design scope to further investigate the research questions.

6.2.2.1 Affinity Diagram

The first step in the define phase was to analyze the result from the brainstorming sessions with an affinity diagram, to be able to define what the participants in the focus group thought to be essential for a wayfinding application and to discover qualities that were important to these users. Everything that had been brought up during the brainstorming sessions were written down as notes and was put up one by one on a digital canvas to then be organized to create separate groups of the ideas. After the groups were created, they were examined and adjusted to create categories based on Singh and Tandon (2018) key elements of universal design; *functionality, usability, performance* and *product attachment*. Since there was no product developed yet, the "product attachment" category was not considered for this phase in the process. However, "functionality" and "usability" became two categories of the grouping in the affinity diagram as they were groups that had emerged from the data. The category of "functionally" focused on the aspect of how well the application was being suited to serve the purpose, and the category usability referred to the ease of use and learnability of the product. Instead of using the category of "performance" that refer to the action or process of performing a task or a function, a category of "navigation" was added based on the grouping from the affinity diagram, and since it is the main purpose and function of the application. Another category named "help tool" emerged from the data and was added as a group in the result of the affinity diagram, since it consists of specific help tools that are desired to be included in the interface that will affect the usability of the product. Another category called "design" was added that only referred to specific design details that need to be considered in the development of this product. Singh and Tandon (2018) claim that if all of the four elements are being satisfied in a design the possibility of the product to be accepted as a universal product will significantly improve and therefore these along with our other categories will lie as the foundation in the start of the development phase of the product. All insights that were gathered from the brainstorming sessions were then listed and organized in their categories, along with support by the literature (Appendix B).

6.2.2.2 The Golden Path

To explore and visualize the ideal path of the interaction with the application, the golden path method was conducted. At first, a general path was created concerning a scenario of the user receiving the invitation with the goal of arriving at their appointment (Figure 6.2). This created a good overview of the intended use and the ideal interaction with the application. In addition to this ideal path, optional outcomes were added at points where alternative scenarios might come across the ideal flow. This showed to be useful as it gave insights to where in the interaction additional scenarios might happen and where there might be a risk for misunderstandings and usability problems. These optional routes showed some guidelines where it may be necessary to put extra focus during the development of the application to avoid mistakes or confusion when using the application.

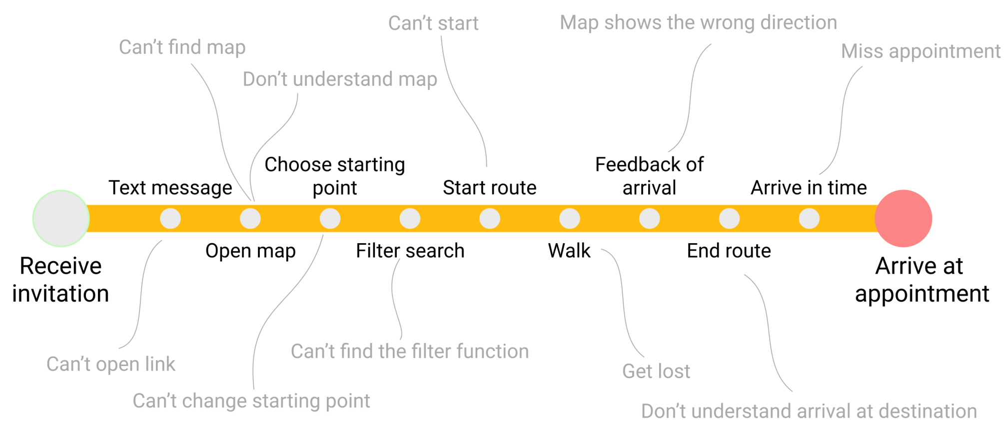


Figure 6.2: The Golden Path illustrating the general and ideal interaction with the application.

When the general path was created it could be broken down into three more detailed paths to target each specific route that the application would include (Figure 6.3-6.5). Similar to the general path, these paths also included alternative scenarios of possible interruptions that could occur in the scenario. This was especially useful to outline all the different steps and possibilities that could appear in the paths compared to the ideal path. This resulted in an understanding of the importance of clear instructions and never to take steps in an interactive process for granted, as all users will interpret the design differently and the application must support different interactions without the existence of any mistakes. Further, this method was a good approach to define the different routes step by step, while discovering potential locations where the wayfinding process might be more challenging.

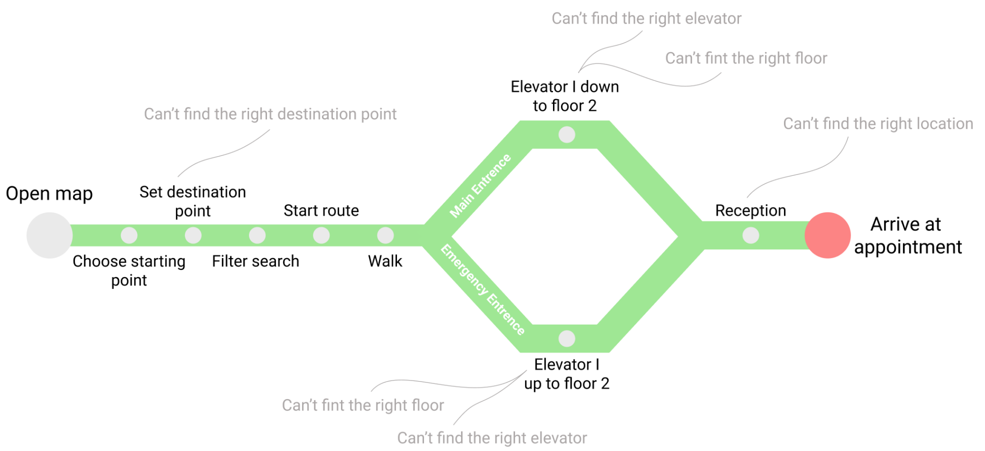


Figure 6.3: The Golden Path illustrating the route to the emergency room.

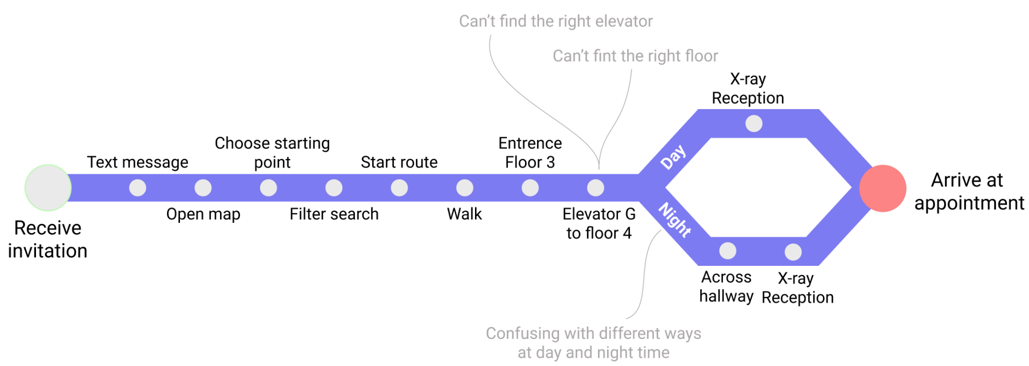


Figure 6.4: The Golden Path illustrating the route to the X-ray.

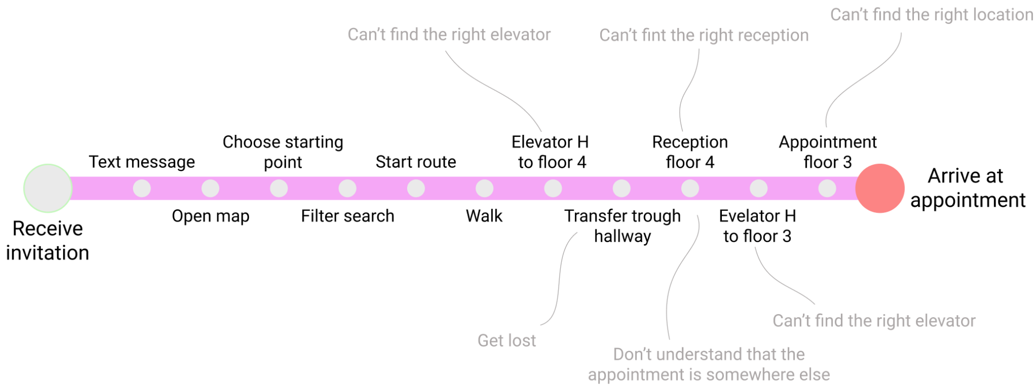


Figure 6.5: The Golden Path illustrating the route to the orthopedic.

6.2.2.3 Extreme Characters

Three extreme characters with exaggerated emotional attitudes and personalities were created to be used to help investigate and explore the design and interaction of the application. These three characters were produced to be different from each other, to cover a wide range of the intended target group. Considering that the design would be accessible to all people, these characters were all assigned a disability, to help focus on difficulties and potential problems that could arise during the interaction with the product due to poor accessibility. The first extreme character was Stina, a young girl who had dyslexia and does not like to plan ahead. Her phone is old and slow to use and she usually does not use it more than calling and texting. The second character was an elderly lady called Greta, who is visually impaired. Greta is a social and forward person who talks to everyone, she is not afraid of failure and often takes on more than she can manage. Despite any adversity, she is always positive and tries to solve the problems she encounters. The third extreme character created was Ove, a middle aged man in a wheelchair. Ove's biggest interest is technology and he does programming in his spare time. He gets angry and annoyed when things do not work as he expects, and he is happy to share his opinions by contacting customer service of the companies that developed the product. He has no patience for trying to understand technology with ill-considered design. These three characters cover different parts of a spectrum for potential users and were created to be used to examine the design, as a complement to the focus group and other usability test participants during the design process.

6.2.2.4 Journey Mapping

To understand different users' perspectives and needs while interacting with the system, a journey mapping was conducted based on the extreme characters. Each extreme character was assigned one of the three routes to create different narratives and provide for a holistic view of the different experiences (Figure 6.6-6.8). The characters' different needs and personalities were considered while determining the users expectations for the interaction. The journey mappings explored the extreme characters' experiences as in feelings, thoughts and actions while interacting with the system. The three characters played out the same scenario, as in starting with receiving an invitation to arriving at their appointments. However their interactions and emotions varied within the characters depending on their needs and personalities. The method of journey mapping was conducted to discover both positive and negative aspects of the system that could occur during the interaction. It provided insights of different steps in the interaction that would likely create confusions, frustrations or problems depending on the users and their expectations, but also insights of where in the interaction positive experiences could occur.

The purpose of this method was to understand the interactions with the system further than only the ideal, golden path. The method showed how users with various interests, needs, and desires use the application in different ways, where a one time user might not have the desire to invest in such an application with a mindset to solve the problem of wayfinding using signage and help from the physical environment. Therefore it must be effortless to start using the application and understand it without any obstacles, or otherwise the user might reject the application, as what happened to Stina (Figure 6.6). Other users like Greta with a mindset that is eager to learn, might be more forgiving which could lead to the users still having a satisfying user experience during misunderstandings or errors as long as the intended goal was accomplished (Figure 6.7). The third user for this method, Ove, displayed a perspective of people with mobility disabilities that might experience obstacles in their everyday life and while encountering an environment or system that does not take into account their impairment (Figure 6.8). This could lead to disappointment, or if the needs can be met instead happiness and satisfaction can appear, which indicates the importance of all functions to be visible to make the application accessible and easier to understand. The gathered insights from the journey mapping were important to consider while designing to be able to meet all the variety of needs different users can have, and guarantee for a better user experience for everyone.

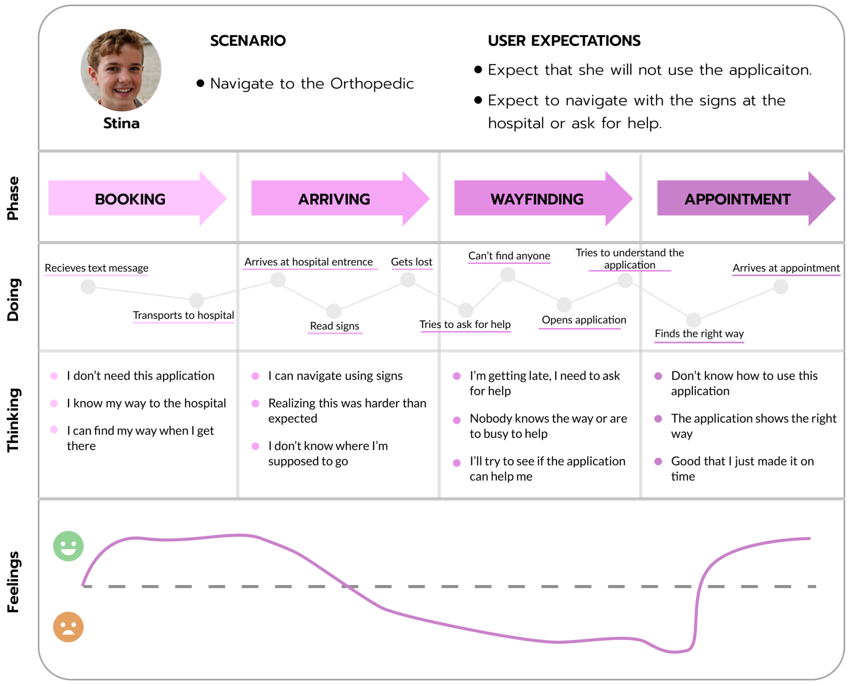


Figure 6.6: Journey mapping illustrating navigation to the orthopedic.

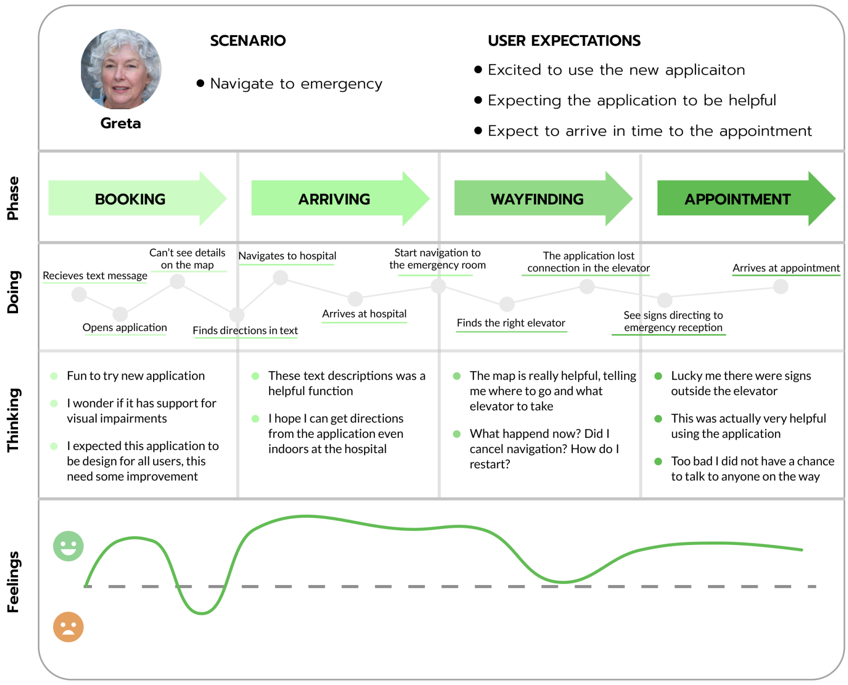


Figure 6.7: Journey mapping illustrating navigation to the emergency room.

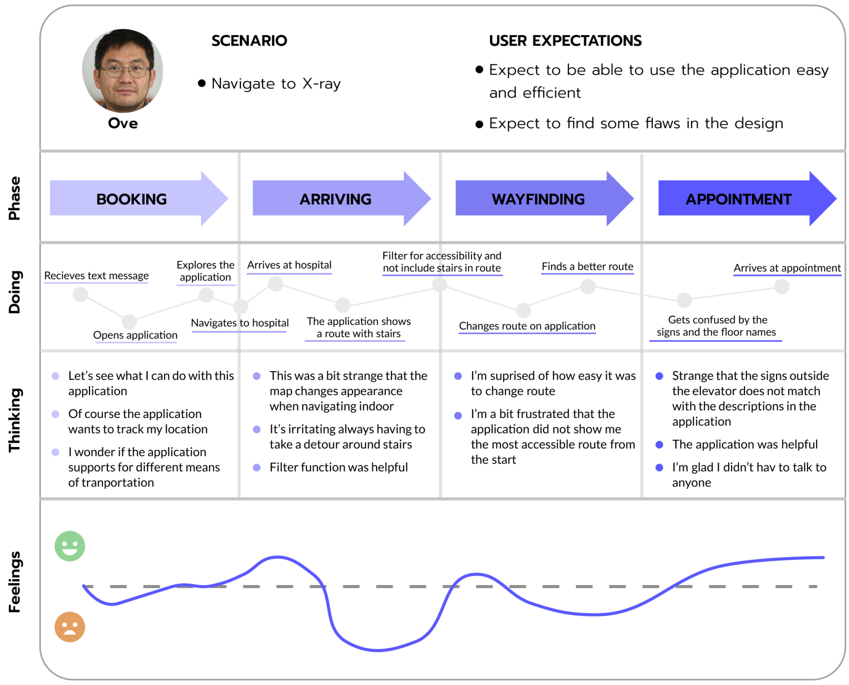


Figure 6.8: Journey mapping illustrating navigation to the x-ray.

Patient Mapping

An additional journey mapping was constructed to see what type of personal data the application could save and how that would affect the experience for the patients (Appendix C). This patient mapping examined if any data should be saved at all, saved for one day, or longer. Depending on how long the data would be saved it could change the experience and the trust for the application. Saving data could create the possibility to implement additional functions in terms of being able to present a return route, favorite routes, most recent searches, or similar. To understand this further, a quick user test was conducted to gather feedback and insights about the subject of how long users desire their personal data to be saved and for what reasons. This was made by interviewing four people of their preference of data saving regarding navigation within the hospital. All participants claimed that they would prefer to be presented with a return route and some participants wanted preferred routes, and all participants were accepted to the fact of sharing data to being able to have these functions. Regarding for how long the data should be saved the participants had split opinions. Most of the participants wanted the data to only be saved for the day, to be able to find their way back or to another position at the hospital. One of the participants preferred if the application provided favorite routes or recent searches, which would require saving the users data for longer than one day. Another participant wanted the possibility to manually delete their saved data whenever they preferred, but saw no problem with sharing data longer than a day, and would prefer to create “their own hospital” in the application as they would have their most common routes and favorite POI in the application saved for the next visit.

6.2.2.5 Benchmarking

A benchmark was conducted to compare the application of MapsIndoor to established navigation applications such as Google Maps and Apple Maps. The reason why these applications was chosen to conduct the benchmark with was due to Apple Maps and Google Maps to be considered the most commonly used navigation applications, which the feedback from the focus group and the interview confirmed. To include MapsIndoors in the benchmarking was mainly a convenience sample as it was decided by Axel Health to be used as the core application for this project "Lätt att hitta rätt", which also made it possible to have access to a demo version of MapsIndoors navigation system. A demo of the application built to work at Danderyds hospital, is needed to be able to investigate the system and the interface of the indoor navigation application. It was discovered that it was not possible to explore any indoor navigation applications without having access to a demo version developed for a specific indoor environment that is supported by the application. Therefore, MapsIndoors was the only indoor application included in the benchmark for this project.

The benchmarking process consisted of three tasks with sub tasks. The first task was to find what menu type each application had. The second task was to use the search function, with sub tasks of how to access the search function, how to make a search, and which features the search function provided. The third task was to set a route with the sub tasks to set a destination and starting point and to make a detour. It also consisted of finding what information that was provided for the route, how the instructions and map were presented and what different settings were provided. The purpose was to investigate how the interface of the applications differed and understand which solutions works better for navigation. With comparison of the two other applications it was possible to see what was lacking in MapsIndoors interface and which features should be changed to make improvements.

The benchmarking was also conducted with an accessibility perspective in mind, where findings from the brainstorming sessions were used to understand what features are mainly important to consider, why these are important and how it can be changed. For example, as the current interface of MapsIndoor provides a hamburger menu it was considered to be better with a menu bar as it is easier to reach as it also provides an overview of the options in the menu which can reduce the cognitive load.

6.2.2.6 Design Decisions

When designing an interface every implementation of elements or functions in the design is a design decision. The design decisions for this project were made with the main priority to design for everyone and design for a universal design interface and are based on findings from the pre-study. The design decisions will be further described in every iteration.

Design Principles

To help and guide the designers to make design decisions in this project some design principles were created (Table 6.3). These design principles were considered throughout the process of designing the interface of the application. The principles are a priority list made from the findings from the methods conducted in the discover and define phase. To support the design principles of font size, button size, layout etc., the design principles both from Material Design and Human Interface Guidelines were considered. The design principles were used to provide a standard design of buttons, font and size that is common for mobile users. The seven principles of design and WCAG guidelines were also considered in the design. Additional common design principles were considered based on the literature review such as balance, repetition, emphasis, proximity and hierarchy to reduce the cognitive load and help the user make quicker decisions while interacting with the interface.

Table 6.3: Applied design principle in the design for an accessible/universal design.

Text	Layout	Features	Icons	Buttons	Contrast
Font size 13-17	Balance	Repetition	Icons and symbols along with text	Height 40px	WCAG Level AAA
Serif fonts	Spacing between buttons	Consistency	Pictures and words go next to each other	Font size 17px	Ratio of 7:1 for normal text
High contrast	Hierarchy	Feedback of users actions	Illustration in sharp focus	Margins top 10px	Ratio of 4.5:1 for large text
Color for contrast	Consistency	Important features always visible	Stands for one word or one concept	Margins side 16px	Ratio of 3:1 for graphics
Lower case	Grid & White space	Functionality of the same type should be grouped together	No irrelevant details		
Headings & titles	Emphasis & Unity	Zoom in and out	Universal meaning		
Left hand margins	Proportion and size of elements in relation to one another				
Simple text	Movement & Flow				

6.3 Iteration One

After gathering insights in the discover phase and defining the design decisions and design principles in the define phase, this section will describe the development phase of the first iteration that will be designed based on the insights from the previous phases performed in the pre-study.

6.3.1 Development

In the first iteration an improved design of the product produced by Mapsindoor based on the design decisions and design principles was developed. The first wire-frames in Figma were conducted based on the appearance, functions and interactions of the MapsIndoors (MID) design to investigate which changes could improve the interface to increase the accessibility. This was done by copying and recreating the interface of MID's design in Figma to be able to make design changes. The improvements that were done changeed the most important features that would increase the accessibility of MID's design without reconstructing the whole interface. Changes that were considered to be the most important to implement to increase accessibility were redesigned, such as providing a search function from the main view, or giving the user feedback of their start point and end destination. The design changes are presented in the section below (Figure 6.9-6.12).

Start page

In the start view of MapsIndoors interface the icons were changed to more universal icons in only black and white, to make the icons easier to recognize (Lidén, 1999), and to provide a higher contrast. Further, a back button was added with complementary text to be able to exit the menu and to allow for tolerance for errors (Preiser Ostroff, 2001). The background picture was removed as the graphical element does not fulfill any purpose and could cause confusion or be disturbing. Additionally, a button was added to show all points of interest on the map (Figure 6.9).

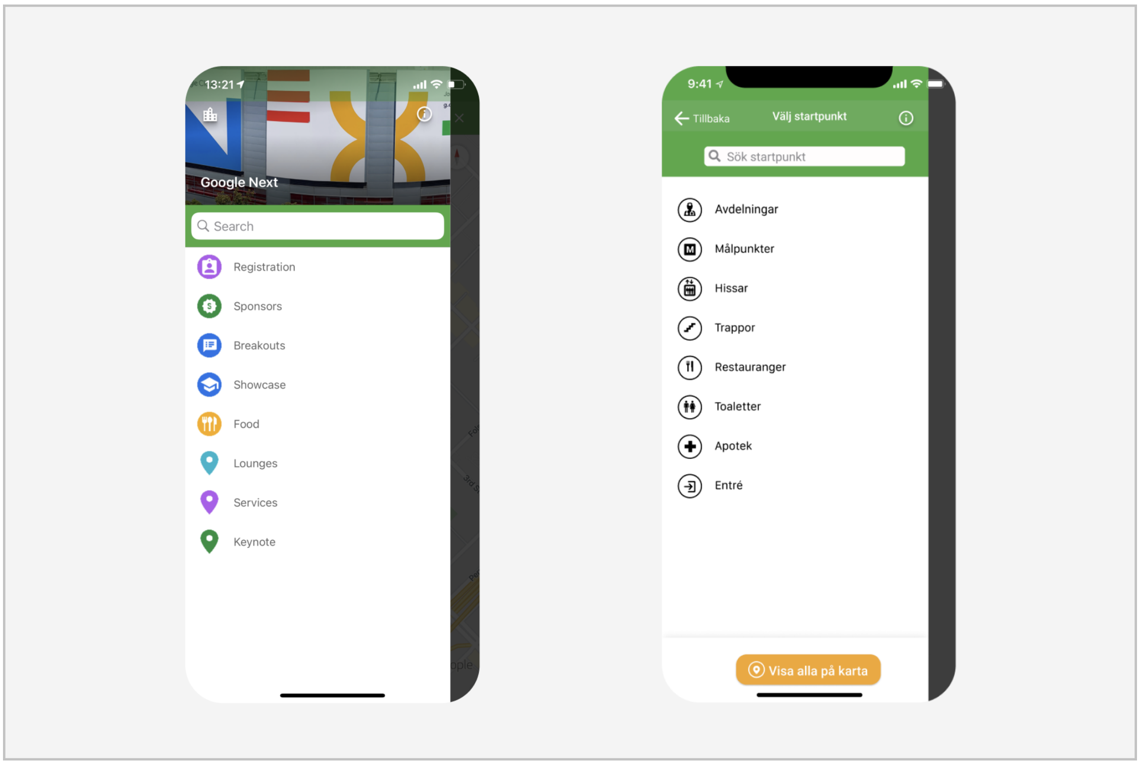


Figure 6.9: Images of the start page of the MID design. The original MID design to the left, and the changes made of the design to the right.

