

# Accessibility within Inflight Entertainment

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# Accessibility within Inflight Entertainment

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## **Abstract**

Flying is a stressful and demanding task for many passengers, where airlines are always in the search for new technologies and methods to make the experience more comfortable and stimulating.

In this thesis, we have evaluated accessibility support within in-flight-entertainment systems available in the market today. The focus has been on usability for users with reduced or no vision. Interactive text-to-speech prototypes with physical remotes were developed to evaluate different methods of interaction. User centred design has been a key factor during the process where testing and development has been alternated with an iterative approach.

The results from our prototype showed an overall positive feedback. Although, the fact that the haptic feedback in large extent became unnoticed because of the high cognitive load from the text-to-speech information had great impact on the final result. Another important learning is how the digital tools within accessibility has improved and can enable, an otherwise impossible interaction, when implemented correctly.

**Keywords:** Accessibility, In-Flight-Entertainment, User Centred Design, Noodl, Text-To-Speech



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# Chapter 1

## Introduction

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In this chapter a brief background and goals of this thesis will be presented. Our contribution to the field will also be outlined here.

### 1.1 Background

During 2015 more than 3.5 billion passengers travelled by flight. The annual number of passengers in the airline industry is estimated to reach almost 4 billion during 2017 [1]. The amount of people to whom flying is an available and affordable form of transportation has increased dramatically the past years, with no stagnation in sight [2].

The majority of passengers experience some sort of difficulty when flying. The most common problem encountered when flying are negative psychological- and physical stress [3]. A popular method to reduce negative stress during air travel is relaxing with interesting reading material, or interact with the in-flight entertainment (IFE) system to take part of the movies, music and games available. However, this option is very seldom available for passengers with, for example, a vision impairment or reduced fine motor control and may therefore result in a less comfortable travel experience. The current established standard with a visual interface controlled by touching the screen or with a advanced remote control makes the interaction very hard for some of the passengers. Not only for the passengers with a vision impairment or reduced fine motor control, but also for elderly passengers who by nature suffering from reduced vision or motion control. In other words, an IFE system requires a lot from the user and many passengers, that have paid full price for their tickets, can simply not use it during their flights.

The present on-demand systems are implemented based on one concept of what passengers like and requires as a homogeneous group that has similar tastes and desires. The airlines present the same interface and entertainment content to all passengers, regardless of that the passengers come from highly heterogeneous groups (gender, age, disabilities, etc.) with different individual entertainment preferences and various capabilities. If the

user wants to get desired entertainment service on-demand for stress reduction or recreation, the user needs to browse and select desired entertainment services. On one hand, if the available choices are many and the interaction design is bad, the passengers tend to get disoriented and therefore not manage to find the most appealing entertainment services. On the other hand, if the available choices are limited, the possibility for the passenger to find wanted entertainment services is slim. Under such circumstances, does the in-flight entertainment system not contribute to improve the passenger's flying experience, on the contrary, to some extent, it exacerbates the experience [4].

An estimated 19% of the population has some kind of disability [5]. In a world where the average lifetime is increasing, and previous baby-booms are becoming part of the elderly, the amount of people with disabilities are expected to grow during the upcoming decades. Given the size of this population, the tourism sector is increasingly turning its attention to provide accessibility to a as wide group as possible. Hence will also the airlines divide more attention into the flight experience of the group of people that today can not use the entertainment system. A few airlines have developed codes of practice regarding passengers with disabilities, those however do not include the in-flight entertainment [6] [7].

## 1.2 Purpose and goals

The purpose of this thesis has been to deep-dive into and investigate IFE from an accessibility point of view. The target, alongside the analysis of IFE, was to get a comprehensive knowledge about accessibility. Researching through written materials and with our own analysis and studies, a goal was to find out what kind of digital solutions that could be applicable within the travel and in-flight experience.

Based on the research, the thesis attempts to predict the trends within digital accessibility looking at a 3-5 year forecast, with the aim to lead the development for digital accessibility for the on-board experience and in-flight entertainment.

With a foundation in the human senses, studies have been focusing on digital accessibility with regards to cognitive disabilities, visual impairment, blindness, hard of hearing, deafness and reduced mobility.