Search

In the search view, the navigation descriptions were changed to be more detailed and visible. From this view it was not possible to start the navigation in the original design, which was changed by replacing the button "show on map" to "start navigation", since the show on map button was added in the previous view. This was important to make the flow more intuitive for the user. Further, a detailed list in text regarding the route was presented in a line to show the whole navigation with descriptive icons added to each step (Figure 6.10).

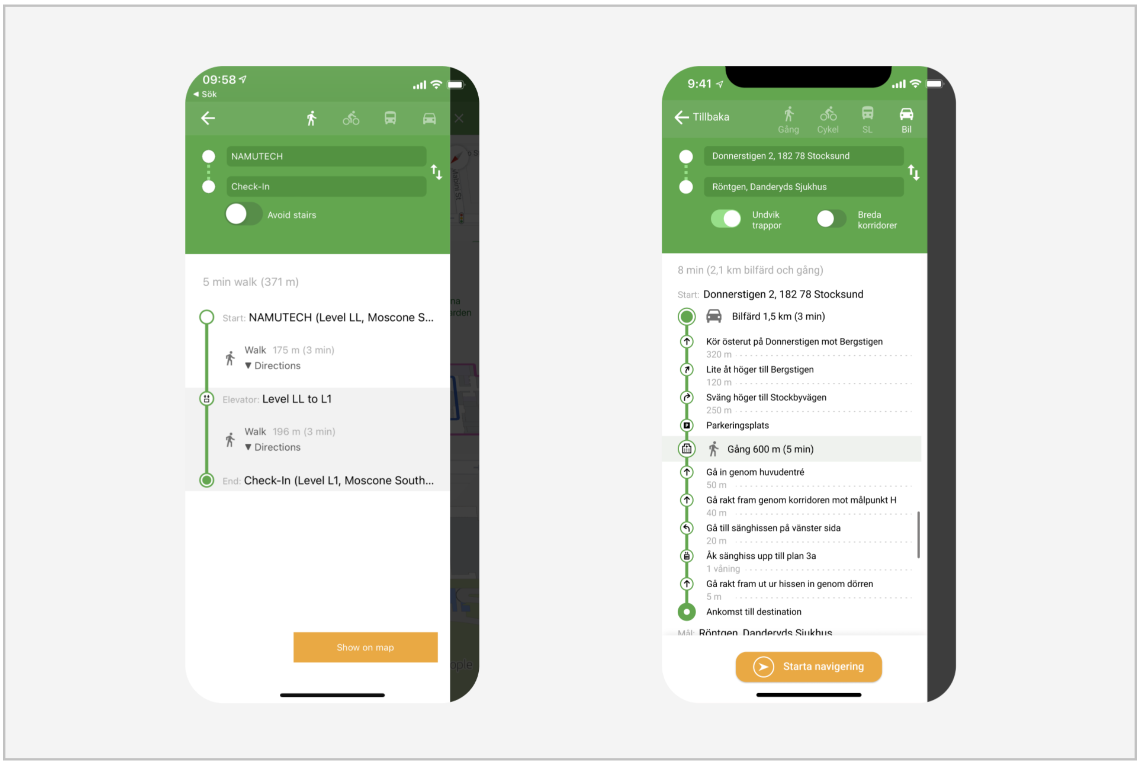


Figure 6.10: *Images of the navigation descriptions in text. The original MID design to the left, and the changes made of the design to the right.*

Textual descriptions

In the map view descriptive text navigations were added as a complement to the map navigation. These textual descriptions provided step by step descriptions showing the current and the next step of the route. An "end button" was added along with information about the route such as time of arrival, time to destination and route distance (Morag & Pintelon, 2021). Further, buttons were added for sound and navigation settings.

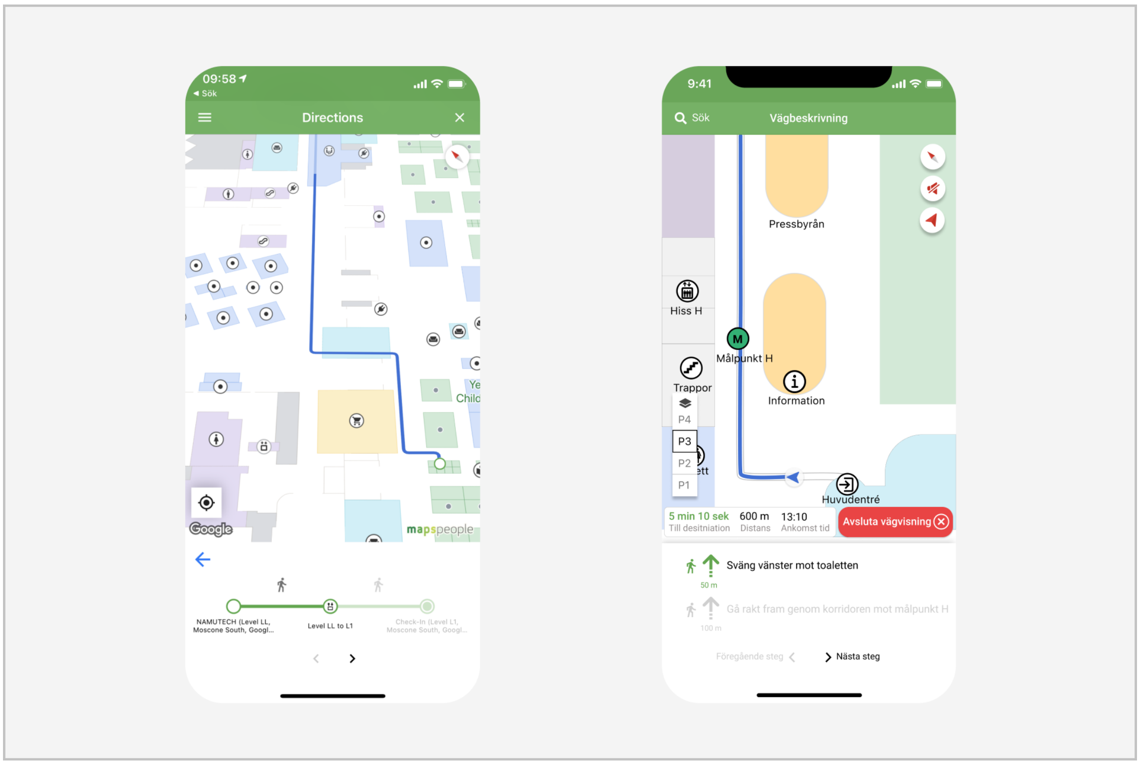


Figure 6.11: Images of the navigation in map view. The original MID design to the left, and the changes made of the design to the right.

Point of interests

In the map view, without any navigation set, the interface was changed to be less cluttered and to provide more information about a POI when interacting with it. It was also added a "start navigation" button to navigate to the selected POI and information about the route.

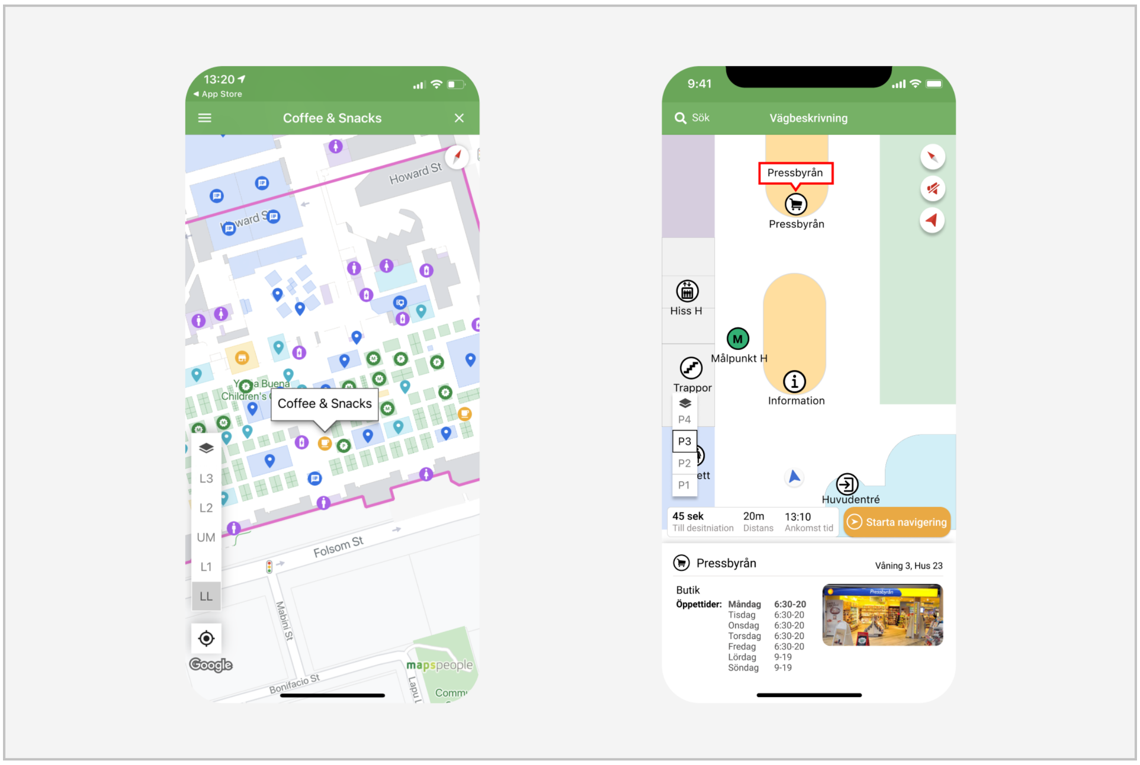


Figure 6.12: Images of the information of a POI. The original MID design to the left, and the changes made of the design to the right.

6.3.2 Designing a new interface

After developing the changes of the MID's design it was discovered that no improvements could be implemented for this project "Lätt att hitta rätt", due to lack of development resources for this project. To be able to further investigate the research questions and to understand how to design for a universal indoor navigation interface a new prototype made in Figma was decided to be developed. Therefore, two designs of the application will exist in this thesis which will constitute two parallel processes described in Figure 6.13, the MID design that will be a working web application with functional navigations at Danderyds hospital, and a new prototype called "Easy Wayfinding". The MID design will be used as benchmarking in the project to investigate good and bad features of the navigation application in relation to the research questions. Therefore, the usability testing will investigate good and bad features in each design, however the designs will not be compared to each other as the MID design will be a working application and the Easy Wayfinding will only be an interactive prototype and not a functional product.

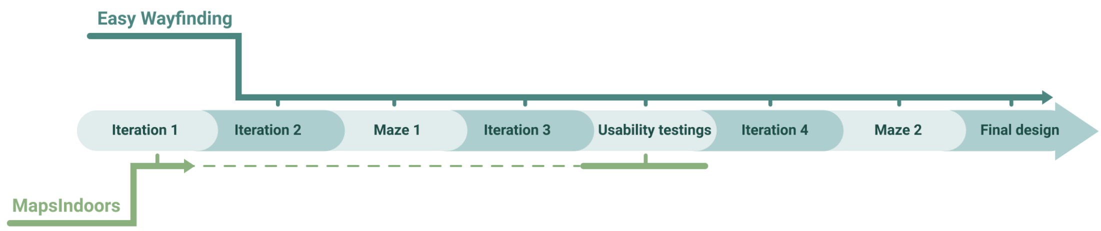


Figure 6.13: An illustrated model of the parallel processes for the two prototypes.

6.4 Iteration Two

The Easy Wayfinding design was developed as an alternative design of the interface that could be used for future implementation of the application later in the project "Lätt att hitta rätt". This design was not based on the MID's design and was designed based on findings from the discovery phase and the design principles in the define phase (Table 6.3). The Easy Wayfinding design was designed by us with changes made based on feedback from Axel Health, RITE sessions that were executed to help gather quick feedback of design elements and features that were blocking the process, and usability testings. A high fidelity prototype including wireframes and interactive mockups was designed before performing usability testing. Subsequent changes of the Easy Wayfinding interface was based on heuristic evaluation executed to find potential usability problems of the design.

A decision was made from Axel Health to create a web based application, instead of a developing native application, to not require the user to download an application. One disadvantage of developing a web application is that live positioning will not be possible to determine the users physical location in the building.

6.4.1 Development

In iteration two, wireframes were made in Figma to design the interface of the Easy Wayfinding design that would present screen content and behaviour of the application. No sketching or low-fidelity prototypes were developed as it was not considered to be necessary since the pre-study had outlined the basis of the core structure of the interface. The design of Easy Wayfinding was based on findings from the benchmarking where the design would follow standards of commonly used navigation applications such as Google Maps and Apple Maps, on the literature review of how to design for accessibility, and the insights gathered from the brainstorming and focus group sessions. The main focus was to design an interface that would be easy to understand and interact with regardless of who the user would be. Interactive mockups were made to be able to communicate the design to the stakeholders and to be used for usability testing.

6.4.1.1 Design Decisions

This section will describe the reasoning behind the design decisions which lead to the appearance of the interface of Easy Wayfinding in the second iteration, such as what functions and features that were implemented in the design and why. Functions and buttons of importance that will be referred to are pointed out and presented in Figure 6.14-6.16 below.

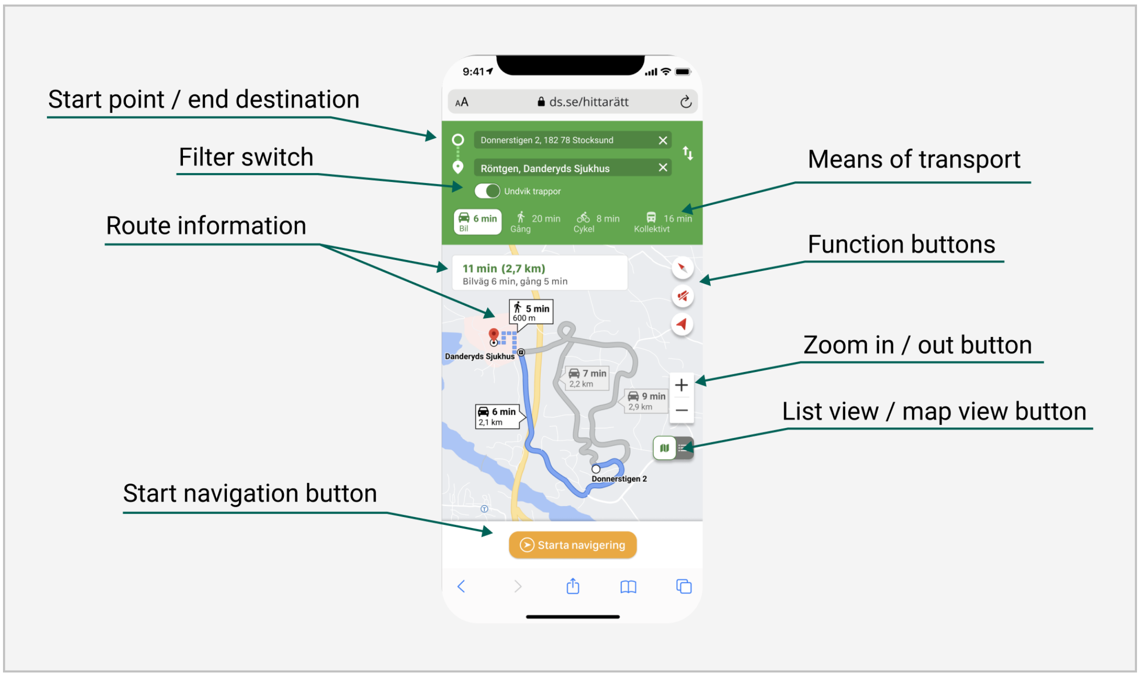


Figure 6.14: Descriptions of functions and buttons in the route overview.

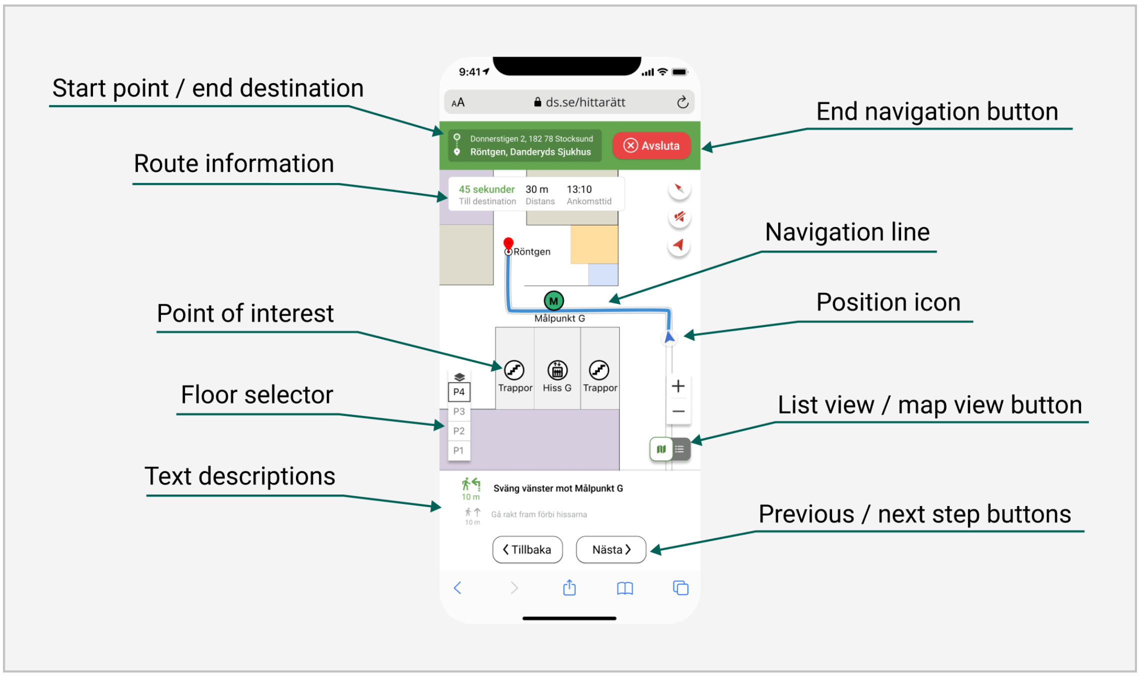


Figure 6.15: Descriptions of functions and buttons in the map view.

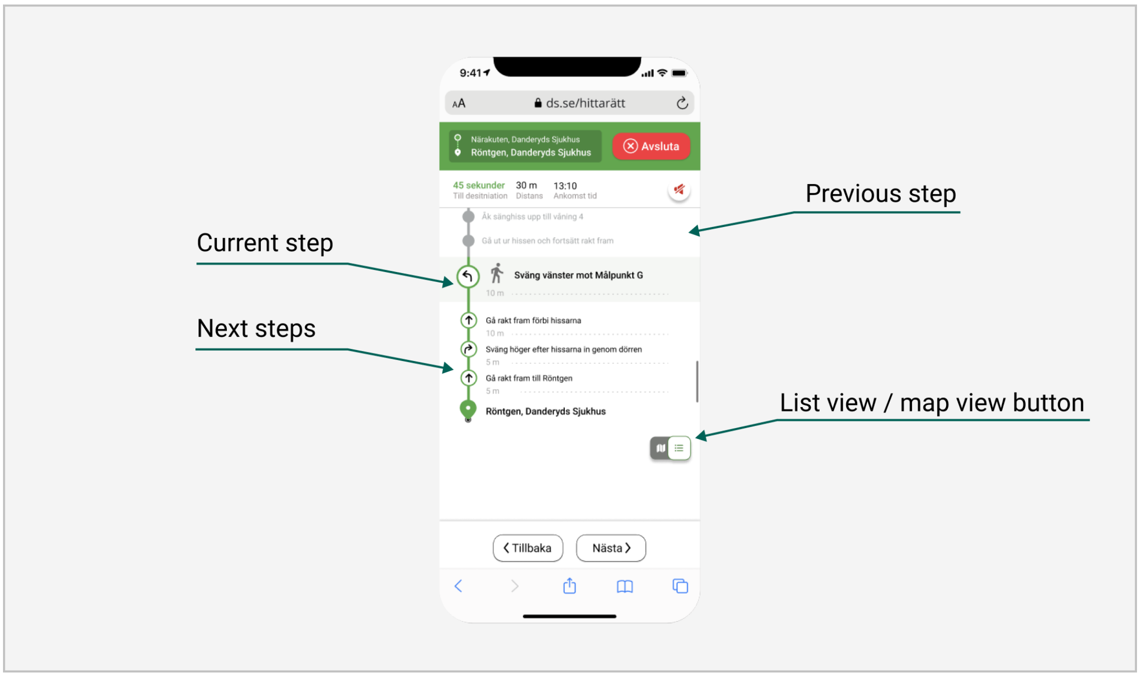


Figure 6.16: Descriptions of functions and buttons in the list view.

Features

The features in the application refers to the application being suited to serve its purpose, and were therefore one of the most important factors to acknowledge in the design of the interface. Singh and Tandon (2018) state that functionalities is one of the elements that needs to be satisfied in a design to be accepted as a universal product. Their Conceptual Framework for universal design (Singh & Tandon, 2018) considers the elements of reliability, simplicity, accuracy, and consistency as important contributors to universal design. Based on this, the interface was designed to only include the necessary features to support wayfinding and all other features and functionalities were excluded as it was important that it would be a simple interface that would be reliable due to accuracy and consistency.

The decision to not provide a menu in the interface was based on having the most important functions visible at all times and that the most important features should always be available directly via buttons and not via a menu navigation (Al-Razgan et al., 2012). As it was important that the interface had a balance of not too many or too little features (Al-Razgan et al., 2012), all functions and features were considered to always be visible and reachable from the main page. Further reason to not provide for a menu was based on the application's main purpose to provide navigation guidance based on a preset starting point from the user's position to their destination where they have the booked appointment at the hospital. For a first time user there is no need to have an account that requires login, and therefore there was no reason to provide for a menu. From the perspective of a one time user it was important to not provide any requirement for an account, to not have to make the effort to create an account for only one visit at the hospital. One time users also might be the ones who have the hardest time finding their way at the hospital as they are least familiar with the environment, and therefore it was considered important to find a simple interface that would be preferred both by one time users and regular hospital visitors.

When designing for universal design it is crucial to provide options for visually impaired users and not only design for fully sighted users. This was not possible to add in the design since it is only an interactive high fidelity prototype and not a fully functional product. However, a working product of this interface would ideally support a VoiceOver or text to speech function to make the design more inclusive. Also, the function buttons (Figure 6.14) involve a icon of a speaker available in the interface and visible on all frames to provide for the option to hear the description instead of having to read them without having to use any other help tools.

User flow

To provide for a pleasant user flow it was important to consider the users goal of the interaction and how to make it as effective as possible (Interaction Design Foundation, n.d.-a). This meant designing for consistent navigation with a simple and not cluttered screen layout (Friedman & Bryen, 2007). Further, it was important to balance all functions and features since a mobile interface is small and can easily get cluttered combined with the decision to have all features consistently visible. Therefore, the design needed to keep a similar standard of how common navigation applications are designed, to make the interface familiar to what a user expects from a navigation application. To have route information (Figure 6.14) such as distance, time to destination and time of arrival constantly visible for the user at all times during the navigation was important based on several aspects. First, as the users were able to see the duration to their destination it reduces the stress level (Morag & Pintelon, 2021), and also based on the result of the brainstorming session users with visual impairments argued that distance to the destination is important to include as time can be very individual. The position icon showing direction of travel (Figure 6.15) were also considered to have an appearance common to icons in other navigation applications. Additionally, time was added next to means of transport (Figure 6.14), which was a similar solution to other navigation applications to provide the user with an overview of what it would mean to change transportation of means and suggestion of different route options before starting the navigation was also added.

Since the user's goal of the interaction was effective and easy wayfinding the buttons in the interface were designed to be clear, large and consistent (Friedman & Bryen, 2007). The button to start the navigation (Figure 6.14) was centered in the bottom of the screen to be easy to reach regardless of mobility possibilities or dominant hand, as it was considered to be a button that was necessary for every user. It was also important to give the user feedback on their actions (Friedman & Bryen, 2007) with direct feedback of executed actions, having a navigation icon of the users position to give feedback of position and provide feedback of arrival when the user has reached the final destination (Figure 6.17).

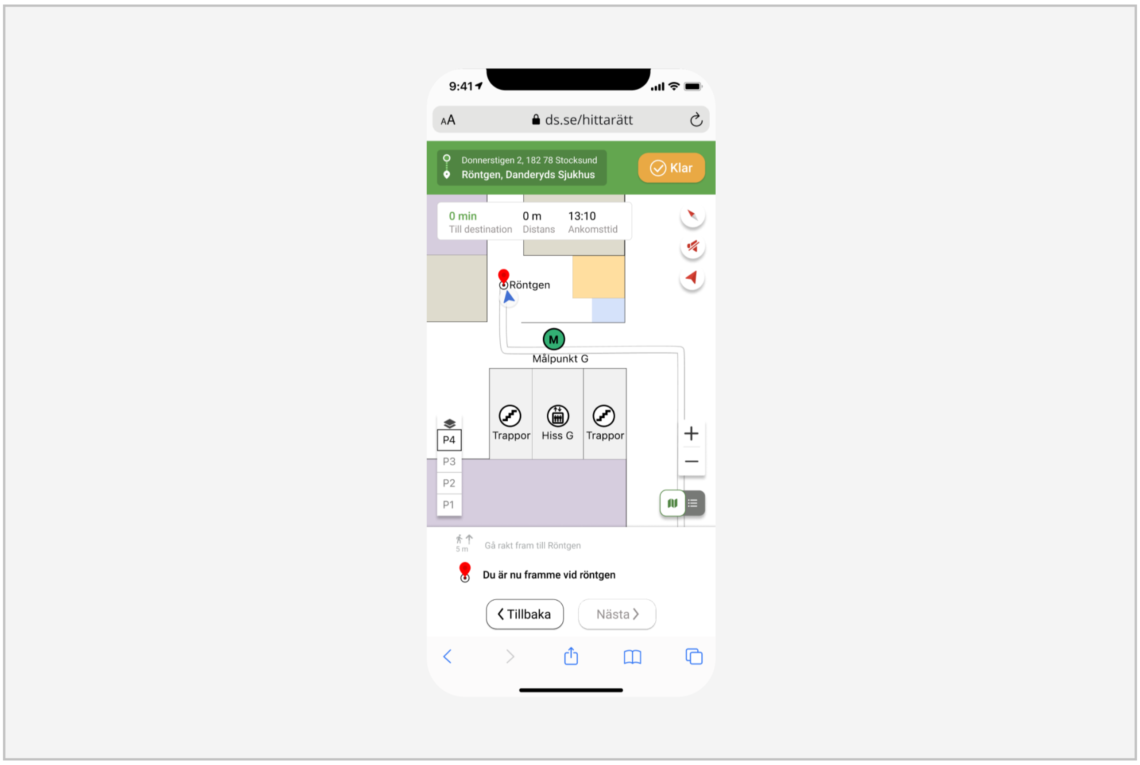


Figure 6.17: The design providing feedback of arrival.

Look and feel

To provide for a conventional look and feel of the interface, design principles were used (Interaction Design Foundation, n.d.-a). To design for repetition some features were visible in every frame, such as the function buttons and route information.

This made it possible to emphasize and draw the users attention to the important features for each frame, such changing position from outdoor to indoor or arrival at the destination. The interface also displays a hierarchy of the most important information at the top such as the start and end point of the navigation along with the route information followed by the map or textual descriptions below. The reason to arrange the information in a hierarchy order with the most important information at the top was because screen readers usually read from top to button and thus the most crucial information is provided first.

To ensure that the layout of the interface would be consistent and not too cluttered, the grid of the design had the same margins and paddings in every frame and for all buttons and functions, and white space was used for wide margins (Friedman & Bryen, 2007). To have a clear difference among text and background, (Vangeli & Stage, 2018; Friedman & Bryen, 2007) high contrast was used. The font was a sans serif font to provide for a universal design (Vangeli & Stage, 2018; Friedman & Bryen, 2007), and the font size was 13-17 based on the Human Interface Guidelines that are standard for mobile interfaces (Apple Developer, 2020).

Interactions

The interactions in the interface were designed to be as easy and intuitive as possible for the user, which mainly meant having standard solutions for mobile touch interfaces, as for example providing tap actions and zoom in and out on the map by pinching (Cooper et al., 2014; Al-Razgan et al, 2012). However, since those interactions are more important to consider when creating a working product this interface instead focuses on affordance and communicating possible interactions to the users. The interface needed to give the user feedback of its actions, communicate to the user which task is active and confirm when a correct or incorrect action is made (Al-Razgan et al, 2012; Friedman & Bryen, 2007). This was done by having a drop shadow on all buttons to indicate afforands and using color and contrast for showing when a button was enabled or disable (Figure 6.14). Further, if the user is not familiar with the pinch in and out gesture, an additional zoom-button (Figure 6.14), with a plus and minus sign, was added in the interface that the user could interact with to execute the action.

Critical interactions needed to be visible on every page such as the end, next, and back buttons (Friedman & Bryen, 2007). To design for tolerance of errors (Preiser & Ostroff, 2001) the back button was added to help users recover when being lost and provide for the possibility to go back to previous steps (Friedman & Bryen, 2007). The end button was placed on the top of the screen to avoid users accidentally interacting with the button. When a user interacts with the end button an overlay appears with two alternatives where the end button changes into a continue button and instead the end button moves to the opposite side of the grid to avoid for the user to accentaly interact with the button and lose the navigation (Figure 6.18).

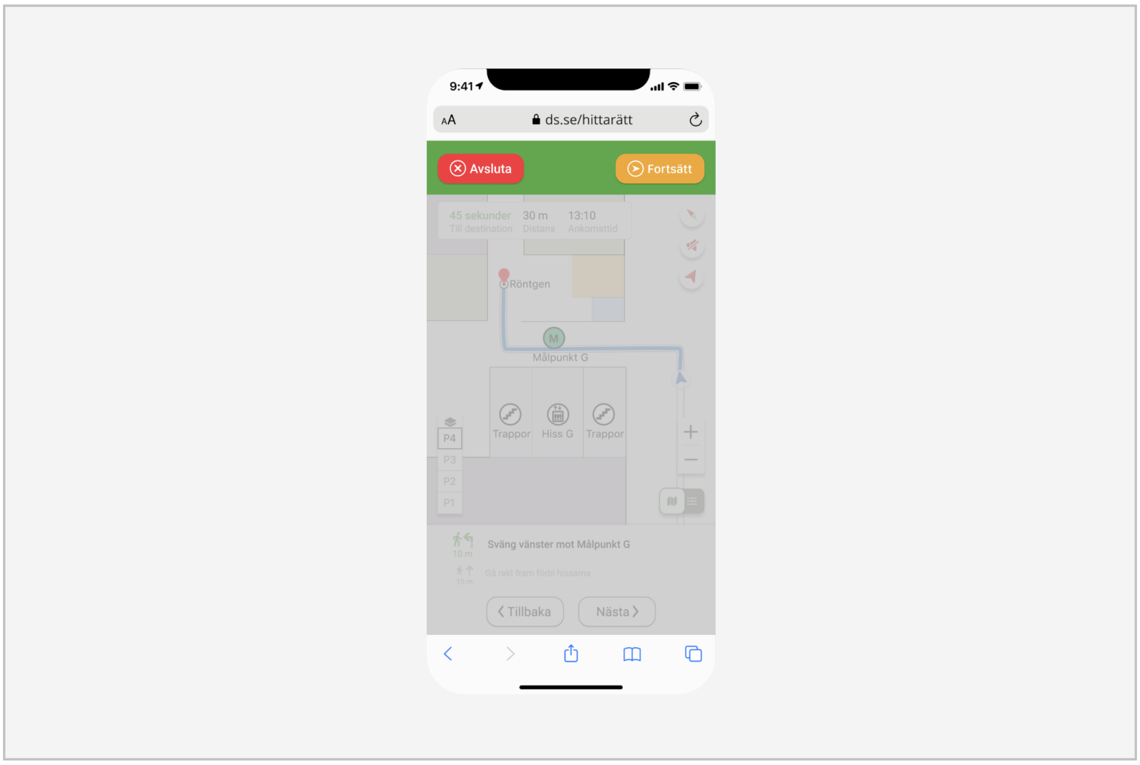


Figure 6.18: The flow when interacting with the end button.

Buttons

The size, font, padding and spacing of the buttons was based on the design principle Material design and the Human Interface Guidelines. The buttons had standard size for mobile interfaces and with a hit area that was big enough for a mobile interface. Font size on all buttons were 17, with padding of 16 pixels and spacing between buttons and functions of 20 pixels. All the navigation buttons, such as the previous and next buttons, the done button or starting and ending the navigation, were designed to be clear, large, and consistent according to the design recommendations by Friedman and Bryen (2007). All these buttons also included both text and icons to make its purpose and action as clear as possible to avoid misunderstandings and frustration (Huang et al., 2002). Spacing, margins, font size and paddings used in the interface can be seen in Figure 6.19.

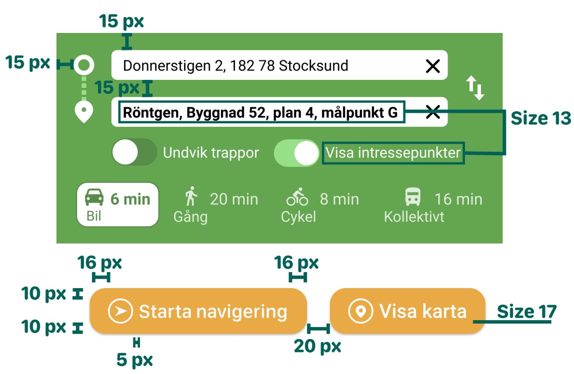


Figure 6.19: Image of spacing, margins, font size and paddings in the interface.

Search fields

The search field was thought to be an auto-complete search which means that when the user types a search term a number of suggestions of complete searches will be presented, which was thought to be available POI:s on the map (Figure 6.21). The search function was also designed based on tolerance for error and auto-suggested searches would be presented even when the user misspells a word that is similar to a search result (Cooper et al., 2014) (Figure 6.20). It was also important that the search field would be visible at all times as it was considered to be an important feature (Al-Razgan et al., 2012), and therefore the search field was always available at the top of the interface.

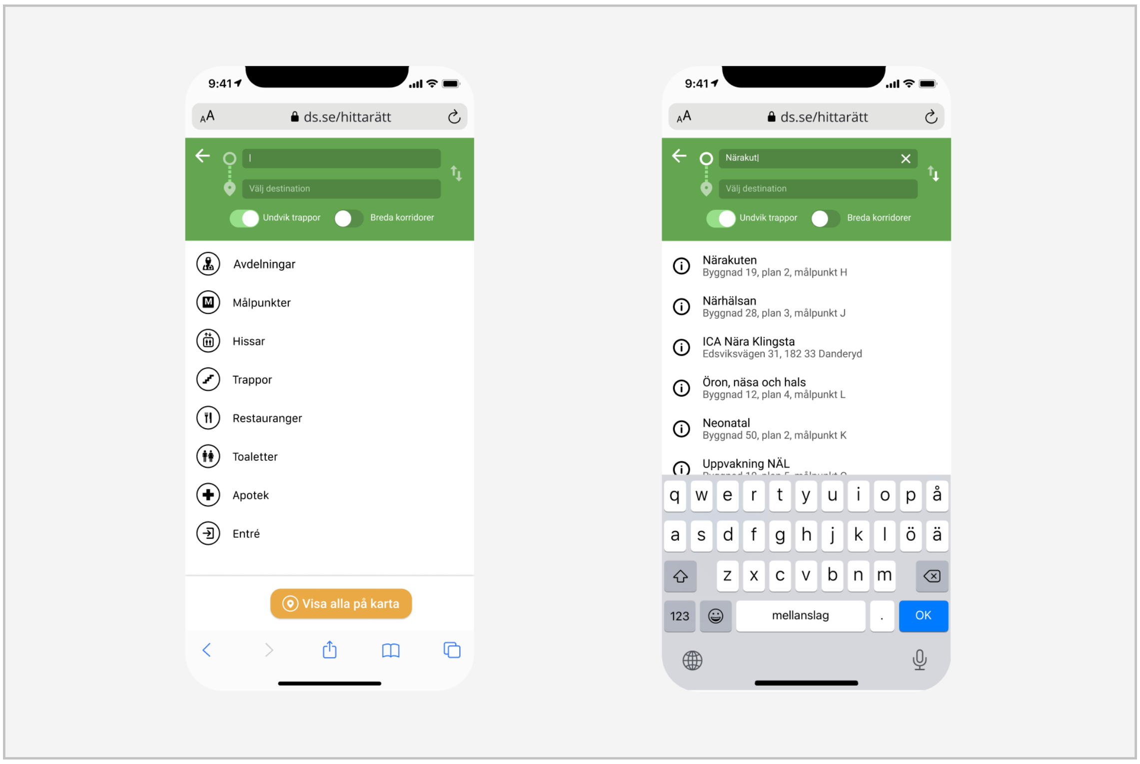


Figure 6.20: The left image shows the search field before putting in a search word, and to the right a search has been made and a list shows auto-complete suggestions.

Icons

The interface was heavily based on icons. This design decision was made due to several reasons, mainly that icons can overcome a language barrier as they have a more universal recognition compared to text (Siti & Swasty, 2017; Huang et al., 2002), but also when designing for children icons should be used (Wu et al., 2014). It was important to provide icons for all elements in the design to make it possible to understand the functions without reading, to include all users regardless of language, age or disability and to provide the same opportunity for everyone to comprehend the interface. Therefore, it was important to provide for universal icons that would be recognizable and easy to understand (Huang et al., 2002) and the icons of the POI:s in the interface were designed to have a universal meaning, such as the toilets, elevator, and stairs. Another advantage of using icons was to save space in the interface compared to using text (Siti & Swastys, 2017).

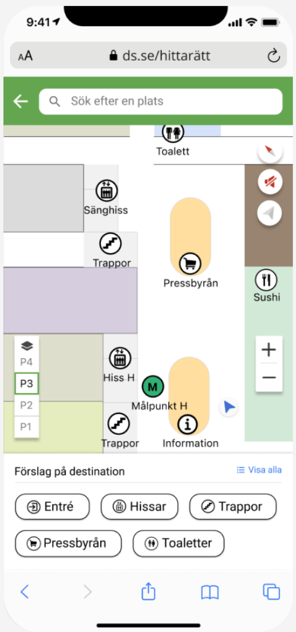


Figure 6.21: An image showing the icons of the POI:s on the map.

Navigation & Descriptions

The navigation and descriptions were considered to be the elements that needed to be the most clear and understandable for the users since it was essential to the user's goal, thus the navigation needed to be detailed and descriptive to be understandable by everyone. The navigation is more effective if the digital map matches the physical environment and also provides written directions (Harper et al., 2020), therefore descriptive text was added in the map view with step by step directions of the navigation (Figure 6.22).

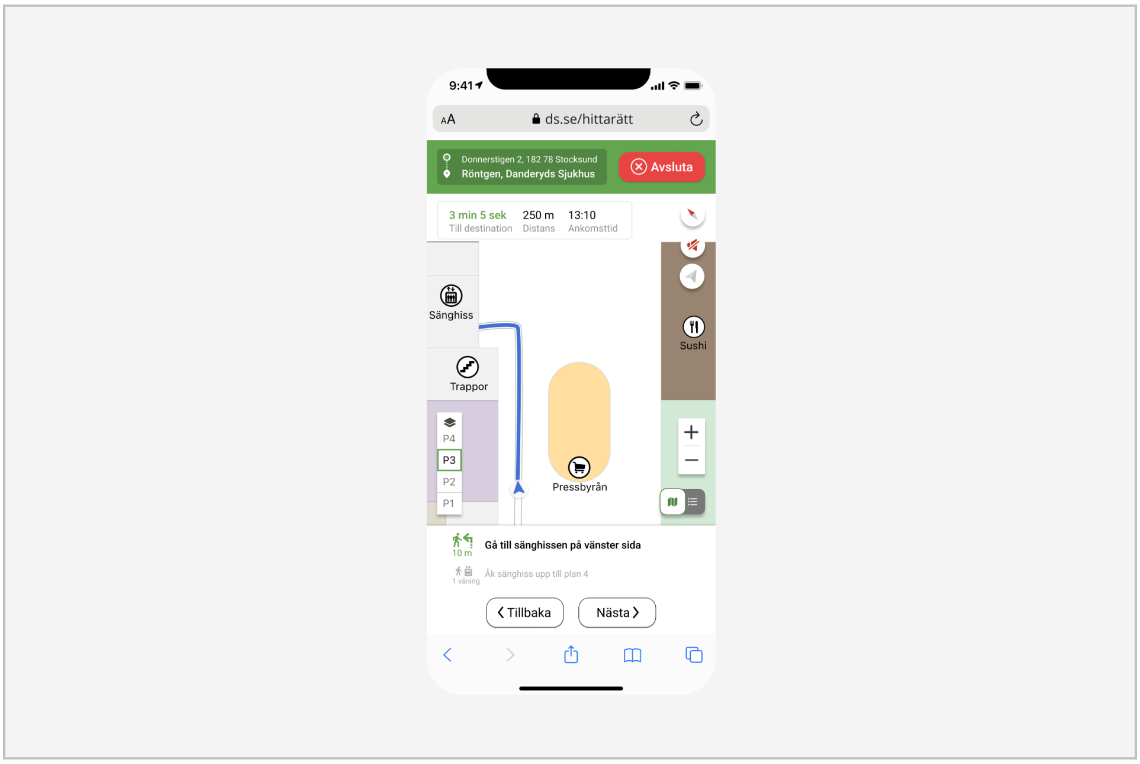


Figure 6.22: Textual step by step directions provided in the map view.

Toggle button for list or map view

A toggle button was added to the interface allowing the user to switch between being presented by the navigation in a map view or in a list view with all descriptions provided in text (Figure 6.14-6.16). The benchmarking revealed that the option to switch between a map view or a list view in other similar applications were always presented in a menu option instead of being visible at all times, and therefore the function could be complicated to find and it could be difficult for the user to navigate back to the map view once they have opened the menu. To implement a toggle button to have the possibility to change between a map view and a list view, was an idea created by us to provide an accessible option for the users, because all users have different preferences. Therefore, this toggle button provided the option to easily change to a more detailed textual description of the navigation and also to easily be able to switch back to the map view (Figure 6.24-6.25).

Maps

The maps used of the hospital environment in the Easy Wayfinding design were designed based on blueprints of the hospital, however, the maps were only produced as a reference point to be used for the usability testing, and therefore no further details were considered in the designing of the maps.

6.4.1.2 RITE

To help with some of the design decisions and to investigate specific elements and features in the interface that were blocking the process, RITE method was conducted. This was done to rapidly gather insights from peers within the field to immediately be able to implement changes in the design based on the feedback. RITE was used for several occasions regarding different elements and appearance, and one of them investigated the icon of the button to start the navigation. Due to an existing standard arrow-icon for "play" and one standard arrow-icon for "navigation" the need for feedback of how to combine these was required, as in this scenario it needed to convey the message of them both. Two alternatives of the navigation button including the different icons were designed (Figure 6.23), and then presented to five peers. Based on the feedback the decision was made to implement the arrow-icon for navigation and the design process could continue.

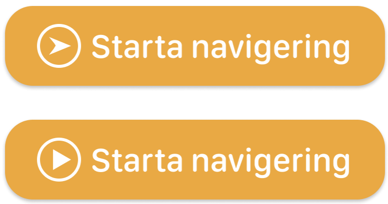


Figure 6.23: Start navigation buttons with different icons.

Another example of when rapid feedback was used were in the process of designing the toggle button for map view and list view. Since it was a conscious design decision to not include a menu in the application the toggle button needed to be easy to find, understand and use at all times. Therefore, the size, icons, placement and colors of the toggle button were important to consider, and also if the user would understand what enabling the button would mean. The first version of the button included both text and an icon and the colors were white for enabled and green for disabled (Figure 6.24). The feedback from RITE indicated that the user understood the function of the button but it was difficult to understand what color was enabled or disabled, and that the size of the button was too big. Therefore, a new version was designed without any supportive text to the icon, and the toggle option was white for enabled and grey for disabled (Figure 6.25). A new RITE was conducted and the result indicated that the users both understood the enable and disable mode and that the size was improved, and therefore the new button was preferred.

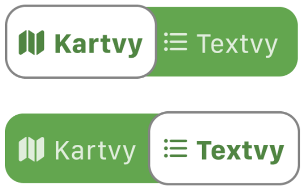


Figure 6.24: First version of the toggle button for map view or list view.

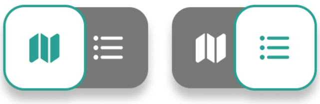


Figure 6.25: Second and final version of the toggle button for map view or list view.

6.4.2 Delivery

To evaluate and test the application, methods of heuristic evaluation and usability testing were conducted. At first a heuristic evaluation was performed to evaluate the Easy Wayfinding design and to discover usability problems in the design. After this the first usability test was performed as a remote asynchronous usability testing of the Easy Wayfinding design. Then a thematic analysis was conducted before proceeding into the third iteration and improving the design further.

6.4.2.1 Heuristic Evaluation

To find usability problems within the interface of the Easy Wayfinding design, a heuristic evaluation was performed by the two researchers to inspect the interface and compare them with the heuristics discussed by Nielsen (1995), the main focus were on *consistency and standards, error prevention, recognition rather than recall, flexibility and efficiency, aesthetic and minimalist design, help users recognize*, and *recover from errors*. The design was first investigated to feel the flow of the interaction and then again with focus on the specific violated heuristics in the interface elements that had been detected during the first interaction. As the heuristic evaluation was conducted by both the researchers, the violated heuristics were documented and then changed immediately. These changes mainly referred to verifying the flow in the interaction, such as adding a back button and placement of buttons. To help understand why these heuristics were violated to be able to provide a better solution for them, interaction design patterns helped to understand what the underlying factors for the violated heuristics were (Botella et al., 2011).

6.4.2.2 Remote asynchronous usability testing in Maze

To perform usability testing on the Easy Wayfinding design the online platform Maze (2021) was used. With Maze it was possible to put together an interactive prototype along with instructions for the participants to follow to perform several tasks during the test, which also could be combined with survey questions between every task. Maze recorded all interactions with the prototype such as clicks, mistakes, time taken to complete a task, and a heat map of the interactions of each screen. The Maze test was shared with a link and it was therefore easy for participants to access and perform the test from a distance. A pilot study with two participants was performed to make sure everything worked effortlessly before continuing with the real test. Survey questions, instructions for each task, the order of tasks and the interaction possibilities were considered during the pilot test. The pilot test resulted in some questions and instructions to be rephrased to avoid confusion, and some changes of the prototype regarding both design and possible interactions were made.

The Maze test was performed by nine participants consisted of three use cases, where the participants were asked to complete the task by interacting with the prototype on the screen, and then after each use case answer two questions (Appendix D). The use cases were constructed to simulate a real user interaction with the application, and the normal course was created to consist of the anticipated most commonly performed actions. All use cases involved alternative courses and could be executed in various ways where different interactions could lead to the same goal. The aim of this usability testing was to investigate what different ways of interaction the users chose, if any mistakes were made and if any confusion occurred during the interaction. The first use case was designed to be an easy task, to introduce the participants to the platform Maze and to let them get familiar with the concept. This use case involved finding information about a specific kiosk at the hospital. The participants could either search for the name of the kiosk, or click on the icon presented on the map to see information about it. The second use case was more complex and included the entire process from the participant receiving a text message with a link to open the application with pre-settings with the navigation of the participants current position set as their starting point and their destination at the hospital set as their end destination. In this use case the participants had several different ways of interacting with the prototype and several features to explore that were not necessary to use in order to complete the task. The third use case was a combination of the two previous, where the participants were asked to find information about a specific department and then start a navigation to that department. At this point the participants had gained experience of interacting with the prototype, and performing this use case gave the participants a chance to interact with the prototype based on their own intuitive feelings and actions and gave insights of how they expected the application to work.

After each use case the participants were presented with a questionnaire including two questions, the same questions after each use case. The first question asked the participants what it was like to perform the use case, where in response they would choose between different smiley faces on a 5-point likert scale, from "difficult" to "easy". The second question was an open ended question where participants had the chance to describe using their own words how they perceived their experience while interacting with the prototype, and were encouraged to report what they perceived went well or not and why they experienced that feeling. Some participants in this study discovered unique findings, but there could be seen that many problems were discovered by several participants. Therefore, testing nine participants was decided to be sufficient for this test, as there would be additional usability tests later in this project.

6.4.2.3 Thematic analysis of Maze usability testing 1

When all data was gathered from the Maze usability test, a thematic analysis was conducted to identify and interpret key elements in the data set. With an inductive approach all data obtained from the test were used to identify patterns within the data set, where several codes appeared in the data set and formed overarching themes. As a result six themes were extracted from the data consisting of; *design, layout, flow, interactions, error*, and *confusion*. These six themes were summarized to create a concrete list of all the participants' experiences and opinions about the design (Appendix E), which formed the foundation for further implementation and improvements of the design. The main usability problems belonged to the map being too cluttered and that the participants felt confused about when changing floors. Overall, the feedback of the flow showed that the application was straight forward and participants experienced an effective interaction using the prototype. However, the result of the rating scale showed an average of each use case of how the participants experienced performing the task where the third task involved the lowest result. The average of the first use case showed a result of 4.4 out of 5, a 4 out of 5 of the second use case, and a 3.7 out of 5 of the third use case, indicating that the third task involved the most usability problems and confusion where the design was most in need of improvements which lead to the start of the third iteration.

6.5 Iteration Three

In the third iteration changes were made to the Easy Wayfinding design based on the result from the thematic analysis. Usability testings were performed evaluating both the MID design and Easy Wayfinding design to gather insights and feedback of the implemented design changes. The data was analyzed using a thematic analysis before proceeding to iteration four.

6.5.1 Development

As the thematic analysis resulted in the four categories of *design, interaction, confusion*, and *errors* the development and improvements of the design were dependent on these categories. Design changes were within the same main focus to design for the interface to be easy to understand and interact with regardless of who the user would be.

Design

Changes made within the category *design* were adjusted to provide for less saturated colors of the map as feedback indicated that the map view was experienced as cluttered. Strokes were added to the rooms on the map to still provide a distinct difference between the rooms and corridors but in a calmer way (Smolenaers et al., 2019). Further, text was removed from icons that were considered to be universal, such as toilets and elevators, to give a less cluttered impression of the map. However, icons that were considered to be important and not universal, such as target points, the icon for the different departments and the kiosk, still had complementary text, to not confuse the user of its context and meaning (Figure 6.26). Lastly, a grey line was added behind the icon of position where the user had passed on the outside map, along with adding an icon of a car as the position pointer. For the indoor navigation an icon with a person walking was added to give modeless feedback to the user if they were walking or driving (Figure 6.27).