Our three main goals with this thesis were:

- Get a deeper understanding of the digital accessibility area within interaction design and development both from a theoretical and practical perspective and primarily what can be used in an IFE application.
- Practice and gain general knowledge of methods and tools within interaction design, usability, development and testing.
- Develop two or more prototypes that explore interaction paradigms focusing on an IFE application with regards to visual impairment, blindness, heard of hearing, deafness and/or reduced mobility. Conduct usability tests to evaluate the prototypes.

## 1.3 History of In-Flight Entertainment

In-flight entertainment refers to the entertainment system available to flight passengers during a flight. The first in-flight movie took place in 1921 when Aeromarine Airways showed *Howdy Chicago* as the plane flew over Chicago. A screen was hung in the front of the cabin and a projector was put on a table in the aisle. All the eleven passengers could then enjoy the entertainment as they flew over the city [8].

The in-flight entertainment as we know it today, with a personal in-seat audio/video on-demand system was first introduced in 1988. Northwest Airlines offered their passengers a 2.7 inches LCD technology system on the airline's Boeing 747, which received an overwhelmingly positive reaction [8].

Airlines are persistently seeking ways of differentiating their product from one another and IFE has been, and still are, one of these areas. At the beginning of 1990, airlines were spending \$1800 per seat related to IFE system. This number increased to \$6000 in 1998. Airbus estimated that IFE stands for 2 % of the overall costs of an aircraft [9]. In 2014 some airlines spent up to \$20 million per year on IFE content alone, with a forecast to rise over the following 15 years [10]. However, the first step to help passengers with disabilities to interact with the IFE system came in 2012 when the first airline provided closed captioning on some of its content [11].



**Figure 1.1:** A personal seatback monitor with appurtenant hand-set.

In today's plan, the IFE systems usually contain various types of entertainment:

- **Video entertainment:** Includes movies, series and documentaries. The passenger can select the content and watch it on demand.
- **Audio entertainment:** Music, podcasts, information and comedy. The passenger can select the content and listen on demand.

- In-flight games: Different types of game can be played, either by just interacting with the touch screen, or combined with a hand unit. Some gaming system are even networked to allow multiplayer games among the passengers.
- Moving-map systems: A real-time flight information broadcast. The system can, besides from displaying a map that illustrates the position and direction of the plane, also give the outside air temperature, altitude, airspeed and distance to the destination.

## 1.4 Tactel AB

This thesis work was done in cooperation with the IT company Tactel AB [12], in Malmö. They are a subsidiary company of Panasonic (which are market leader within in-flight entertainment and communications solutions) where Tactel supports Panasonic with development. Tactel have therefore an extensive experience of IFE systems. The thesis was suggested by them since they in the future want to be able to make their IFE systems accessible for as many of the passengers as possible. Tactel has contributed with their knowledge in the area and continuous feedback during the thesis.

## 1.5 Contribution

The work of this thesis will help contribute in developing the next generations of IFE in the aspects of accessibility and how to enhance the experience of IFE for passengers that today are unable to use the IFE. Also generally in the area of accessibility and how to make a system accessible for as many users as possible

With technology development more time is spent interacting with computers. Situations previously carried out with human-to-human interaction, has in many cases been digitalised. To avoid leaving some user-groups behind in this transformation, all types of users needs to been taken into account and not only in daily situations, but also in more rare occasions e.g. travelling by airplane.

Hopefully can this thesis results in an awareness of the situation for passengers who are today unable to use the entertainment system during a flight. To inspire companies and developers to see this rapid tech-development as an advantage also for people with disabilities, and not the other way around.

In the same way that we have gathered inspiration to this thesis from other contexts, we encourage other people to the same with our results. A greater part of the work presented in this report can be implemented in other contexts, outside our primary scope.

## 1.6 Distribution of work

A majority of the work in this thesis has been performed in parallel between the two authors. The tasks have been divided in a flexible way as they arise. During development this approach lead to an informal responsibility for different functions. Some parts of the

thesis, especially the research phase required more cooperation e.g. the workshop and interviews. All test sessions during the thesis has been carried out by the authors together, working in pair.



# Chapter 2

## Theory & Technology

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This chapter will cover theories used in this project. Tools and techniques used in the development process will also be described here.

### 2.1 Accessibility within human-computer interaction

Accessibility can be defined as to what degree an interactive product is accessible by as many people as possible with a focus on people with disabilities. The concept of accessible design and practice of accessible development guarantees both “direct access” (e.g. unassisted) and “indirect access” (compatibility with a person’s assistive technology, e.g. computer screen readers) [13].