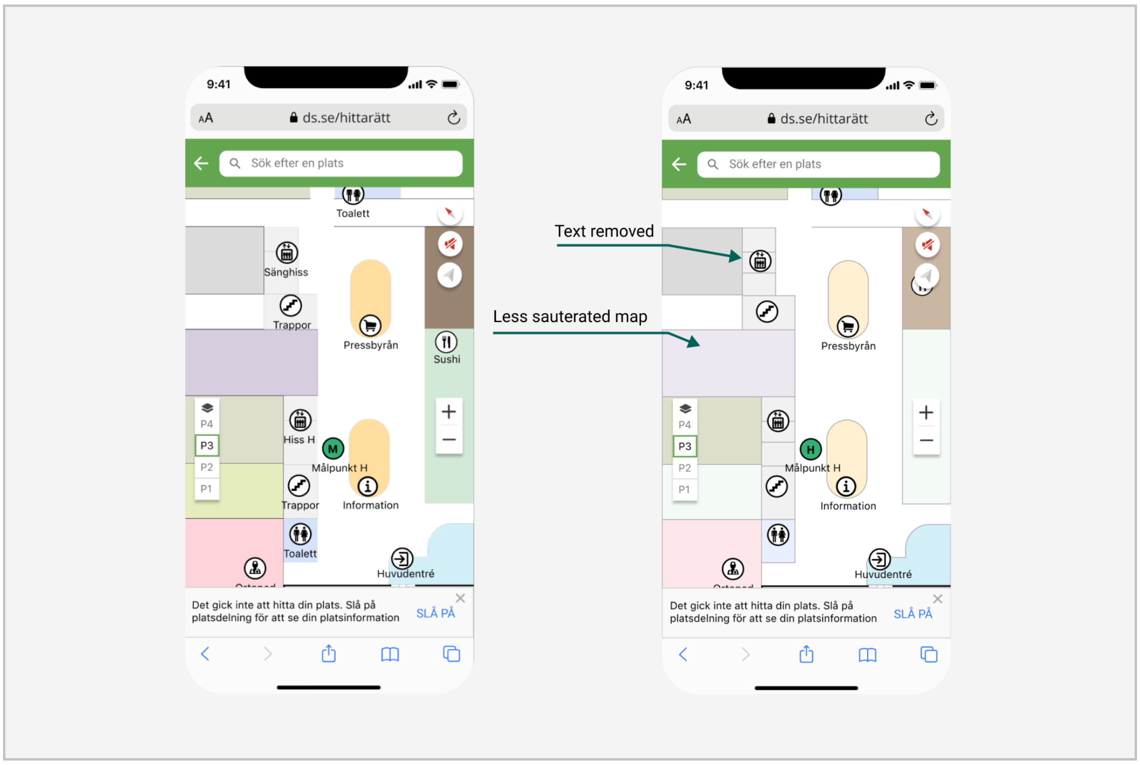


Figure 6.26: Image showing the old interface (left) and the new interface (right) with changes made to a less saturated map, removed text of icons.

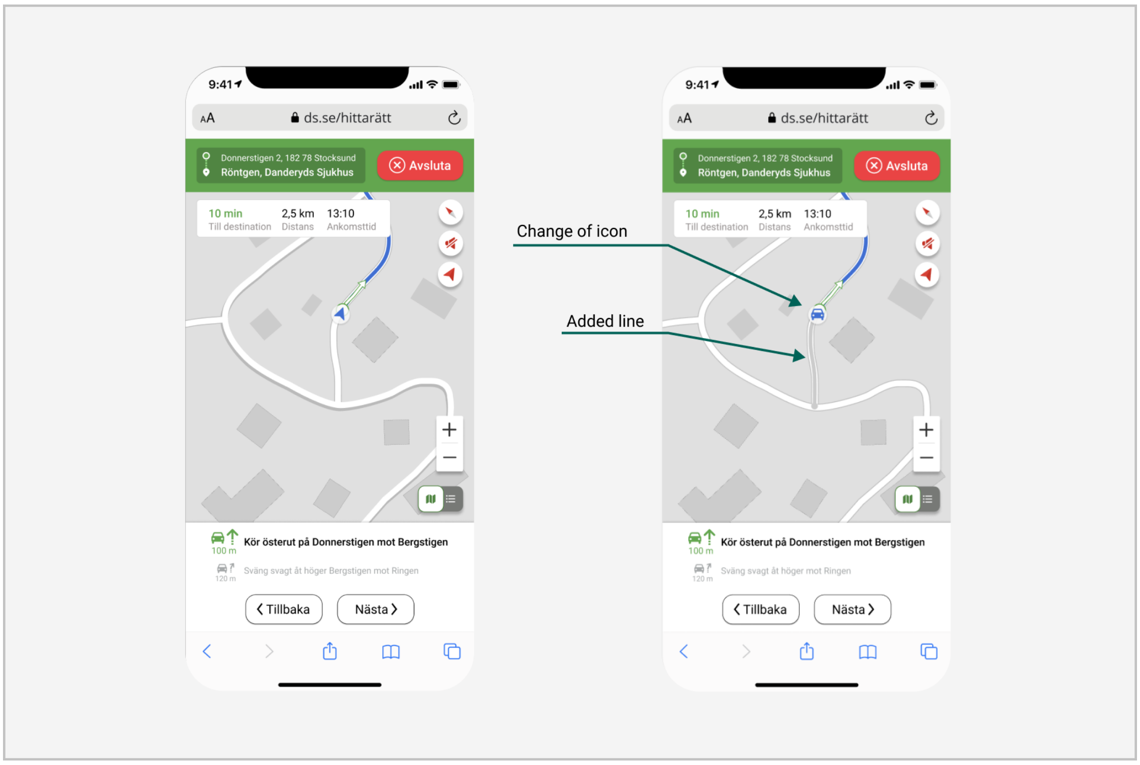


Figure 6.27: Image showing the old interface (left) and the new interface (right) with changes of navigation line and the position icon.

Interaction

Within the category interaction changes were made regarding the information provided when interacting with a POI, where a button was added to be able to close information about a POI when selecting it. This was to signify the affordance of closing the information if a user accidentally interacted with a POI or did not need the information further (Figure 6.28).

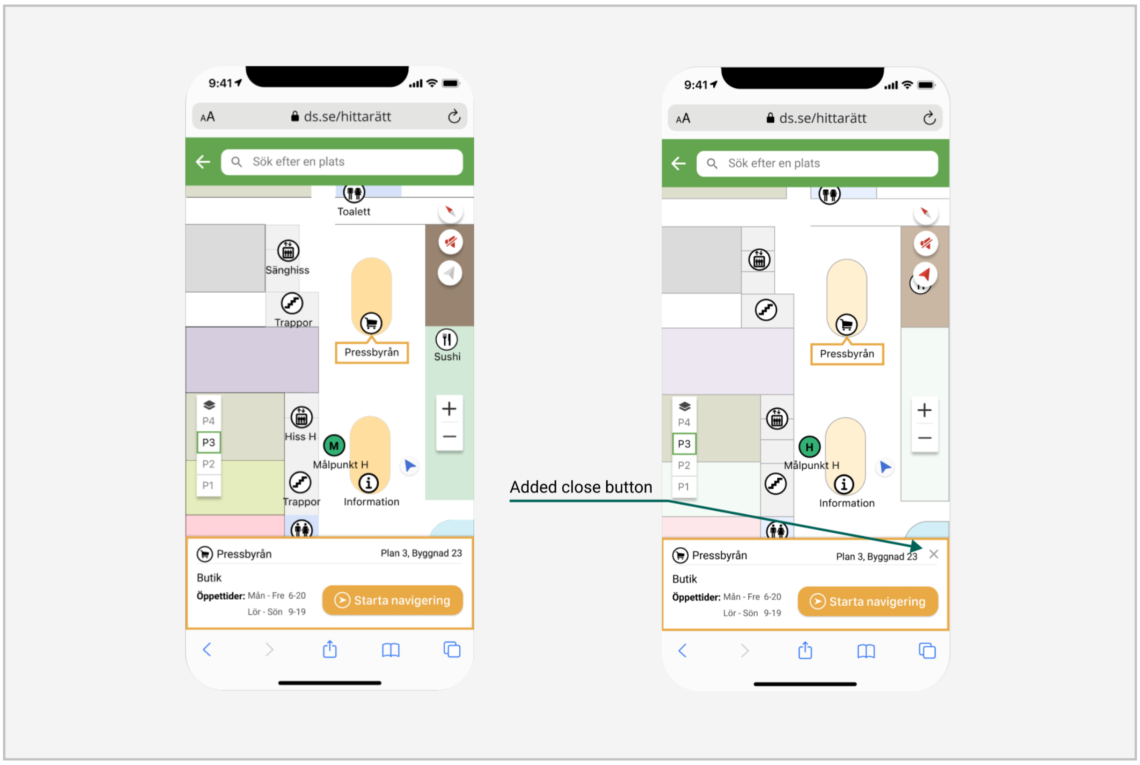


Figure 6.28: Image showing the old interface (left) and the new interface (right) with the added close button on the information about a POI.

Confusion and errors

The navigation descriptions were changed and rephrased to better relate to what was showing on the map, to minimize confusion. As the feedback from the usability test revealed that it was somewhat confusing of what floor they were on and which they were going to, a text of "one floor up" was added next to the navigation line at the elevator to give modeless feedback to the user that they were changing floor (Figure 6.29). Further, as the meaning of target points were experienced as difficult to understand, the letter in the icon for target points was changed to the same letter as the specific target point to reduce confusion of the icon and to match the textual description better. Lastly, misspellings in the design were corrected.

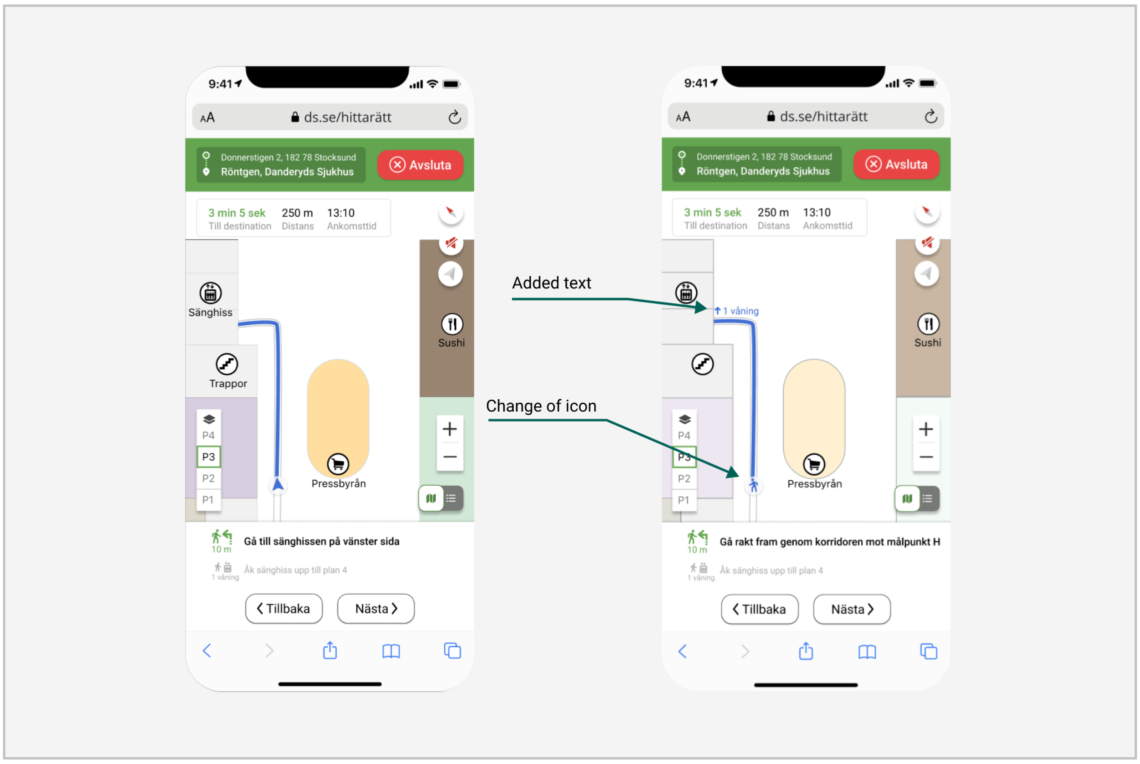


Figure 6.29: Image showing the old interface (left) and the new interface (right) with the position icon, and text when changing floors.

6.5.2 Delivery

Usability testings were conducted to investigate the design changes made in iteration three, testing both the Easy Wayfinding design and the MID design to be evaluated and tested with users. The first test was a synchronous usability test on smartphones, and the second test was a remote synchronous usability test performing a cognitive walkthrough. Lastly, all usability testings were analyzed with a thematic analysis where the feedback of the MID design was used as benchmarking to investigate good and bad features of the navigation application in relation to the research questions and the feedback from the Easy Wayfinding design was used for future design changes in the fourth iteration.

6.5.2.1 Synchronous usability testing on smartphone

The anticipated use of the Easy Wayfinding application is when patients are supposed to visit the hospital and navigate to their destination, and therefore, the device for using the application will presumably be a smartphone. Testing both designs on smartphones examines their intended use, and the usability tests were conducted in synchronous settings. The tests were performed by nine participants in temporarily assigned controlled environments using a computer and a smartphone to interact with the prototypes and record the interactions. By using a temporarily assigned controlled environment these usability tests could be performed in a controlled setting to make the participants' experience as similar to one another's as possible. The unique focus of this usability test was to investigate how the prototypes would work on a mobile screen, such as hit areas and examine the placement of buttons and functions. Further, other design principles such as emphasis, feedback of actions, and the flow of interactions were considered during the testings.

During these tests the participants tested both the MID design and the Easy Wayfinding design, and the start order of the two designs varied with every other participant. The same three use cases as in the Maze test were used for the Easy Wayfinding design, while for the MID design this usability test only consisted of one use case. The first use case for the Easy Wayfinding design started with a simulated text message with a link to open the application with pre-installed settings of starting point and end destination, and the participants assignment was to complete the navigation to the end destination. This was used as the first use case for the test because it simulates the expected use of the application. The second use case consisted of finding information about a specific kiosk at the hospital, and the third was about starting a navigation to a specific department and completing the route to that department. The use case regarding the MID design the participants were given instructions to start a navigation to the x-ray and select the entrance to emergency as their starting point. Then the participants were asked to interpret the navigation route and descriptions to describe how they perceived the provided navigation. Since the navigation could not be started if the user were not located at the hospital, and the prototype does not facilitate any simulation of a started navigation, this application could not include any more tasks for the users to test.

Data was collected through direct observations, voice recordings, and open ended interview questions, to investigate how well the different prototypes supported each use case and its goal. By having these use cases it could be ensured that all participants explored the same part of the interface and that all participants were treated in the same way. During the observation the participants were urged to use the think aloud technique to enable the evaluator to understand what the participants were thinking and experiencing during the interaction. After each use case, the evaluator asked interview questions to get a deeper understanding of the participants experiences. These questions were about whether the participant understood the task or not, if they understood when they had completed a task, if the task was easy or difficult, and how they experienced the map.

6.5.2.2 Remote synchronous usability testing with cognitive walkthrough

To examine and evaluate the ease of learning of how to use the prototype and to gather insight of the interfaces accessibility, a second meeting was held with Locums focus group consisted of people with different disabilities, testing both the MID design and the Easy Wayfinding design. This usability testing was performed remotely using Microsoft Teams with ten participants to communicate with the participants and share the designs with screen sharing to conduct a cognitive walkthrough. As both users, developers and researchers were present during this walkthrough it was a mix of pluralistic walkthrough and cognitive walkthrough. However, the purpose was to gain insights of the users perspectives and experiences and the researchers and developers did not perform the task together with the users, rather they were observers of the meeting.

The two designs were tested one at a time, starting with the MID design performing the same use case as in the smartphone test, followed by the Easy Wayfinding design with the use case of a simulated text message with a link to open the application with pre-installed settings of starting point and end destination. The designs were shared on the screen for all participants to see while the research leader described every frame of the design in detail to explain it for the participants with visual impairments who did not have the possibility to see the screen. To move forward in the task, the researcher explained the intended use of the application step by step by clicking through the use case. Looking at the design, all participants were encouraged to individually study the design and consider how they would have interacted with the application to perform the use case. After each use case was completed, all participants one by one described their thoughts about the design. First about the MID design and then the Easy Wayfinding design. This lead to a discussion regarding if functions and actions worked as expected or not, the reason behind it and what improvements could make the design more accessible.

6.5.2.3 Thematic analysis of usability testings

After conducting both usability tests with participants testing the designs on a smartphone and the remote usability testing of cognitive walkthrough with the focus group, the data from the tests were analyzed with a thematic analysis together with affinity diagram. This analysis had an inductive approach with support from the principles by Langemar (2008) following six steps to perform the analysis. In the first step all recordings from the tests were transcribed and voice recordings were combined with notes from the observations to be able to understand what interaction the participants performed when making a comment about a specific feature or function. Data of the MID design and the Easy Wayfinding design were analysed separately, as findings for these would only be related to the specific design. In the next step key elements were identified within the data set and these codes were then categorized and sorted into groups, and overall themes emerged from the data. Further sorting and categorizing of the codes and themes were made to ensure no themes were overlapping with each other. To categorize even further, sub themes were created including similar aspects within each theme. The analysis for the MID design resulted in six themes all with three sub themes each; *navigation, design, functions, experience, accessibility*, and *improvements*. The analysis of the Easy Wayfinding design resulted in four themes also with three sub themes each; *design, navigation, functions,* and *icons*. All findings are presented in Appendix F.

6.6 Iteration Four

In the fourth iteration, improvements were made to the Easy Wayfinding design based on the result from the thematic analysis in iteration three. Further, an additional Maze usability test was conducted to gather insights and feedback of the implemented design changes. Lastly, the usability testing was analyzed with a thematic analysis.

6.6.1 Development

After the thematic analysis in iteration three was performed, design adjustments and changes were made to the Easy Wayfinding design in Figma. In the following section the improvements that were done to the Easy Wayfinding design will be presented.

Color scheme

The color scheme of the Easy Wayfinding interface was changed on all graphical elements such as backgrounds, icons, and buttons, to be similar to Danderyd hospital's color scheme and also meet the highest WCAG requirement of level AAA (DIGG, 2018) to provide an accessible interface. The colors was changed based on user feedback that it would build more trust to the interface if the color scheme matches Danderyd hospital's existing color scheme (Figure 6.30).

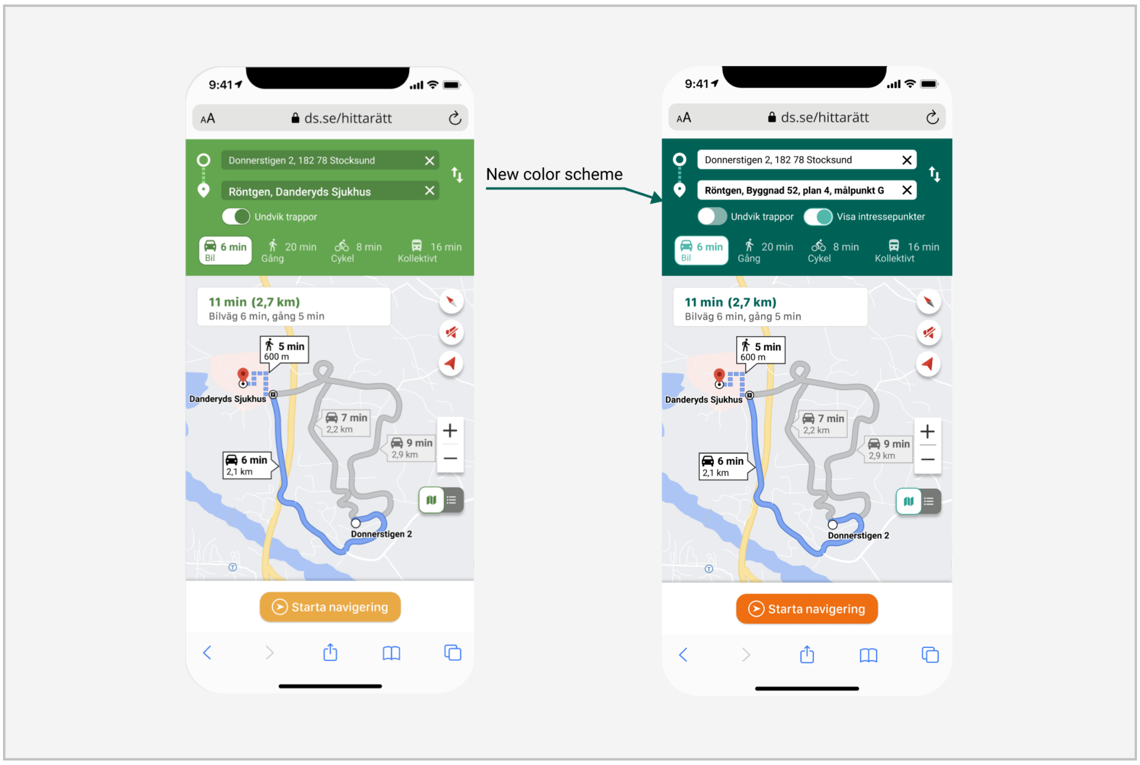


Figure 6.30: The image to the left is the interface with the old color scheme, and to the right is the interface with the new color scheme.

Text and font

As the color scheme was changed on the graphical elements, the color of text elements was also changes to match the background and provide high contrast and some text elements in low contrast were changed to darker grey color to be more visible (Figure 6.34). Additionally, complementary text to some icons were removed, such as text for the main entrance as these were causing the interface to feel cluttered and were not considered to be necessary (Figure 6.31). However, the text for the target points and departments were not removed since these icons were not considered to be universal.

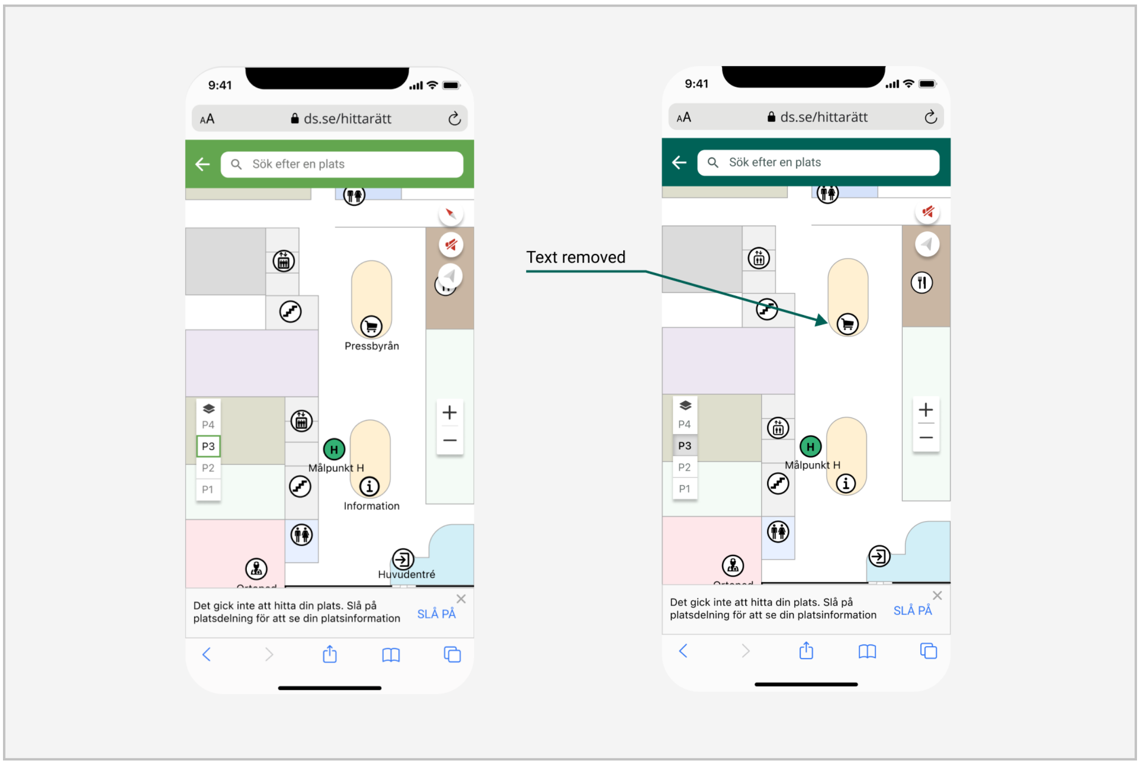


Figure 6.31: The image to the left is showing the old interface with complementary text to the icons, and to the right changes are made only providing complementary text to the target points and departments.

Additional switch to filter POI

An additional filter switch was added, that allows the user to filter out irrelevant POI:s on the map. Based on feedback from the usability testings some participants were confused and disturbed by unnecessary POI:s in the interface that did not regard their route, in contrast to others who claimed that they needed the POI:s to help navigate and locate themselves in the environment. Therefore, a filter switch was added to allow the user to customize their navigation based on what suits them best. Additionally, the filter switches were both added to the view when the users have interacted with the “end navigation” button (Figure 6.32). The reason for adding the switches there was to give the user an opportunity to apply a filter without having to end the navigation if they missed adding it before starting the navigation.

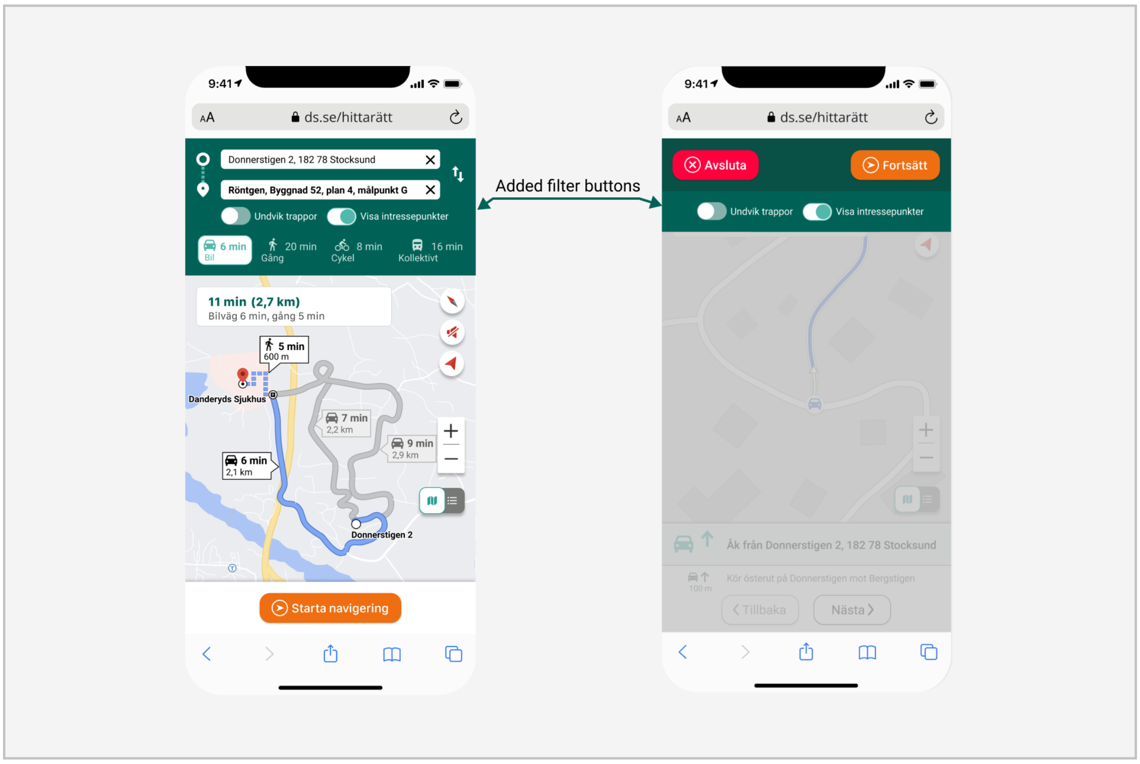


Figure 6.32: The image to the left shows the filter switch that was added next to the switch to avoid stairs. The image to the right shows both filter switches that were added in the overlay that appears when interacting with the “end” button.

Changing floors

The usability testings revealed some confusion for the participants of what floor they were on, which floor they were going to and how to change floors. To make this clearer the floor selection was changed to better demonstrate what floor the user was on by removing the stroke that previously had been used to indicate the selected floor and instead adding an inner shadow to make its appearance more similar to a button (Figure 6.33). Additionally, when the user's navigation involved changing floors, a dashed stroke was added to the floor selector to provide modeless feedback of which floor they were changing to. However, the dashed stroke was only visible in the step before going into the elevator. Lastly, the text that previously was presented next to the navigation line, informing the user of how many floors up or down they were going, was removed (Figure 6.34). This was mainly because it only seemed to cause confusion and that it might be too much different information provided when changing the floor. Therefore, it was considered to be better if the user only relied on the textual descriptions as in the other navigation steps with hints from the floor selector.

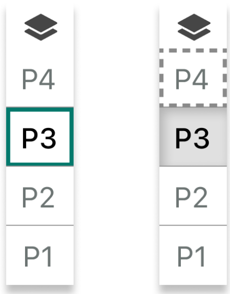


Figure 6.33: The left image shows the old floor selector, and to the right is the new appearance of the floor selector.

Textual descriptions

Some participants did not notice the textual descriptions in the map view and only interpreted the navigation based on the map and the navigation line. Therefore, the textual descriptions were changed to be more visible using a colored background on the current step (Figure 6.34). Additionally, text and icons were made bigger to make it more accessible and easier to read for visually impaired users (Friedman & Bryen, 2007). In the list view more padding between the steps was added to make it easier to separate them.

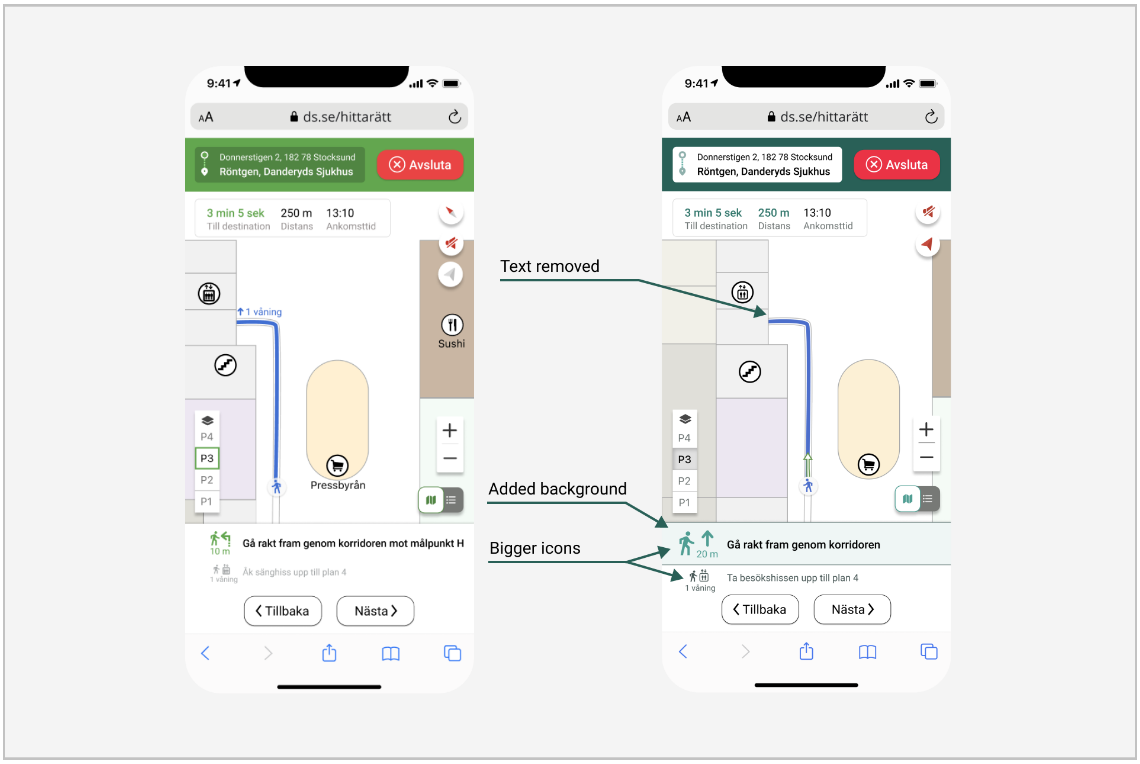


Figure 6.34: The image to the left is showing the old design of the textual descriptions, and to the right is the new design presented with its changes.

Feedback of arrival

To provide for a clearer feedback of arrival the colored background for the current step was expanded for the whole section of the textual descriptions and the text of the previous navigation step was removed. As the colored background catches the user's attention and covers a larger area of the screen this change was intended to make it clearer to the user that the final destination has been reached, and that there are no further steps for navigation (Figure 6.35).

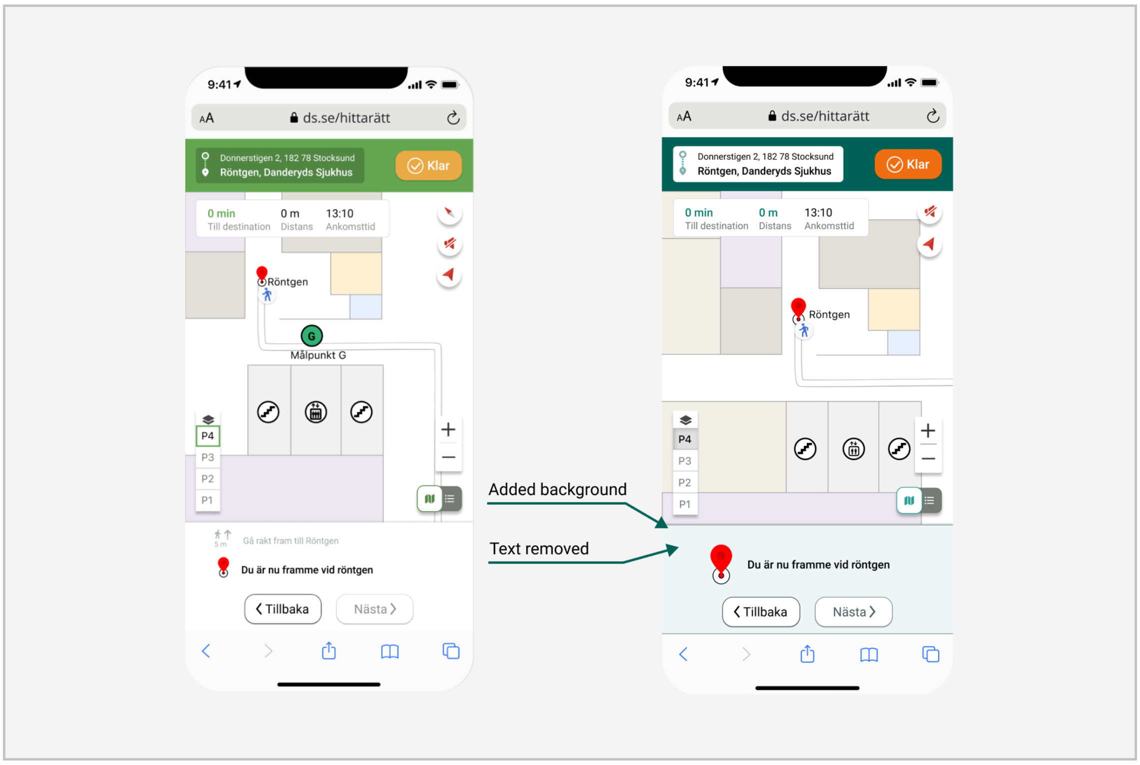


Figure 6.35: Image showing the old interface (left) and the new interface (right) of when arriving at the destination.

7

Results

This chapter will introduce the final design of the Easy Wayfinding design together with the last usability test, followed by the analysis of the experience of interacting with the design, as well as the problems that arose during the use. Lastly, guidelines and a list of design solutions to consider when designing an accessible application to provide for indoor wayfinding will be presented as the core result of this thesis work.

7.1 Final Design

In the following section the final design will be presented with images showcasing the design and the appearance of the prototype along with explanations of the possible interactions and the intended use. The last usability test evaluating the final design will be explained and the result will reveal further improvements.

7.1.1 Delivery

After conducting usability tests and analysing the results, changes were made to the design and the prototype was further improved leading to the final appearance of the interface of the Easy Wayfinding design. To evaluate these changes a last remote asynchronous usability testing in Maze was conducted, followed by a thematic analysis to interpret the result.

7.1.1.1 Final interface of the Easy Wayfinding design

The result of the Easy Wayfinding design was a combination of the findings gathered throughout the entire design process, and based on previous established guidelines from literature. In this section wireframes of the final appearance of the Easy Wayfinding will be displayed.

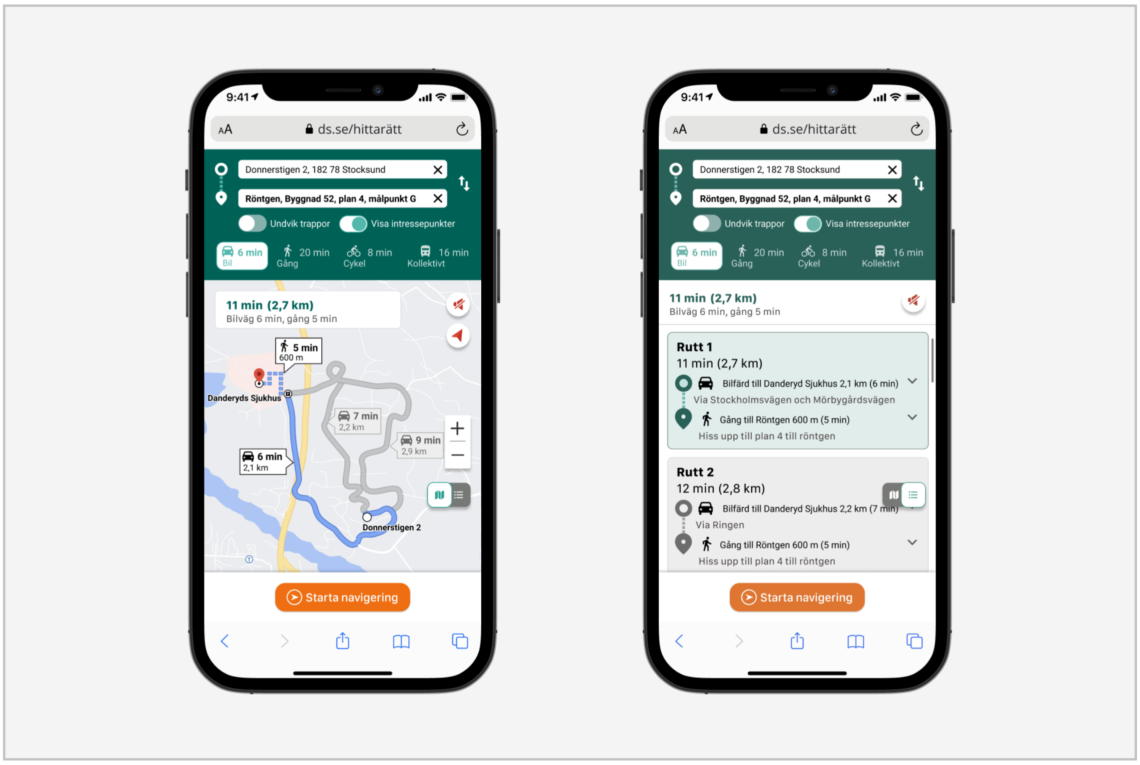


Figure 7.1: First screen when opening the application with a preset destination, presented with a map overview on the left & a list view on the right.

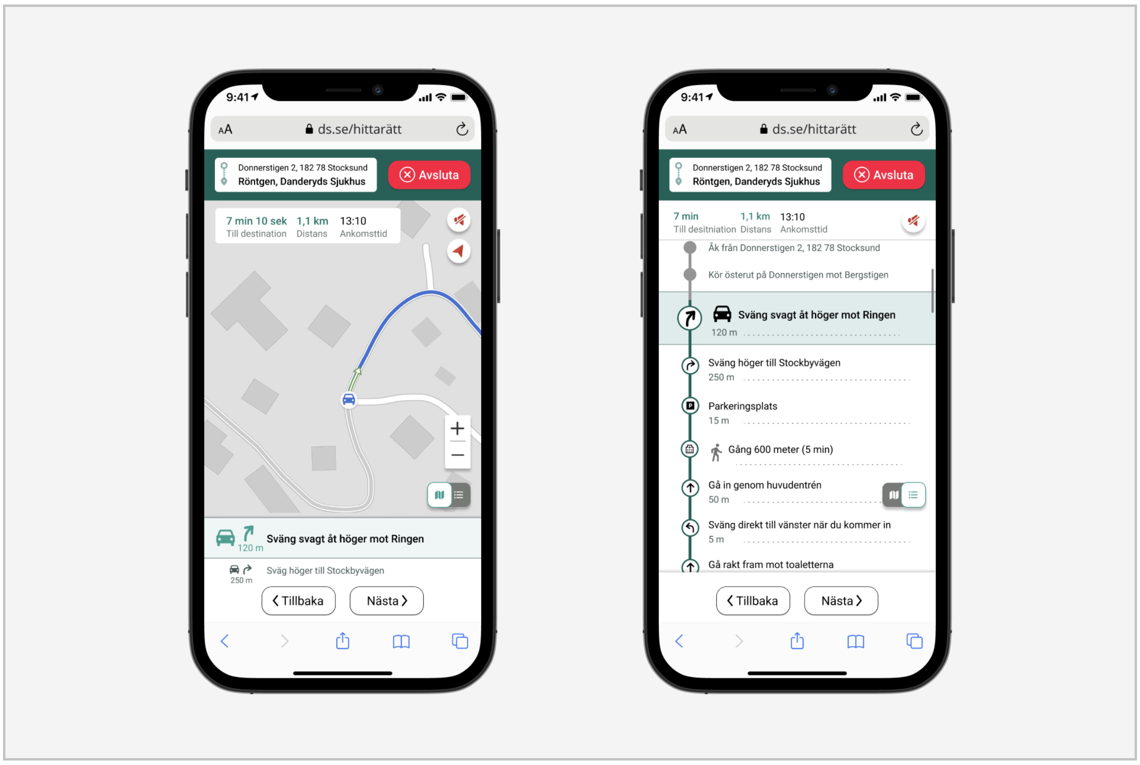


Figure 7.2: An example of the map view (to the left) and on the list view (to the right) when the user has started the navigation.

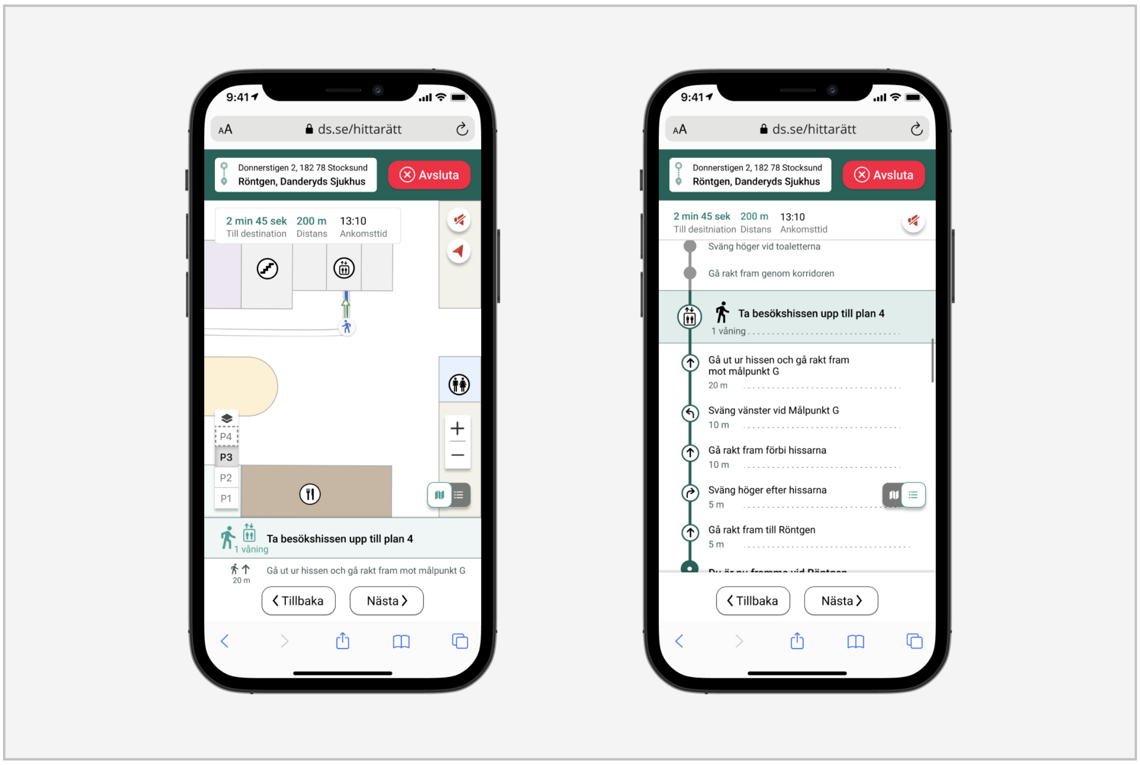


Figure 7.3: An example of the map view (to the left) and on the list view (to the right) of the indoor navigation when the user is approaching the elevator.

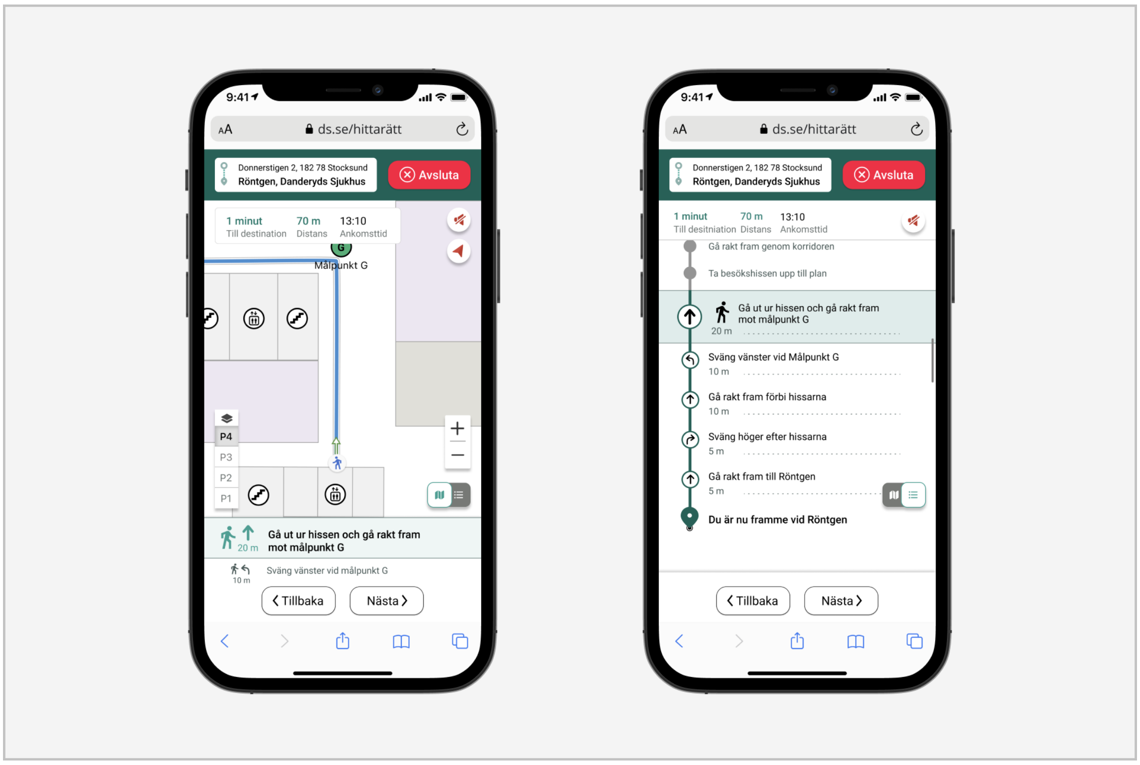


Figure 7.4: An example of the map view (to the left) and on the list view (to the right) of the indoor navigation when the user is leaving the elevator.

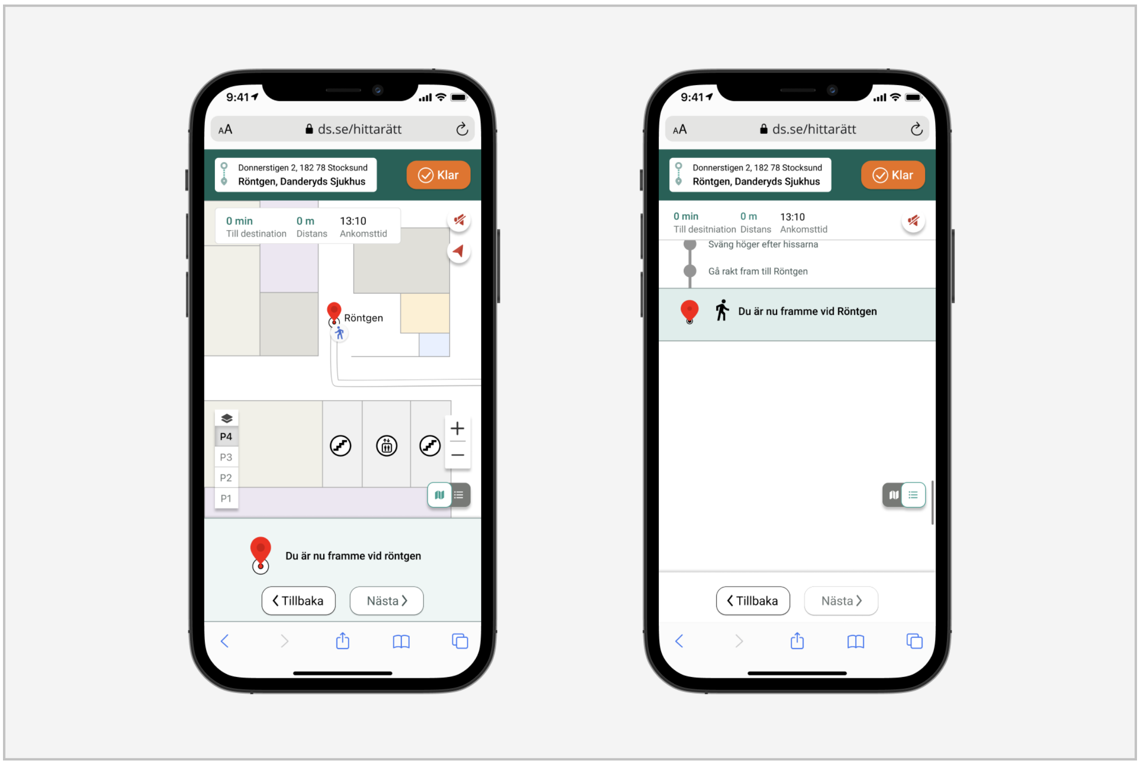


Figure 7.5: An example of the map view (to the left) and on the list view (to the right) of when the user arrives at their destination.