Accessibility is not to be mixed up with usability, which has the meaning of to what extent a product can be used by specified users to achieve specified goals with efficiency, effectiveness and satisfaction in a specified user case.

There are various definitions about what it means to be disabled, but the following captures the main points. A person is considered to be disabled if:

- Having a mental or physical impairment.
- The impairment has an adverse effect on their ability to carry out normal day-to-day activities.
- The adverse effect is substantial and long term (meaning it has lasted for 12 months, or is likely to last for more than 12 months or for the rest of their life) [13].

Whether or not a person is considered to be disabled changes over time with age, or as recovery from an accident. In addition, the severity and impact of an impairment can vary over a day or in different environmental conditions.



During interaction with a system a non-disabled user may utilise many of their abilities without reflecting over it. If there is a touchscreen the user will use their fine motor control combined with their vision to navigate to the desired service. The system might give both haptic feedback and audio feedback during the navigation to simplify and enhance the interaction. Merely in this short example, the system requires many different resources from the user for the user to have a good experience. A user with vision impairment will find it hard to distinguish text and icons and therefore have a hard time navigating in the system. Whereas it would be impossible for a blind user without assistive technology. A user with hearing impairment would lose the audio feedback and therefore have an inadequate feedback- and user experience.

When people consider the topic of accessibility, it is rather common to consider it mostly in terms of a specific physical impairment, such as the incapability to walk or problems of hearing. Although, it can often be the case that a person will have more than one disability. Also, there is a wide range of disabilities beyond the well known physical ones:

- Color-blindness: The inability to distinguish between two colors affects roughly 1 in 10 men and 1 in 200 women. The disability can for e.g have an impact on how well a user can distinguish interface elements in a system.
- Dyslexia: Mostly associated with difficulties in reading and writing. However, there are many different forms of dyslexia, some of which affect the way in which people comprehend the totality of concepts. This results in that people may find it difficult to define the contrast between foreground and background text or images [13].

Quesenberry points out how accessibility is often considered as ensuring there aren't any barriers to access for assistive technologies, but without the consideration of usability. The challenge is, therefore, to create a good user experience for people with disabilities that is both accessible and usable [14].

## 2.2 Stress-related cognitive disabilities

The fear of flying is a common psychological problem [15] and can combined with stress make a journey very demanding for a passenger. Previous research claims that the prevalence of this psychological problem in industrialised countries lies between 10-40% of the population [16]. Another study states that 10% of the population within this group completely avoid flying [15].

Stress may occur whenever a demand exceeds the regulatory capacity of an individual, particularly in situations that are uncontrollable and unpredictable. Stress evokes psychological, physiological, and behavioural reactions that differ across individuals [17]. Stressful situations or actions pre-flight may be, bringing all important items and papers to the airport or the airport tumult with safety controls, delayed flights, etc. In-flight stresses may include unfamiliar noises, vibrations, cramped seating and fear of flying.

Everyday decision-making often occurs under stressful conditions whereas emotional states that can underlie adaptive decision-making can be interrupted by stress [18]. A simple and suitable example of this during a flight can be when a stressed passenger has

to order food. Instead of choosing the most desirable one for the person, the person is stressed because of the flight situation and end up ordering something else.

Another aspect of stress is the fact that stress often accompanies decision-making tasks, and research suggests that this can alter both the cognitive and emotional processes involved in decision-making [18]. For example, stress can have a negative effect on cognitive processes such as impairing working memory capacity, reduce decision accuracy and a negative impact on the learning and information processing abilities. Suitable examples in a flight situation can be that a passenger constantly has to check its flight number on the ticket before boarding because the stress makes it difficult to remember. Another example is the situation during a flight when a passenger has to choose between the available meals. The decision often has to be made fast and in short notice, and if the passenger is inexperienced this decision may be a source of stress. The passenger may start to think: “What are you expected to order? What are everyone else ordering? I don’t wanna make a fool of myself” and the stress is subsequently a fact.

However, there is a long-going debate in psychology concerning the interplay between cognition and emotion, and it remains unclear which of these levels of processing is more disrupted under stress conditions [18].

## 2.3 Related work

Tools and resources for computer interaction for users with disabilities has been around since the era of personal computers. *DECtalk*, for its time a popular device for speech synthesis and text-to-speech, was released in 1984 [19]. A version of *DECtalk*, the speech synthesis *Calltext 5010*, released in 1988 is still used today by the famous scientist Stephen Hawking [20]. Since the amount and types of disabilities are numerous and therefore the field so wide, this section will focus on two main subjects.