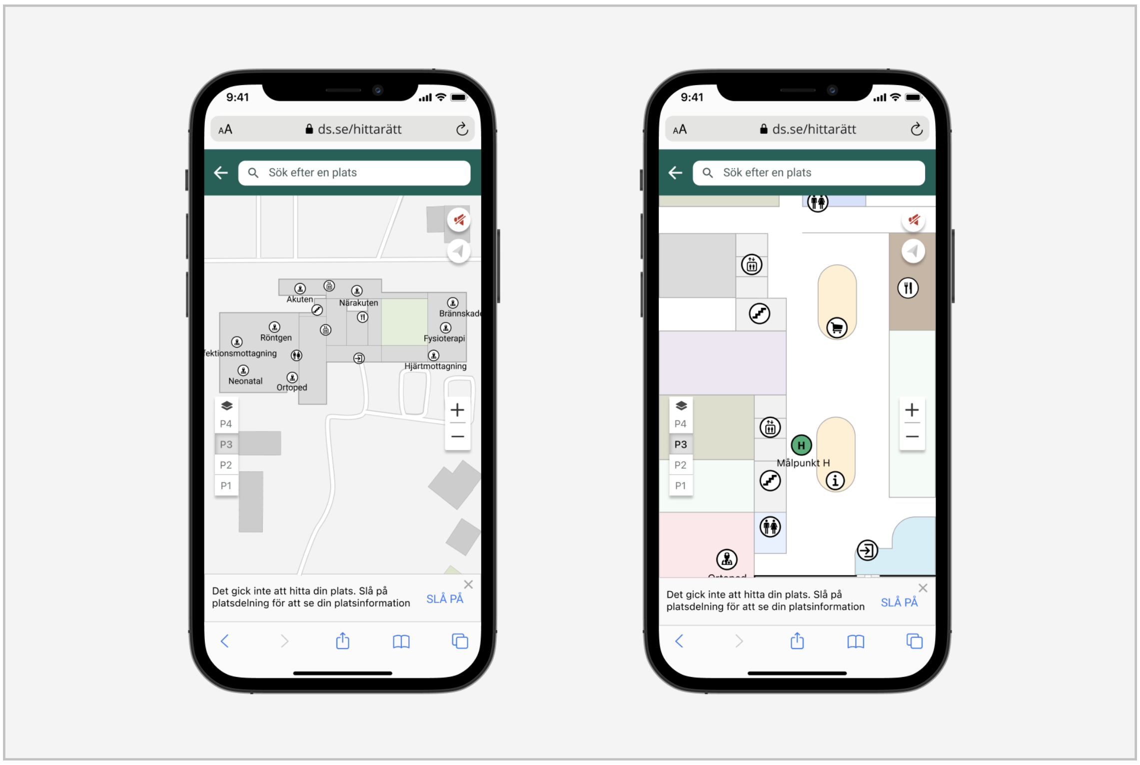


Figure 7.6: The interface without any navigation set before the user has shared their location. The outside view (left)and inside view (right) of the hospital.

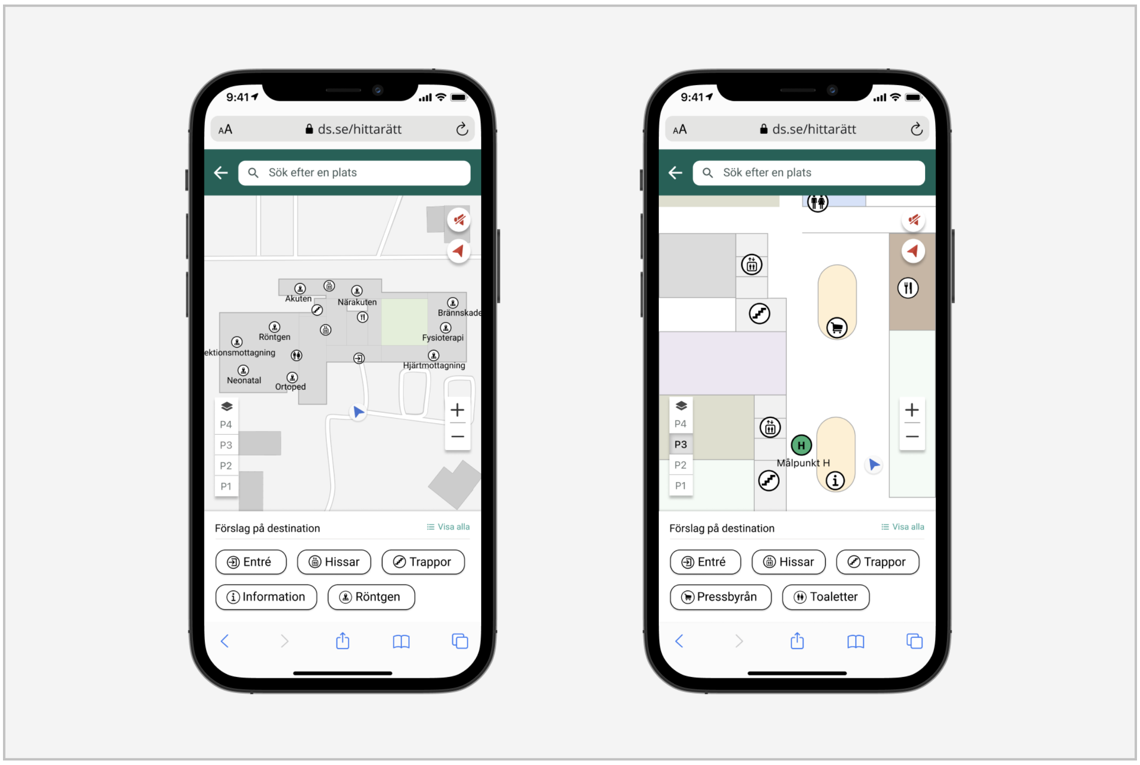


Figure 7.7: The interface without any navigation set after the user has shared their location. The outside view (left)and inside view (right) of the hospital.

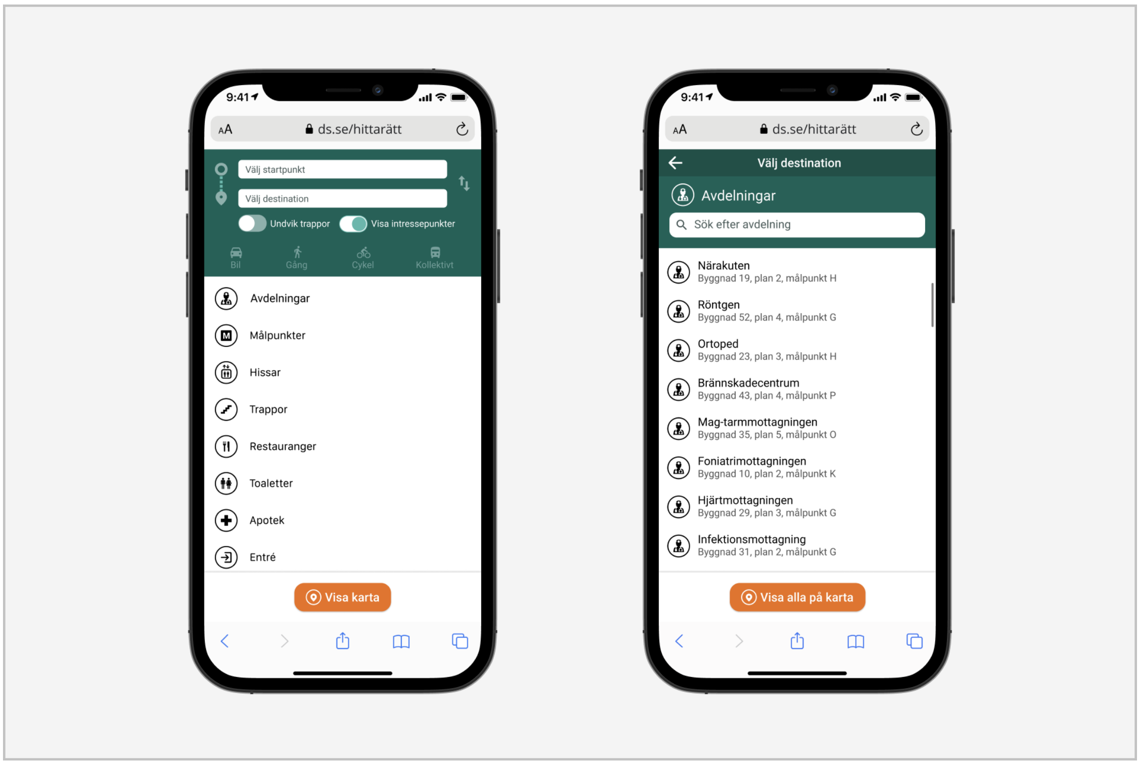


Figure 7.8: The interface of setting up a navigation. To the left are the categories and to the right the listed options within the category “departments” presented.

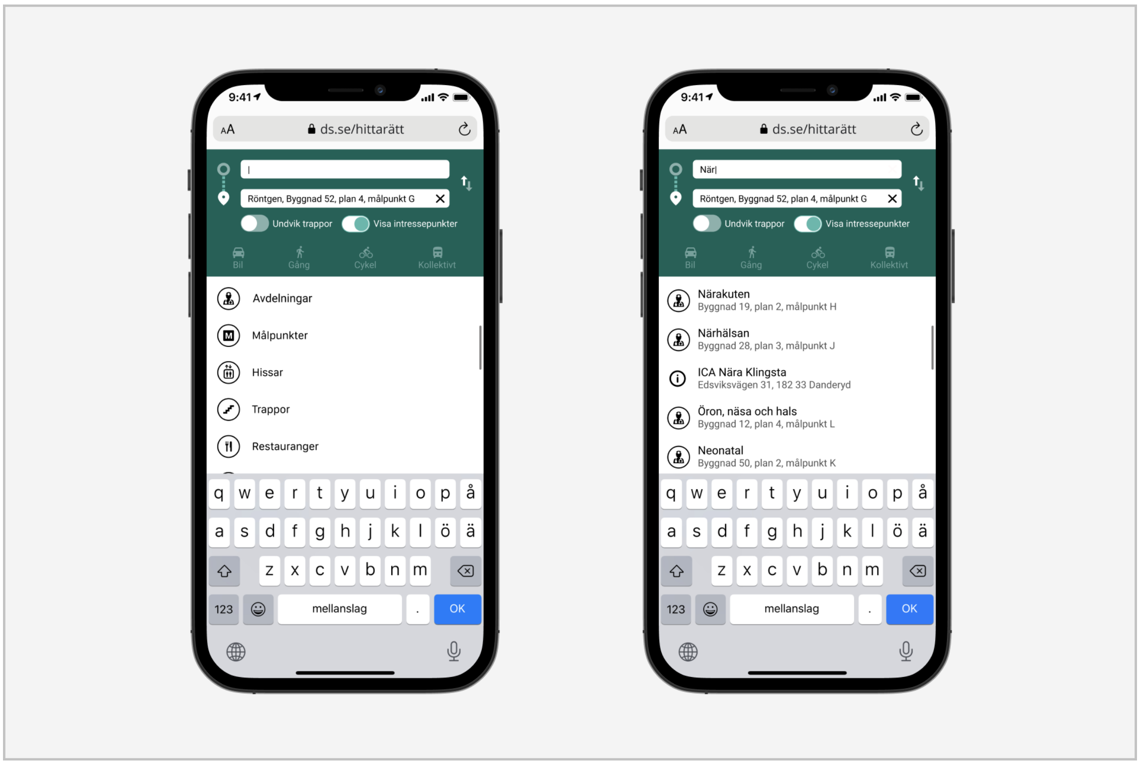


Figure 7.9: The interface when making a new search. It is possible to search by choosing from the categories in the list (to the left) or by typing (to the right).

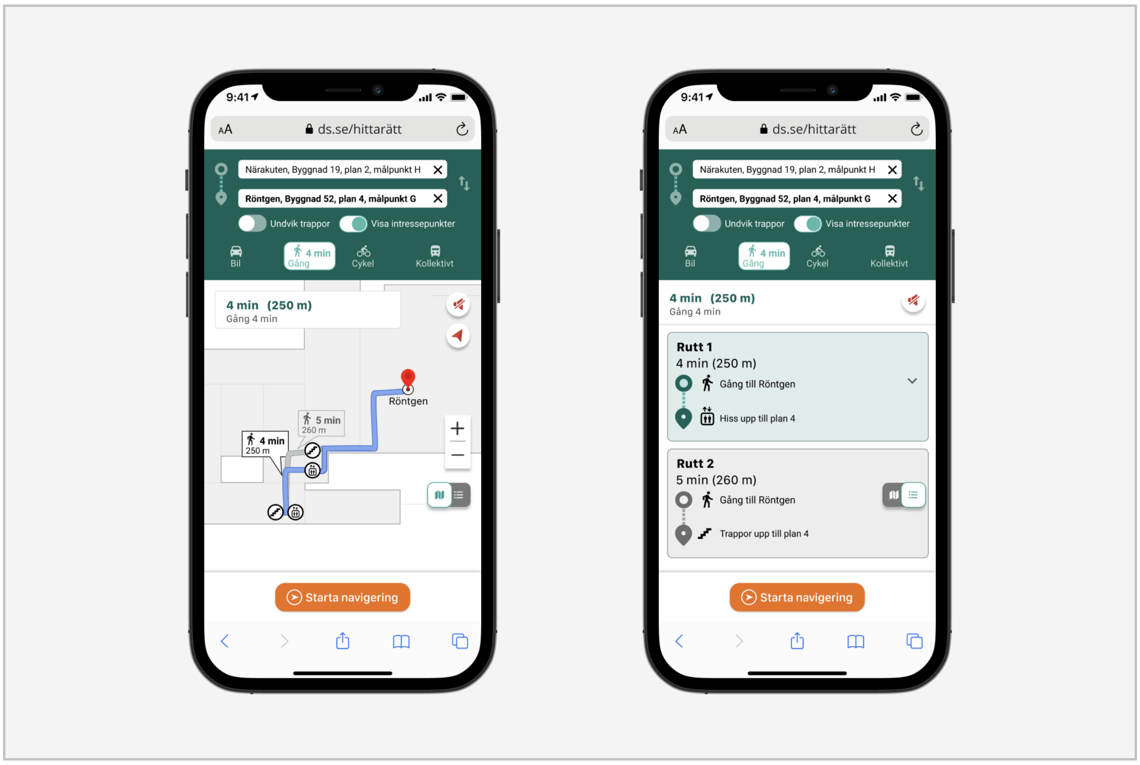


Figure 7.10: A new search within the hospital between two different departments. To the left is the map overview and to the left is the list view of the route.

7.1.2 Remote asynchronous usability testing in Maze test 2

After conducting the usability testings, analysing the results and making changes to the Easy Wayfinding design in iteration three, another online test using Maze was performed. This Maze test had the same construction as the previous Maze test, to be able to compare the results with each other and thus know with greater certainty that it was the design changes that affected the result and not the design of the test itself. Therefore, the tasks and evaluation questions were unchanged from the first Maze test, only with the improved design (Appendix D). This Maze test was conducted with new participants who did not have any previous experiences of the application to gather insights and feedback from new perspectives and viewpoints.

7.1.3 Thematic analysis of Maze usability testing 2

An inductive thematic analysis was conducted to analyse the data for the Maze test. 14 participants performed the usability test, where four tests were removed due to incomplete tests or technical problems and the result of the analysis is therefore based on data from ten participants. All feedback and answers from the participants were organized and sorted into themes. The analysis resulted in six themes of usability problems that were discovered from the data; *flow, design, interactions, usage, confusion*, and *improvements*. These themes contributed to recommendations for improvements and refinements to the design to enhance the prototype further (Appendix G).

The result indicated that the participants understood the flow as easy and logical. The design was clear and provided the user with valuable and detailed information to be able to follow the navigation, as POI:s on the map matched the environment to assist the user to locate their position. The interactions showed that the participants experienced the prototype as intuitive where they could perform the actions and complete the task without any problem. Throughout the analysis it was discovered that this application was highly favorable to use as guidance and to provide navigational instructions within the hospital, thus the participant would not use it for outdoor navigation on their way to the hospital. However, the prototype had great recognition from other applications, which contributed to a positive experience among users where they felt familiar with the product.

There were still some usability problems within the design where the users felt confused and disorganized. This mostly concerned the unawareness of the application providing for live positioning or not, and the desire to have this function to support the orientation within the hospital. The transfer between navigation outdoors to indoors created some confusion where the user did not perceive this transition as easy to understand right away. Another confusion regarding transfer between floors, where one participant perceived that the application did not provide any clear information about what floor to go to. Some users thought it was unclear if to set the start or end destination first, but then expressed that it became clear when the prototype by default selected the searched destination as the end of the route. Further, one participant experienced some time searching for the “done button” when finished with the route, and desired for the button to appear in the spatial relation to the “next button”. Lastly, based on the rating scales provided in the section of survey questions in the Maze test the result indicated that the prototype had improved compared to the results from the previously Maze test, where the average of the first use case had improved from 4.4 to 4.6 out of 5, from 4 to 4.4 out of 5 in the second use case, and from 3.7 to 4.4 out of 5 for the third use case.

7.2 Guidelines

In this section nine guidelines of how to design an indoor navigation application with a universal design will be presented. The guidelines are a part of the project’s outcome derived from insights gained throughout the work process, mainly gathered from the pre-study and the usability testings. The purpose of these guidelines is to appeal to designing with a universal design perspective in the creation of future indoor navigation applications and to be used as guidance. Further, the guidelines aims to answer the research questions stated below in no particular order:

What design solutions are important to consider when designing a universal accessible application for indoor wayfinding?

1. **Design with standard solutions and consistency**
   The layout of the interface should be designed to be simple and clear and provide good spacing within the interface to afford a consistent grid and maintain white space, with the use of wide margins throughout the design (Friedman & Bryen, 2007). A simple and clear interface has a logical order of the included elements and are structured to be easy to find by containing the same position in all frames within the interface. Information provided in the interface should be consistent and comprehensible (Hughes et al., 2015), to help guide the user in their interaction. To design for everyone, it is important to use a large font size with a minimum of 12pt or 14pt (Friedman & Bryen, 2007), and based on feedback from participants with visual impairments the most important feature is to have colors with high contrast. Further, the design should support the standards based on Material Design (n.d.) and Human Interface Guidelines (Apple Developer, 2020). Lastly, when designing a digital product WCAG guidelines and requirements for level AA must be met to create a good and accessible product, and preferably the level AAA should be met to accommodate additional users needs.

2. **Design for interactions that creates a natural flow for the user**
   One of the most important aspects to consider when designing is the user’s intended interaction, and how it will affect the flow in the user’s experience. To design for a seamless interaction with a satisfying flow, the users should be in control of the interactions (Cooper et al., 2014), as it was claimed by

participants in this study that they need to have time to make their decisions of when to proceed in the interface. The interface needs to express feedback of the user's actions (Al-Razgan et al., 2012; Friedman & Bryen, 2007; Cooper et al., 2014), such as when executing an action or confirming when arriving at the destination. Feedback is an important feature to consider when designing for people with cognitive disabilities (Friedman & Bryen, 2007). Therefore, no action should be executed without the users knowledge or approval, which was also mentioned in usability testings during this study. Further, the navigation buttons need to be clear, large, and consistent to be visible and easy to locate (Friedman & Bryen, 2007). All buttons should in an effective way clearly convey its purpose to avoid misunderstandings and frustration, as claimed by participants with visual impairments in this study. This could be done by using both text and icons in combination.

A mobile interface has a multi-touch interaction and the available gestures in the interface should be standard and apply to the most frequently used gestures for a mobile touch interface (Cooper et al., 2014). Tap gestures should be used to select, activate and toggle. To move around in the map the user should pinch in and out to zoom and rotate the map by twisting the thumb and forefinger. This gesture is important for both elderly users (Al-Razgan et al., 2012) and for users with visual impairments (Huang, 2018). It should also be possible to scroll by tap and then drag.

3. **Have a logic structure and implement navigation buttons on all pages**

   In order to not make the user feel lost within the interface it is important to have a logical structure with features that have the similar functionality and actions grouped together (Al-Razgan et al., 2012; Interaction design foundation, n.d.-a), and that critical functions should never disappear (Al-Razgan et al., 2012). The main navigation should be placed identically on all the pages in the interface (Al-Razgan et al., 2012), which was found in this study to be important for users interacting with the interface using a VoiceOver. Further, to maintain a good structure and to avoid mistake actions it is essential that important functions are placed at the top of the screen to be more difficult to reach by mistake (Al-Razgan et al., 2012). Also, to help users recover from mistakes and when getting lost it is important to be able to use navigation methods, as for example a 'undo' or 'back button' (Friedman & Bryen, 2007). However, findings from this study reveal that users wish for a minimum of options and places to navigate to, as this can cause navigational excise. Therefore, avoiding unnecessary navigation can reduce the risk of navigational excise (Cooper et al., 2014).

4. **Provide a detailed map with marked POI:s with possibility to customize**

   An indoor navigation application should contain a detailed map with point of interests (POI) presented as objects in the surroundings, both to indicate the presence of the POI:s and to help visually impaired users to easier determine their location on the map, as they constantly compare the surroundings around them with what is described on the map (Ponchillia et al., 2020). This design guideline is also supported by this study as participants with visual impairments preferred to have all POI:s presented on the map at all times, however, sighted users can perceive this as disturbing information as it does not provide any necessary information regarding their route and thus does not want this information to be displayed. Therefore, the POI:s should be provided without any risk of the map being too cluttered and further, it can be important to provide a possibility for individual customization, as for example where the user can choose which symbols the map should display (Friedman & Bryen, 2007), which can be done with adding a filter button. Furthermore, when designing for a navigation application that consists of both outdoor and indoor navigation, it is important to provide a clear transfer between these. An example is to use colors to distinguish inside rooms from outdoor areas (Smolenaers et al., 2019).

5. **Use detailed guided descriptions for the navigation instructions**

   When designing with a universal design approach it is important to address users with disabilities, which means designing with a clear and simple text (Friedman & Bryen, 2007). Therefore when designing a navigation application with a universal design approach it is important to provide detailed and descriptive textual navigational instructions with a clear and simple language, without interference of medical terminology (Marshall, 2017). The effect of including the POI:s in the textual descriptions was claimed by participants in this study to help to locate their current position and easier determine when to make turns based on the positions of the POI:s instead of time or distance. Further, it is important that icons and textual instructions overlap with signage and instructions in the physical environment, which is especially important since elderly users are familiar with the signage system and might prefer using it (Morag & Pintelon, 2021). As found in this study, when guiding the user of changing floors, it is crucial that the textual descriptions both clearly guide the user of changing floors and match the environment to reduce the risk of confusing the user.

6. **Use icons with universal recognition and provide complementary text if necessary**

   The use of icons can be an effective way to overcome language barriers and make the interface more accessible for children and people with cognitive disabilities (Huang et al., 2002; Wu et al., 2014; Friedman & Bryen, 2007). However, in the usage of icons it is important that they are easy to recognize and remember, are of universal recognition (Huang et al., 2002), and icons that can not convey their meaning on its own need to be provided with complementary text. In this study, the participants did not found the icon for departments as universal, and therefore it needed to be supported with text. When using icons in an interface each icon should stand for one word or one concept and not involve irrelevant details to be able to effectively convey its meaning (Specialpedagogiska skolmyndigheten, 2020; Lidén, 1999). Additionally, the icons should be designed with high contrast and sharp focus, such as black and white, to help the user to effectively and quickly perceive the icon (Lidén, 1999).

7. **Include a search function to be visible at all times**

   A search function should be provided in the interface, and it is essential that the search function is designed to always be visible for the user as it is important that it is easy to discover and easy to use (Harper et al., 2020). Therefore, if it is possible the search function or other important features should not be hidden inside a menu. During the benchmark in this study, it was revealed that when designing for a navigation application, the most important feature is for the user to make a search to and from a destination and to be able to change that search. Thus, this needs to be an easy action to execute for the user, and therefore the importance of having the search function visible at all times.

8. **Support for the use of accessibility tools to include all users**

   In order for an application to provide for universal design, it needs to be usable, accessible and functional without any need for adaptation to the greatest extent possible, regardless of age or ability, which means that it is designed for everyone, not only the "average" person or a person with a disability (Silva, 2011). Therefore, when designing an application that will be functional for everyone, it is important that it is compatible with different help tools. This implies that the application should be able to support for example a 'VoiceOver' function. Participants in this study declared that for help tools to function without any frustration, it is important that the application is correctly coded in a logical order, with the right information provided first. It was is also claimed to be important that it needs to be possible for the user to stop the screen reader in order to not have to listen to all information from top to bottom all at once, and instead be able to understand the interface and perform actions at their own pace. Additionally, alternative text needs to be provided for every image, function and button in the code. This is especially vital for the user's experience since without any alternative text to the buttons, the user does not know where they are navigating in the interface, or what action that will be performed. Further, the application should provide options without any need for external help tools, and the best output mode for a navigational application to assist users who are visually impaired are verbal output and vibrational cues (Ponchillia et al., 2020). This means that the application should provide for an integrated VoiceOver function for users to get verbal instructions and hear what choices that can be made in the present mode. However, it is important that this feature is optional. Additionally, vibrational cues can alert the user with tactile feedback, describing an action that has or can be performed.

9. **Provide for the ability for users to know their location with live positioning**
   A crucial feature of a navigation application is to provide for live positioning with the ability to let users know their location at any time during the interaction (Ponchillia et al., 2020). Throughout the design process for the present thesis project, the desire of wayfinding with the possibility to know one's live position has been expressed by almost all participants. When wayfinding with the assistance of an application, users are used to outdoor navigation applications that provide for the feature to know one's live position at all times and being navigated with the help of a blue dot. Therefore, preferably an indoor navigation application should provide the same option, however as live positioning for indoors is a rather new area this can be difficult to implement. Also, when providing live position it is of importance that the user is provided with their exact positioning, without it differing by any meters, for both sighted users but especially for visually impaired users to trust the application.

8

Discussion

The following chapter will hold a discussion regarding the work performed in order to investigate the research question for the present thesis. The topics of this discussion revolves around background and theory, followed by the execution and process of the work. The chapter also touches upon improvements for future work.

8.1 Background and theory

The purpose with the present thesis was to investigate how an indoor wayfinding application can be designed to be as accessible as possible, with all users in mind, with the aim to fill the gap of the existing research regarding this subject (Morag & Pintelon, 2021). The reason for conducting this study was based on signage being the most obvious method of wayfinding in public spaces, but unfortunately it often involves complexity and difficulty (Smolenaers et al., 2019). Along with hospital environments being too complex to explain with signage and spatial cues such as arrows, numeric encoding, color coding, since they are not simple enough which hinder natural movements in the hospitals (Morag & Pintelon, 2021). The equivalent problem exists at Danderyd hospital, which was established during the exploratory research conducted at the hospital. When hospitals grow and reconstructions are being made, it becomes even more complex to navigate when having to adapt to new routes, which is especially challenging for elderly people who are common visitors at hospitals (Morag & Pintelon, 2021). As previous studies have indicated, digital wayfindings systems can be used to solve this problem, and are of significant value both for the hospital and its users (Morag & Pintelon, 2021). Since it reduces the task complexity, it reduces the wayfinders cognitive load due to the possibility to bring the navigation with them (Harper et al., 2020). It also reduces the user's stress and anxiety as the user more easily can navigate and move around from one department to another (Morag & Pintelon, 2021).

To help the users with their wayfinding the present thesis work aims to solve this issue with designing a wayfinding system to help the users navigate within the hospital. However, how to oppose this issue was a challenge. Mainly since the field of indoor navigation systems is a rather new area, and despite the benefits that digital wayfinding systems contribute with the actual presence of them in hospitals are low, even if they offer assistance (Morag & Pintelon, 2021). However, as these digital wayfinding systems increase, literature of the system's ability to support people with disabilities is lacking, and therefore, it was considered to be of importance to investigate not only how to design an interface for an indoor navigation application but also how to apply universal design to it. To include the universal design perspective was considered to be important since people who visit the hospital are a broad variety of people. Nevertheless, to design a navigation application aimed to be beneficial and helpful for everyone was considered to be a challenge, the work process in the present thesis investigates how this could be done by consolidating how to design for disabilities by incorporating different users in the design process. The approach was to use human-oriented design to meet all potential hospital users needs, since if the indoor navigation system does not provide the users needs, the system won't be used, especially by elderly people and people with impairments (Morag & Pintelon, 2021). Thus, it was considered to be important to involve users to investigate the research question based on their needs with the aim to find a solution of how to design an indoor application that creates a natural movement for everyone.

8.2 Execution & Process

In this section limitations and other potential factors that could have had an effect on the outcome of the work in this project will be reviewed.

8.2.1 Implementing the Easy Wayfinding design

After conducting the first iteration of improvements it was discovered that the solution delivered by Mapsindoors did not offer any possibilities of customization, and with the lack of development resources in the project it was not possible to implement any changes in the MID design for this pilot project. However, as the aim of this thesis project was to investigate the research question, which was no longer considered to be fully possible with the MID design, a decision was made to implement a new interface, the Easy Wayfinding design. This decision provided an opportunity to design an interface based on the findings in the pre-study and conduct iterations with usability testing to implement changes based on that. As the MID design still would be used in the pilot-project as the main interface and be developed to work as a web-based application to be tested at the hospital, this thesis work could use the MID design as benchmarking. Thus, it was possible to use both designs to investigate the research question further. Therefore, we instead became observers of the MID design and actors of designing the Easy Wayfinding design. The reason for using the MID design for benchmarking was a convenience sample based on Axel Health's decision to use MID's design for this pilot project.

8.2.2 Usability testing

In the original plan for this thesis project additional usability testings in a field environment at Danderyds hospital was planned to be executed. However, due to the COVID-19 restrictions it was not possible to visit the hospital and perform usability testings on site. To conduct a usability test of the application in its intended environment would have increased the credibility of the application's usability for indoor navigation. The executed usability testing for this project cannot ensure exactly how helpful the Easy Wayfinding design would be for the users wayfinding to and at the hospital. Nonetheless, as previous studies have compared results from conventional laboratory tests and remote usability testing (Baravalle & Lanfranchi, 2003; Andreasen, Nielsen, Schrøder & Stage, 2007; Tullis et al., 2002), the results revealed that the same core problem was uncovered during the different tests (Baravalle & Lanfranchi, 2003). According to Baravalle and Lanfranchi (2003) a laboratory testing proved to identify the users motivation and usability issues better, which indicates that it would have been enhancing to have conducted the usability testing located at the hospital to gain better knowledge of the user's navigation experience with the application and issues occuring while interacting with the Easy Wayfinding design. Since no usability test was performed on site, it is not possible to claim that the intended use of the application, to help users with indoor wayfinding, has been fully investigated.

In addition, as remote testing has been shown to be valuable for understanding problems that are unique to specific types of environments and users (Baravalle & Lanfranchi, 2003), the usability testings for this thesis project were considered to be enough even if no testing was performed on site. The remote usability testing allowed for a diversity of participants, and a larger amount, that would not have been possible on site which increases the probability to uncover usability problems that are unique to specific types of users (Tullis et al., 2002). Understanding usability problems for specific types of users was considered an important aspect for this thesis project, and by being able to perform online usability testing with people in the focus group a diversity of disabilities could be included in the research. It was during the usability testing with the focus group that several different possible solutions to increase the accessibility and universal design of the interface of the application were uncovered. Even if some of these suggestions could not be implemented, due to this project only incorporating a prototype, these opinions and insights were still of importance to be able to investigate the research question and to gain further knowledge of how to design for a universal design. Furthermore, the conducted remote usability testing could have consisted of an even greater number of participants, though it was considered to be enough to expose the most common usability problems according to Nielsen (2012), who argues that five participants is enough in a usability study. However, predictably, further testing would have uncovered further usability problems which would help to increase the credibility and finding more usability errors in the design.

Further, the result from the online usability test in Maze discovered some confusion where participants experienced some difficulty distinguishing between outdoor and indoor navigation, as well as determining when to take the elevator. These experienced problems might not occur using the application on site, as the user is present in the physical environment and aware of the change between outdoor to indoor or the act of going into the elevator. Another reason for this confusion might come from the prototype not including all steps in the navigation and thus skipped a few steps in the navigational descriptions, which could be confusing for users not being present in the environment.

8.2.3 Technical limitations

As stated in guideline number nine in the previous chapter, implementing the possibility for a user to see their live location is one of the most important factors when designing for a universal indoor navigation application. Previous studies, as of this thesis work, have presented the desire of the ability to know one's location at any time (Ponchillia et al, 2020). However, indoor navigation is still a new rather undiscovered area that has not reached the equivalent technical possibilities as outdoor navigation. Since GPS cannot be used for indoor navigation (Santosh et al., 2016), other solutions are required such as BLE beaconing technology (MazeMap, 2021; Bekkelien, 2012). However, this technique still is unexplored and demands for transmitters to be installed at the physical environment to be able to communicate with the user's smartphone via an algorithm to calculate its physical location (Wang et al., 2015), which only is possible with a native application.

To develop a native application, instead of a web application, which was the case in this project, decreases the accessibility of the application where it demands the user to download the application to their smartphones. For a first time user it can be difficult to understand how to download an application, where a one time user can consider this to be unnecessary or frustrating. Further, it decreases accessibility when the option to follow a link or scan a QR code to access the application with pre-installed settings for a determined destination is no longer possible with a native application. These aspects of requiring the user to download an application in combination with installing transmitters at the hospital need to be considered and studied when developing an application for indoor navigation. Further research regarding this aspects is required to investigate what is most preferable for the users, to be able to see one's live position when navigating at the hospital which requires the effort to download the application, compared to not having to make the effort of downloading an application but with the possibility to only navigate within the hospital with help of the textual description and map guidance provided in the application. Since a hospital has a broad user group, there will probably exist opinions with advantages and disadvantages of both options. It all depends on who the user is, if it for example is a first time user, a one time user, a regular user or a user with disabilities. Regardless, it was not possible to implement any BLC beaconing technology for this pilot project and therefore it was decided to design a web application for this thesis project. Instead the main focus became on designing for the best navigation descriptions as possible without any live positioning. However, for the user to be able to see their location is to prefer and it lies within the future technology developments to be able to combine these two aspects to be able to provide indoor live position with a web application.

Since an application for indoor navigation requires to be developed individually for each purpose with associated floor plans and maps of the indoor environment it can be difficult to test a variety of different indoor navigation applications. Unlike outdoor navigation applications that use satellite images to develop the map, indoor navigation requires the application to be adapted to each building, and most existing indoor navigation systems can offer a demo version of their product, but at a cost. As mentioned earlier, the MID design was used based on a convenience sample as Axel Health decided to use this service in the project “Lätt att hitta rätt”. This meant that the MID design was created as a demo version for Danderyds hospital including floor plans and marked POI:s on the map especially designed for this project. As there is limited access to test and evaluate different applications for indoor navigation, it was difficult to include further indoor navigation applications in this project. Having the possibility to test and evaluate more applications could have had an impact on the result. Evaluating different applications and how they have solved the problem of indoor navigation could mean discovering additional features, functions or solutions to multiple problems that have not been explored in the MID design or the Easy Wayfinding design. By comparing multiple systems and how each has solved various problems within the interface but also investigate its accessibility could have increased the credibility for this thesis.

8.3 Further improvements and research

Although several iterations were conducted during this design process and improvements were implemented in the interface throughout the project, there are additional implementations and research that could improve the application further. Since this project lasted for a limited period of time and only developed an interactive prototype, some of the functions and features could not be implemented within the scope of this project. In this section improvements to the application will be discussed which could make the application better and increase the accessibility and wayfinding.

8.3.1 Usability testing in field

Future research for this project would be to perform usability tests of the Easy Wayfinding design on site at Danderyds hospital to examine and ensure if the map along with its descriptions can be helpful for people to navigate within the building. As discovered in this study, it is of great importance that the map matches the physical environment, and provides PIO:s to help the user locate themselves. Even though the development of the maps in the two prototypes for this project, the MID design and the Easy Wayfinding design, have been carefully created based on blueprints and floor plans of the buildings, it is not possible to say with accuracy how well this correlates until conducting usability tests on site. Further usability testing at the hospital would also help to reveal if the confusions of changing floors would remain, and additional research could be conducted to investigate how to design the interface to clearly communicate the floor change for the user. These usability problems might not exist if conducting usability testing on site. However, to be certain further research in the form of additional usability testing is required.

8.3.2 Live position

To determine what is the most preferable and important function to provide for an indoor navigation application, regarding providing live positionsing compared to a web application, both methods must be tested and evaluated. This project did not have the possibility to set up a network with BLE beacons or any other devices within the hospital to provide for live positioning, and therefore the application could not test this functionality. However, the function of providing the option for the user to see their live position at all times was highly desired by the participants, and it would facilitate the wayfinding enormous by enabling the participants to individually navigate within buildings, if the positioning could provide the users very exact location. This however, is continuously being tested and explored as there are no standard solutions for it yet, and thus would be necessary to conduct further research on.

8.3.3 Help tools

For future implementation the application should be equipped with integrated help tools to increase the accessibility and therefore applying to a more universal design approach. Primarily, a VoiceOver function should be implemented, as designed for in the Easy Wayfinding design. However, additional help tools and features in the design could be implemented in further improvements of the application, such as tactile feedback, and as the interviews with people with visual impairments revealed, it is important to be able to zoom in and out and to use inverted colors. Since the aim is to design for a universal design the users should not need to use any external help tools to be able to interact with the application. However, for this to work fully, the coding needs to be done correctly and in the right order.

8.3.4 Including additional disabilities

This thesis work does not include, investigate or design for all different existing varieties of impairments and disabilities. Which means that some generalisations have been made regarding what specific traits are preferable, which have been based on the pre-study and the usability testing conducted in this project. However as disabilities can vary within individuals, what design solution that works best can also vary. Therefore, additional research should be conducted to further investigate how to include all impairments and disabilities to apply for an even more universal design that will meet more individuals' needs.

9 Conclusion

The purpose of the present master thesis was to investigate the research question and to explore design guidelines to take into account when designing an indoor navigation application with a universal design approach, while designing an interactive prototype by the means of research through design. The aim of this thesis project has been to answer the following research question:

What design solutions are important to consider when designing a universal accessible application for indoor wayfinding?

The research question has been investigated with research through design by designing an indoor navigation application for Danderyds hospital, resulting in the Easy Wayfinding design, that has been tested and evaluated with usability testings, both with remote asynchronous and synchronous usability testings online and with synchronous usability testing on phone. The finding from the evaluated usability testings and the pre-study conducted for this thesis project resulted in nine guidelines. These guidelines aim to answer the research question with guidance of how to design for an indoor navigation application with a universal design approach. The guidelines are a summary of the research through design conducted in this project, as the Easy Wayfinding design was used in the usability test to gather feedback from the users of the interface appearance to investigate how to design for a universal design and how to design to help the users with their indoor wayfinding within a complex environment, such as a hospital.

The first part of the research question regarding universal design, were studied and explored first by conducting a pre-study with a literature review of how to conduct digital design for different impairments and disabilities, followed by interviews conducted both with participants individually and with a focus group. Before designing the Easy Wayfinding interface, design principles were produced (Table 6.3) to be followed when designing the interface to make the design more accessible, with focusing on balance, repetition, consistency, large font size, high contrast, use of icons etc. Thereafter, feedback was gathered of the Easy Wayfinding design from the usability test with focus on the accessibility. The goal of universal design is to design for accessibility and functionally for everyone, without any need for adaptation, regardless of age or ability and to ensure this in the design, the usability testings were conducted on people both with and without disabilities to gather varied feedback from a broad perspective. The evaluated feedback indicated that the interface of the Easy Wayfinding was clear, understandable and user friendly for all users, which demonstrates that it is conceived to meet the users needs, and therefore to be an accessible design with a universal design approach. However, to fully meet the needs of everyone and to be an even further accessible design it needs to provide for integrated help tools, which was not possible with the Easy Wayfinding design as it is only a prototype, as stated in guideline number eight.

The second part of the research question regarding an application for indoor wayfinding was harder to investigate as no testing could be conducted on site. To help understand how to design for an indoor navigation system, a literature review and benchmarking was conducted. It revealed that when designing for indoor navigation that meets the requirements for all users, the most important features are the textual descriptions of the navigation to be clear and easy to understand and to have POI presented on the map to help the users in their wayfinding. Since no testing could be conducted on the premises at Danderyds hospital there is no certainty or grantee to what extent the Easy Wayfinding will help the users in their wayfinding at the hospital. However, the feedback gathered from the usability testing indicates high resemblance of similar navigation applications and improvements were made in the design regarding the navigation based on the feedback, which indicates that the users did have an understanding of the navigation guidance provided. It is not possible to claim how specific the Easy Wayfinding design will help users at Danderyds hospital, however what important features to consider when designing for an accessible indoor navigation application was revealed throughout the work of this thesis project, and are included in the guidelines.

Furthermore, there are improvements and further research to be done in order to gain a better understanding of how to design an accessible indoor navigation application, as stated in section 8.3. However, with the opportunities within this thesis project and the methods used we believe that the research question can be answered with the use of the established guidelines presented below. The process of this work has shown that if these guidelines are being followed when designing an indoor navigation application with the aim to have a universal approach it will of high probability increase both the accessibility and the users success in wayfinding within a complex environment. The whole work within this thesis supports the nine guidelines stated below:

GL 1 Design with standard solutions and consistency

GL 2 Design for interactions that creates a natural flow for the user

GL 3 Have a logic structure and implement navigation buttons on all pages

GL 4 Provide a detailed map with marked POI:s with possibility to customize

GL 5 Use detailed guided descriptions for the navigation instructions

GL 6 Use icons with universal recognition and provide complementary text if necessary

GL 7 Include a search function to be visible at all times

GL 8 Support for the use of accessibility tools to include all users

GL 9 Provide for the ability for users to know their location with live positioning

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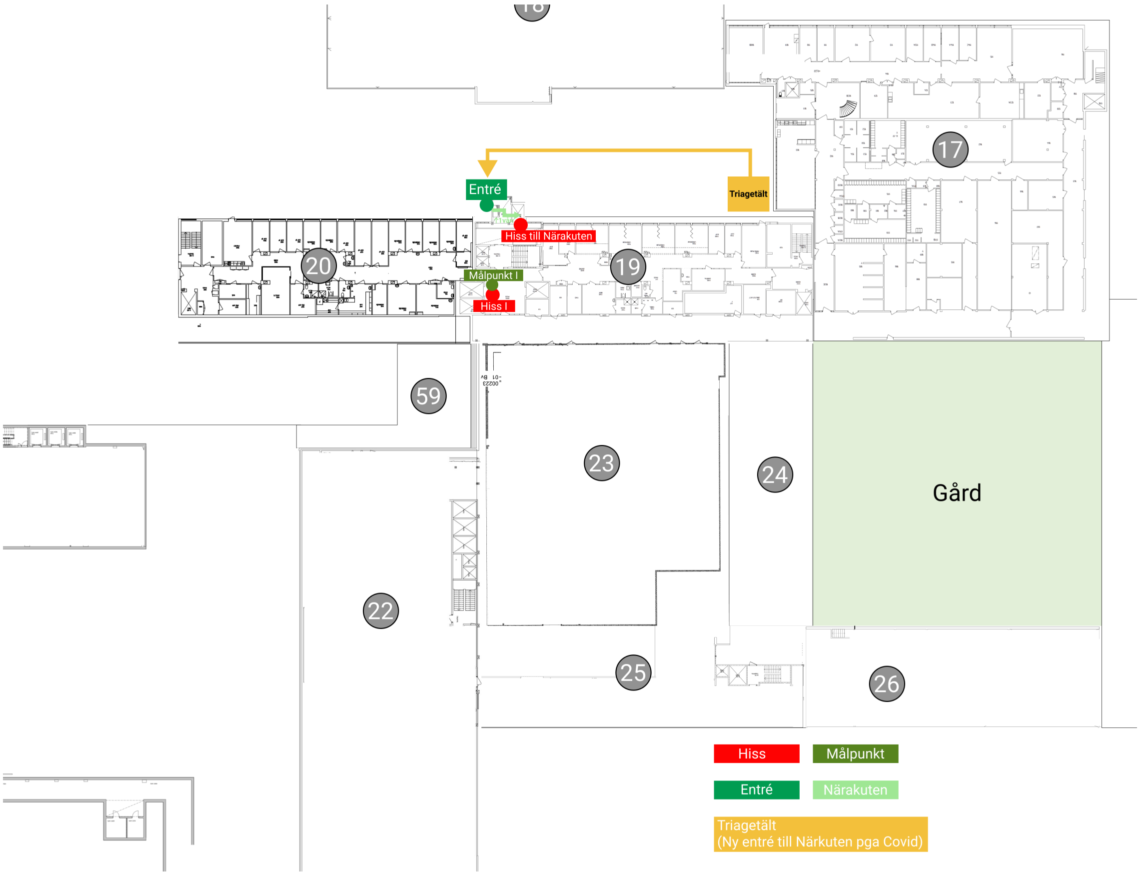
A

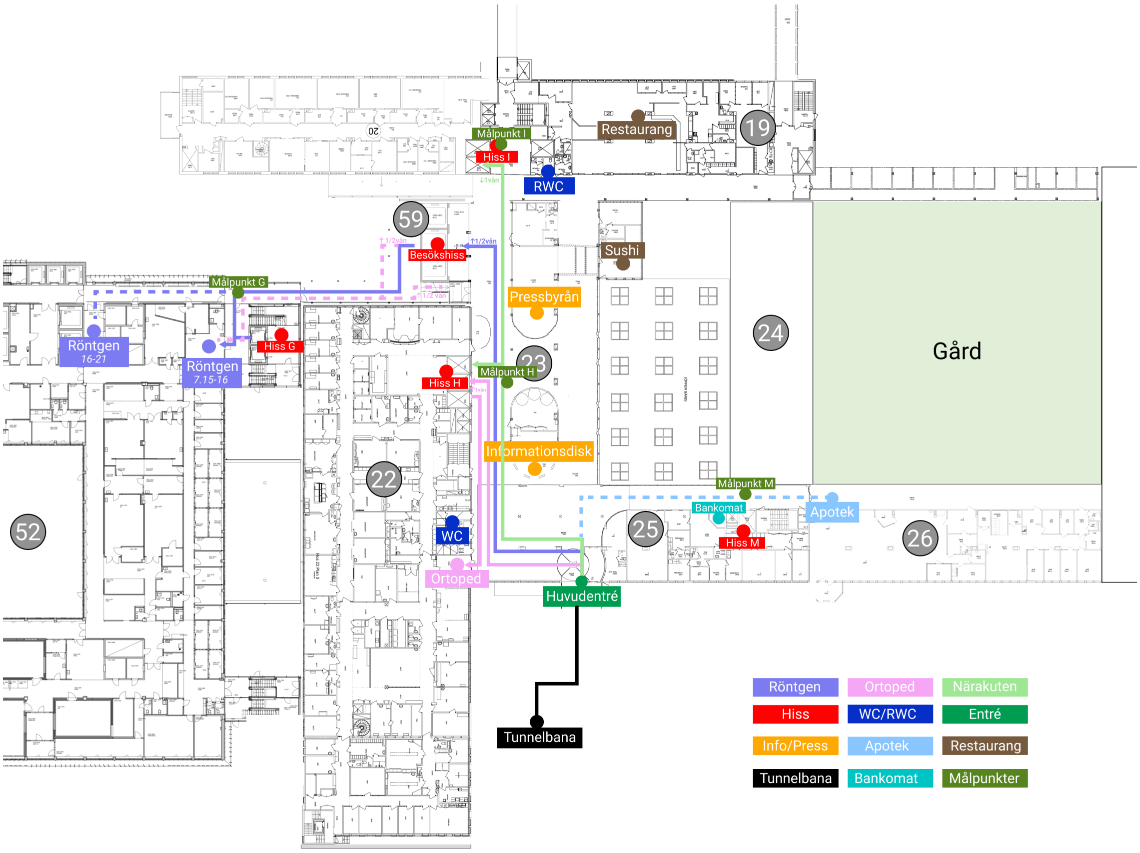
Maps created of each floor of the hospital with their routes

Floor 1 - Entrance to the emergency

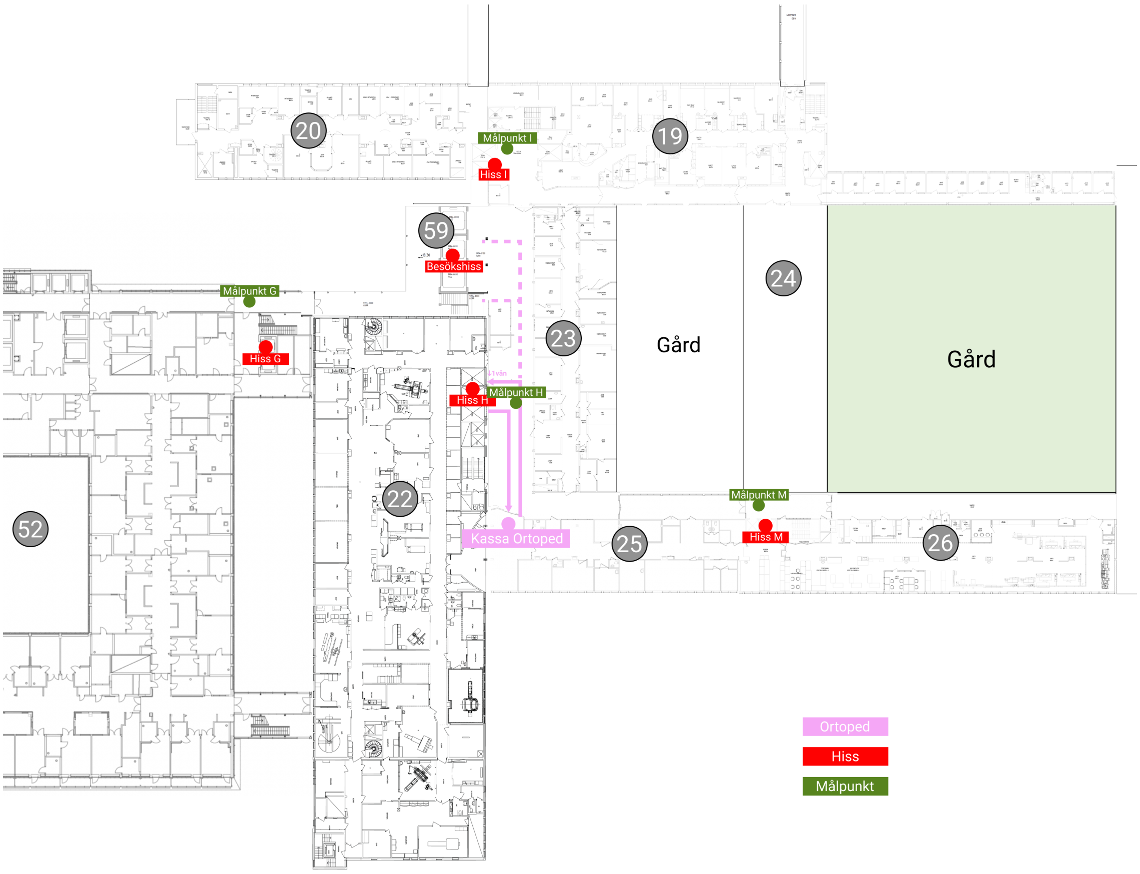


Floor 2 - Emergency room

Floor 3 - Main entrance and the X-ray



Floor 4 - The orthopedic



B

Findings from the brainstorming supported by literature

General	Literature reference
The application must be available for both iOS and Android operating systems	
The application should work as similar applications do, to make it easier for people using the application for the first time	
The application should be easy and simple to understand and use	(Cooper et al., 2014)
According to the Gestalt psychology elements that are near each other are being perceived as one group	
The application must not contain advertising or other irrelevant and disturbing elements	(Friedman & Bryen, 2007)
The application can contain advanced features but it should not be advanced for the user to use it	
The application should work as expected	
The symbol for the application should be in clear colors and contrast to stand out among other applications in the smartphone	
The application should be easy to access	

Functionality	Literature reference
QR code on the clinical appointment letter can open the application and details for the visit	(Smolenaers et al., 2019)
The home screen of the application should display the navigation options (the most important feature)	(Al-Razgan et al., 2012)
Possible to save directions as favorites so it is easy to start the same navigation later	(Smolenaers et al., 2019)
QR code opens the application and set the navigation to the hospital from home	(Smolenaers et al., 2019)
The application can show suggestions of means of transport to and from the hospital, such as travel by public transport or car	
The application can suggest to start guidance if near the hospital	
It should be possible to print the directions from the application, either at the hospital or from home	

Navigation	Literature reference
GPS navigator that shows the user's exact position with a symbol, must not deviate by a few meters	
The map must correspond to the physical environment	(Harper et al., 2020)
The application must be updated with renovations or other changes in the physical environment, for example if a room changes name	(Marshall, 2017)
Easy to understand the maps rotation	(Smolenaers et al., 2019)
Easy to see where you are going and where you have been on the map	(Smolenaers et al., 2019)
Descriptions and maps for directions that not just refer to reading physical signs	(Smolenaers et al., 2019)
Descriptive directions that explain the environment in detail	(Harper et al., 2020)
Clear descriptions and naming of destinations and surroundings that correspond to the physical signage	(Harper et al., 2020)
Should be possible to turn off the navigation, but still see the position on the map	

Usability	**Literature reference**
Easy to select starting point and destination for the route	
A possibility to change the destination in a route, for example, stop for a toilet visit and then continue on the same route	
A possibility to filter specific choices for navigation, for example if the user do not want to use an elevator	(Morag & Pintelon, 2021)
The application must show the estimated time of arrival	(Morag & Pintelon, 2021)
The user receives feedback that they have arrived to their destination	(Friedman & Bryen, 2007)
A possibility for individual customization, for example to choose which symbols the map should show	(Friedman & Bryen, 2007)
Time should be given for the user to make their choices	(Cooper et al., 2014)
The starting position of the route can vary between the hospital's areas, such as the parking lot or the public transport station	
A possibility to have sub-goals and set a detour to something on the way to the final destination	
It should be easy to set a return-route	
The application should primarily show the route that most people prefer	(Morag & Pintelon, 2021)
It should be possible to use the application without logging in	

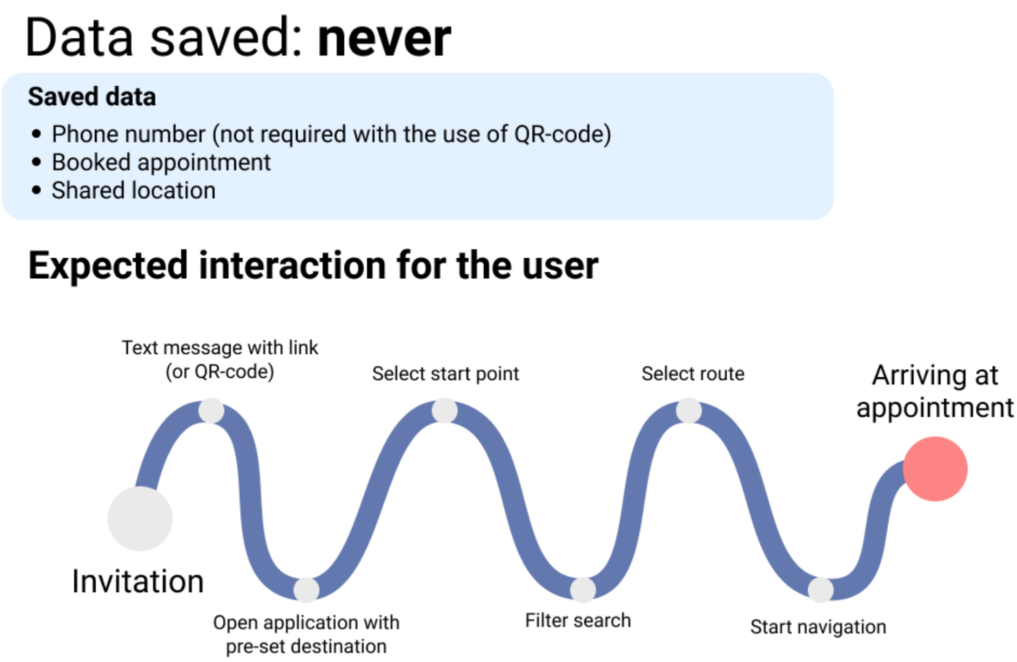
Help tools	**Literature reference**
The application must work with screen reader and other help tools	(Huang, 2018; Friedman & Bryen, 2007)
It must be possible to choose between navigating with a map that shows the exact position, or be provided with descriptions in text or having auditive descriptions	
Being able to use multi-touch-gestures, easy to zoom and pinching	(Al-Razgan et al., 2012; Huang, 2018)
The interface needs to express feedback of the users actions	(Al-Razgan et al., 2012; Friedman & Bryen, 2007; Cooper et al, 2014)
The application can provide auditory instructions of the navigation	(Friedman & Bryen, 2007; Huang, 2018)
The application should provide auditory and tactile feedback	(Huang, 2018)
The application must provide different languages	(Morag et al., 2016)

Design	Literature reference
The application should be designed for everyone	(Silva, 2011)
The application must be designed according to the user	(Cooper et al., 2014)
Buttons and functions are named and explained to easy understand their functionality	(Al-Razgan et al., 2012)
The application's design consists of a lot of images, icons and symbols and not much text	(Friedman & Bryen, 2007; Vangeli & Stage, 2018)
Good contrasts between images, text and background	(Huang, 2018; Friedman & Bryen, 2007; Vangeli & Stage, 2018)
A clear border around functions and buttons, to show the button's delimitation	(Huang, 2018)
Terminology that everyone understands	(Marshall, 2017)
Correct language and grammar, for example not text with only lowercase or uppercase letters	(Friedman & Bryen, 2007)
Use of san serif font	(Friedman & Bryen, 2007; Vangeli & Stage, 2018)
Good contrasts when using inverted colors	(Huang, 2018)

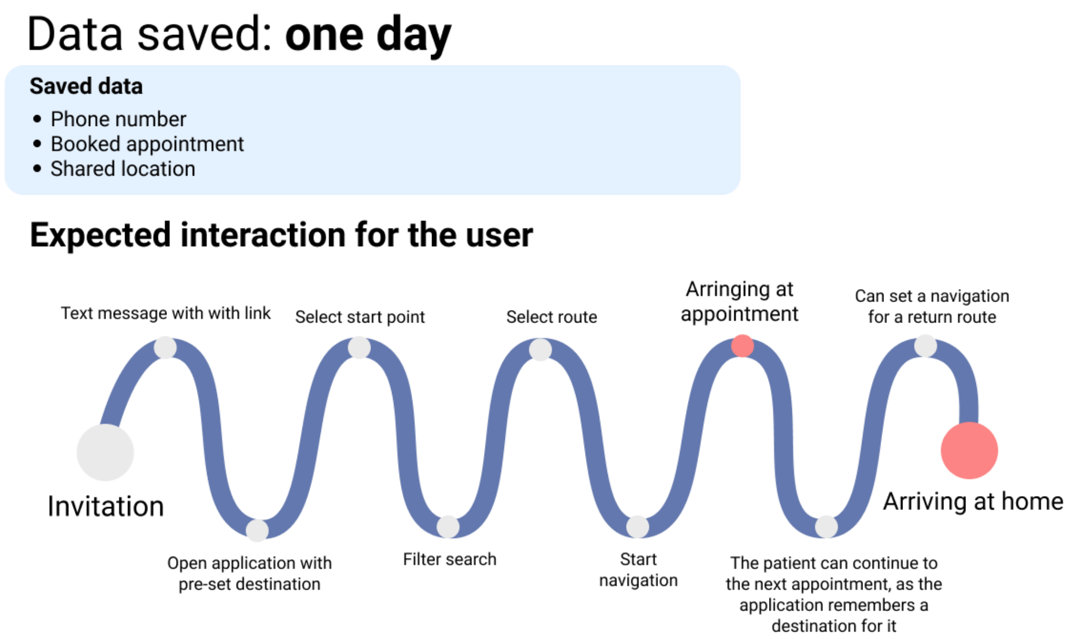
C

Patient mapping of personal data

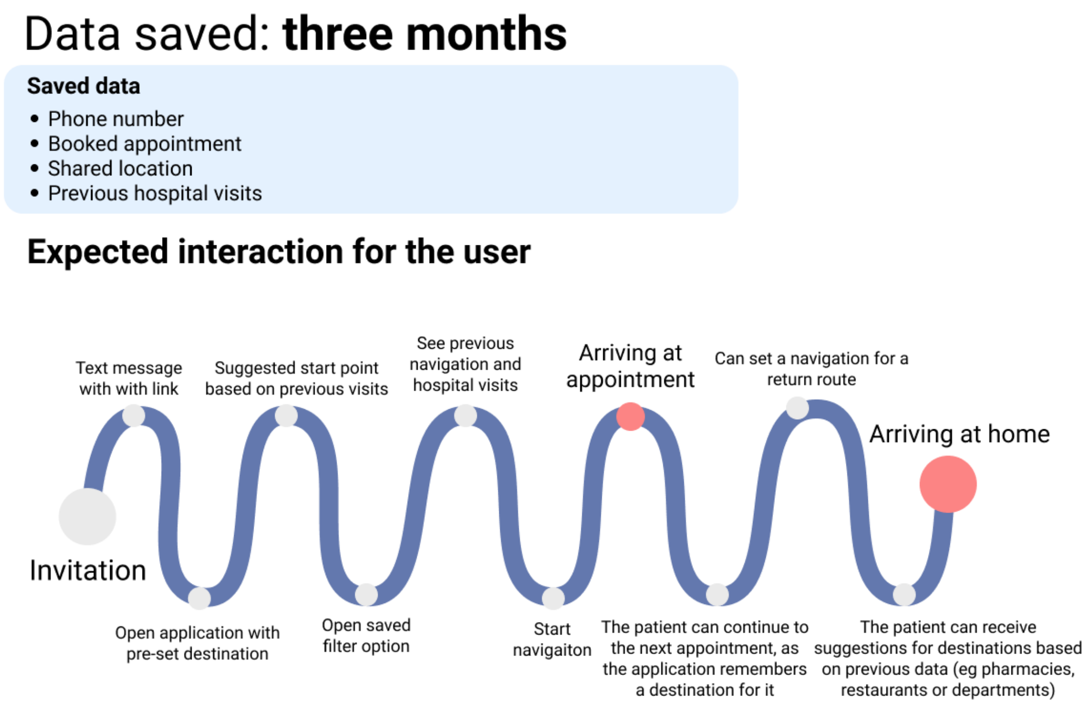
Patient mapping of the expected interaction when never saving any data.



Patient mapping of the expected interaction when saving data for one day.

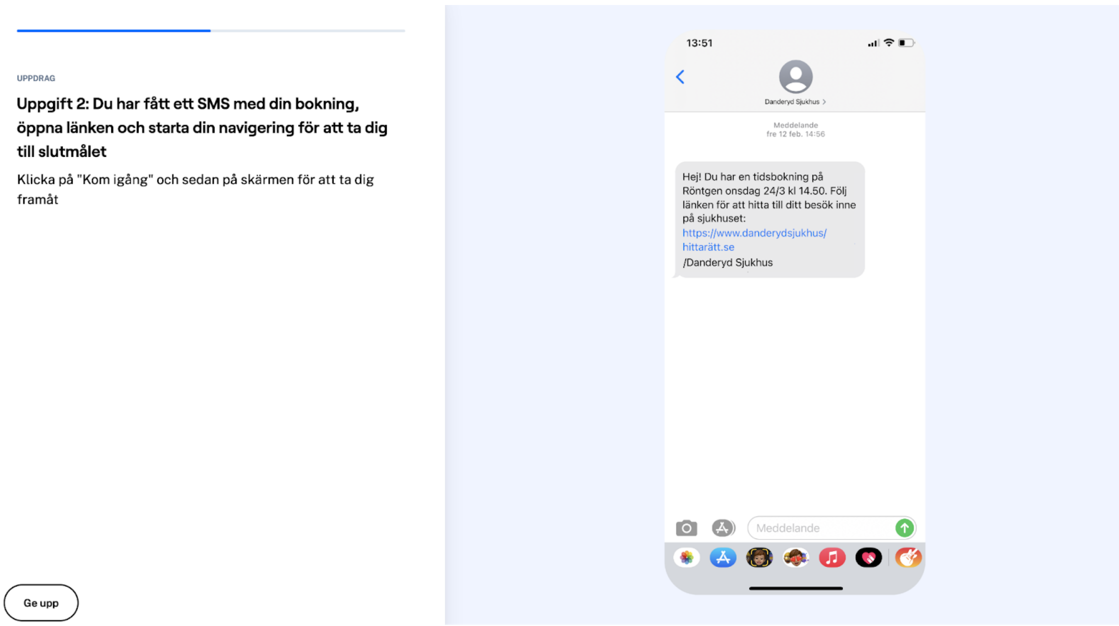


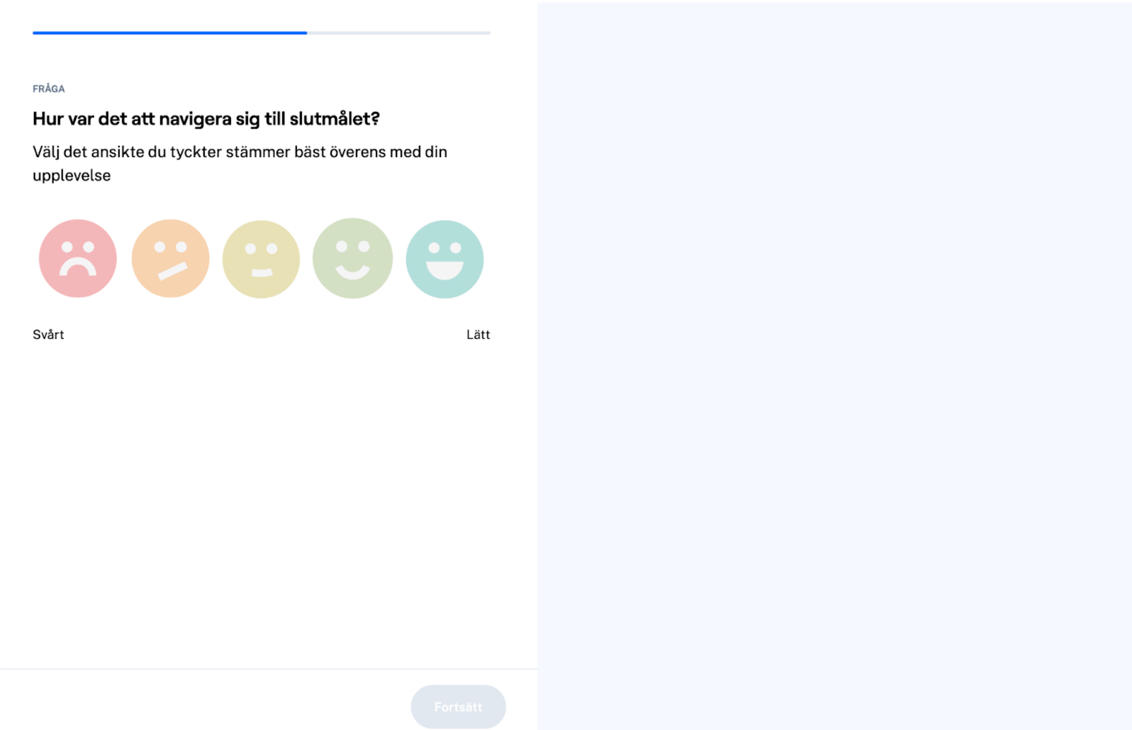
Patient mapping of the expected interaction when saving data for three months.

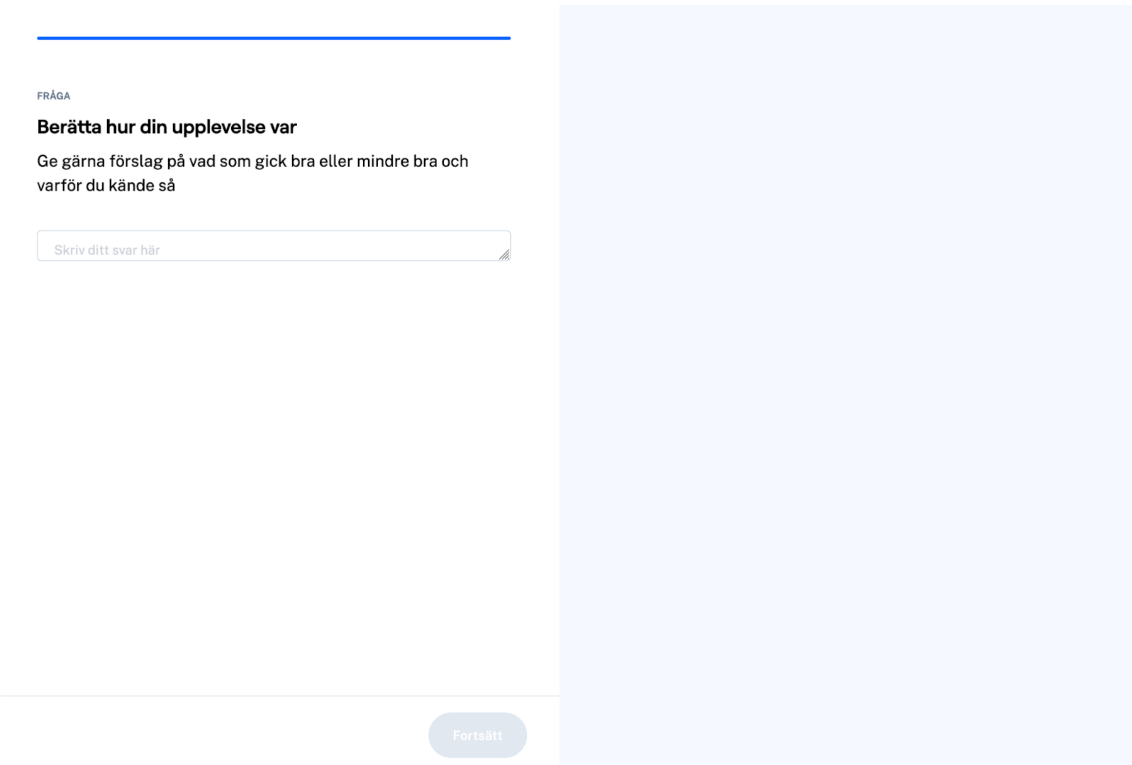


D

Construction of the two usability tests in Maze




FRÅGA
Hur var det att navigera sig till slutmålet?
Välj det ansikte du tyckter stämmer bäst överens med din upplevelse
Svårt
Lätt
Fortsätt


FRÅGA
Berätta hur din upplevelse var
Ge gärna förslag på vad som gick bra eller mindre bra och varför du kände så
Skriv ditt svar här
Fortsätt

E
Findings from the thematic analysis of Maze test one

Design

- Map contains many different colors
- Map is messy
- Grey line where you have passed
- Buttons for next/previous is separated from cancel/done
- Clarification for walking/car
- Clarification of target points and their icons
- There is a clear "done-button"
- Look over pictogram and text

Flow

- It went quick
- It was clear
- Clear suggestions
- Centered search result at the screen
- Simple to click next
- Pre-set location facilitates for the user
- Logic structure
- Recognition from other applications

Layout

- Good when it is not too much information
- Good with description in both text and map

Interaction

- How should information-box disappear?
- Good affordance for icons
- Good with suggestions based on location
- Weird having to click next when you have moved
- Can't the application find my position?

Errors

- Check for misspelled words
- Clearify for the user not to write on their keyboard on the computer during the test

Confusion

- Check for misspelled words
- Clearify for the user not to write on their keyboard on the computer during the test

F

Findings from usability tests in iteration three

Results from usability tests of the MID design.

NAVIGATION

Navigation	Steps in the navigation	Floors
• Unclear where the navigation starts or ends • The user does not feel as they are being navigated and must interpret the navigation themselves • The user does not notice the text descriptions of the navigation	• Don't understand that there are several steps in the navigation and that it involes different floors • Interpret the second step as a more detailed and zoomed out view of the route • The user should decide when to change steps	• Does not understand navigation between floors • Does not understand the button for selecting floor or why some floors disappear when selecting different buildnings • Rely on the elevator or signage to provide information of what floor to go to

DESIGN

Design	Information	Icon
• The interface contains elements with bad contrast • Have a similar look as Google maps • Give an old fashion impression	• The map is cluttered and contains too much information and text • Corridors is unnessacary to mark on the map • Does not understand how and why the pink border of the buildings is showing • The user found it difficult to find the main entrance	• The user experience more trust to the interface if the icons are recognizable • Did not understand the icon for X-ray or the icon in the button for selecting floors

FUNCTIONS

Position	Search	Interaction
• Wants to see their current location on the map • The user does not understand their location on the map • Tries to locate themseves on the map by interpret the surroundings	• Not all users understand how to open the hamburger menu to make a search • Unsure if the search alternatives is located at the hospital or not • Confused by first having to search for the end destination and then open the menu again to set starting point	• Zooms on the map to help locate themselves and to find their start point • Clicks back and forth trying to understand the interface • Selects "show on map" immediately instead of reading the text descriptions

EXPERIENCE

Feel lost

- Experience the interface as very difficult and it takes time to understand which causes much confusion

Information

- Feels confused because not enough information or descriptions is provided to help understand the navigation

Slef blame

- The user feels stupid when interacting with the interface because they don't understand what to do

ACCESSIBILITY

Help tools

- It is important that the application is coded correctly so it works with a VoiceOver and other help tools
- The applicaiton must be coded so that buttons are described as buttons and their functions must be understood before a selection
- When entering the application the VoiceOver should start in the search field or it should be easy to find
- It should be possible to change language
- It is possible to print out the navigation

Sight

- Important that search fields and other similar functions have a clear border and stroke
- The interface is difficult to understand for users with visual impairments, such as understanding the map, follow a navigation line and undersand that text descriptions also are provided
- The POI on the map helps the user to locate oneself in the surroundings

Errors

- Expresses that they understand what to do but make mistakes
- The navigation was lost for several users
- The application needs to be in only one language
- Swedish should be the default language on all functions and elements

IMPROVEMENTS

Navigation

- Should provide the search function in the first view
- The user wants to be able to see their live position on the map
- Wants to be able to set navigation based on current location, set a pin or using a POI
- The end of the destination should be marked in a red color
- Wants to be able to rotate the map

Information and descriptions

- Not all POI:s need to be presented at all times, would be better if more appeared when zooming in
- Information about a POI should only be provided when selecting it
- Wants to be able to filter out unrelevant POI:s
- Should provide more detailed text descriptions of the navigation in the map view

General

- Could provide a tool tip to help find the hamburger menu
- Would be better to have a native application to avoid ads and to allow cookies

Results from usability tests of the Easy Wayfinding design.

DESIGN

Experience

- Easy to understand
- Provides a good overview
- Does not provide too much information
- Feels comfortable for the user when it is easy to understand
- Works well navigating both outdoors and indoors

Look and feel

- Clear and simple design
- Similar to other navigation applications
- Clear colors that helps the user to understand the navigation
- Wants the application to have the same color scheme as the hospital to build trust

Flow

- Easy to understand and have a logic flow
- Easy to find information about a POI
- Important that all options are clear
- Understands how to start the navigation and follow the descriptions
- Understands that the start point and destination is pre-set when following the link

NAVIGATION

Confusions

- Important that it is possible to choose means of transportation
- Confusion about what floor the destination is on, when the user is changing floors, and how to change to take the stairs instead
- Some confusion occured when the user changed from being outside to inside

Navigation

- Most users prefer having the navigation in map view
- Important to provide a clear feedback of arrival
- Good that the destination is marked with a red color
- Good that it provides information such as time of arrival, distance, etc.
- Good that the selected start point and destination is always visible
- Positive that it is possible to be able to change between the list or map navigation
- Understands that the navigation involves both car and walking

Desciptions

- Good that the descriptions are big, in a fixed place, clear and always visible on the screen
- Good that text descriptions are provided as a complement to the map
- Prefers when the descriptions are divided in seperate steps
- Important that the descriptions are detailed and match the environment
- Good that distance is included in the text descriptions

FUNCTIONS

Interaction

- Most users prefer searching for a POI, instead of using the categories
- Understands that the categories could be used to find a POI
- Understands that it is possible to click on a POI to find more information about it
- Wants to zoom in and out on the map to help locate their position

Accessability

- Could be good with tool tips to hint about existing functions
- Colors, contrast and size must meet WCAG requirements
- Good that it is possible to choose to avoid stairs
- Good that the list view function exist for more step by step descriptions

Position

- Wants the application to provide live position both for outside and inside so it is easier to understand and locate ones position
- Important that it is possible to set starting point based on current position
- If live position is not possible it is important to get the navigation in detailed step by step descriptions and to be able to navigate with the help of signage in the surroundings
- Want to see the direction of travel

ICONS

Design

- All icons needs to be universal, clear and recognizable
- A non universal icon needs complementary text
- The departments should always be presented with both text and icon
- The icon for the floor button needs to better communicate that it refers to the floors and provide better feedback when changing floors

Map/list view

- Most users understood the function of the list view/map view button
- The list view/map view button have a good position and size where it is easy to reach and does not change position when switching between the views
- Alternativley it could be placed closer to the descriptions

POI

- Good that the POI:s are categorized
- Wants to be able to filter out unrelevant POI:s
- The target points could be difficult to understand if the user is not located at the hosptial

G

Findings from the thematic analysis of Maze test two

Design

- Good with clear arrows, names, and the blue line for navigation
- Good with clear descriptions and inclusion of the environment in the text descriptions where it can work as a help to ensure one's position
- Good that it is familiar and similar to other systems
- Recognition from other navigation applications

Flow

- Logic and easy to follow
- The flow was almost automatic
- Clear and natural
- Easy and clear how to follow the navigation
- There were no problem using this applicaiton
- Easy to use categories
- Easy search function

Usage

- Some users might not use the applicaiton to navigate to the hospital only when they are on site trying to find their way within the buildnings
- Users do not appricitate the function of having to click throught the navigation steps manually

Interaction

- Easy with POI:s presented on the screen as suggestions
- Though that all POI:s would be clickable
- Easy when it only required a few clicks
- Intuitive to be able to search for destination or POI
- Good to be able to make free search
- Wants to have the "done button" where the "next button" is when finished

Improvements

- Could have the button for accepting to share location to blink to be more visible
- Provide support for CarPlay
- Possible to scan a QR code provided in the hospital to update to my exact position