- The in-flight experience for passengers that because of impairments are unable of a adequate interaction with the IFE system.
- Computer interaction for people with disabilities, regarding tasks usually performed with a touchscreen interface.

The article *Accessible in-flight entertainment systems for blind and deaf passengers* gives the reader an interesting insight in the current flight experience for a blind and/or deaf passenger [21]. It describes some of the shortcomings in today’s IFE systems regarding accessibility for this group of passengers. The study contained several test sessions, and in the first test phase eight people participated. The test persons were given four tasks to complete. Blind and low-vision participants were given an EZ Access controller [22] for navigation and deaf test persons used the touch screen.

How blind users develop a mental model when navigating in computer systems are information of great value for us. This reminds us of the importance of a logical navigation flow and sequences. The article cites much what other similar research within the area states. Judging by the article, the adjustments needed to fulfil requirements for most of the deaf users are relatively easy to fix. Text-based captions for all audio based media will greatly increase the support for deaf users. Despite this, in comparison small modification, there is almost no airline supporting captions in their respective IFE systems.

For blind passengers and passengers with reduced vision, the adjustment needed for full accessibility is larger. Along, or on top of the visual system, an audio interface must be developed. There are many options and software for visual graphics-to-audio available on the market today. Nevertheless, there is to our knowledge, no IFE system today offering that functionality.

It has been hard to find research with a primarily focus on IFE for disabled passengers. However, regarding the complete flying experience for those group of passengers there is research to find. *The Flight Experiences of People with Disabilities: An Exploratory Study* [6] investigates the flight experience from pre-flight to post-flight, with main focus on physical constraints and concerns. Despite parts of the discoveries presented in the report stands outside the scope for this thesis, it has given us a good idea of the difficulties and challenges passengers with disabilities can experience during a flight.

Studies show that music, games and other type of entertainment can help reduce stress and discomfort levels among passengers [23]. Experience and knowledge of flying from a disabled passenger's point of view can therefore help us to develop supporting functions and digital resources to facilitate their trip.

*Assistive technology software for people with intellectual or development disabilities: Design of user interfaces for mobile applications* [24] is an article full of hands-on information and advice. The article gives the reader an brief overview while tries to describe previous research and where it stands today. It contains examples of applications designed, using methods mentioned in the article. The presented list with design requirements and technologies has been very useful for us during development.

Today, the combination of human senses and computer science is becoming more and more common. A detailed study of haptic technology is described in *Haptic Technology: A comprehensive review on its applications and future prospects* [25]. The article describes how haptic devices can help people get a sense of touch with computer generated environments, so when virtual objects are touched they seem real and tangible. The paper gives a brief explanation on haptic functions and its implementations in different fields, it discuss future application areas and a few limitations of this technology.

The work of *User Centered Design of Non-Visual Audio-Haptics* describes how the technology of haptics can be combined with audio to create audio-haptic interfaces that let persons who have visual impairments access visual information and digital graphics. The work gives an comprehensive description of haptic and audio interaction and how to develop audio-haptic applications with a user-centered design approach. The author describes how the recently increased interest in multimodal interfaces will lead to more and more research and development in combining visual, haptic and auditory displays.

## 2.4 User-centered design

The importance to involve users in the design of interactive systems was emphasised 1985 by Gould and Lewis. They formulated three principles they believed would lead to a “useful and easy to use computer system” and formed the foundation of User-centered design (UCD) [13] :

- **Early focus on users and tasks.** First understand *who* the users will be by directly study their cognitive, behavioural and attitudinal characteristics. To do this, one has

to observe users doing their normal tasks, studying the nature of those tasks and then involve the users in the design process.

- **Empirical measurement.** Involves both objective measurable quantities like learning time, task completion times and other performance based data. As well as participants' thoughts and opinions of the tested product.
- **Iterative design.** When problems are found during the user testing, they are fixed and then more tests and observations are carried out to see the effects of the fixes. In other words, the design and development are iterative, with cycles of design, test, measure, redesign being repeated as often as necessary.

## 2.5 Comparison Testing

Comparison testing can be used at any point in the product development lifecycle [26]. In early stages, the technique can be used to compare several different interface styles, to evaluate which has the greatest potential. In the middle of the cycle, the technique can be used to measure the effectiveness of a single element. For example, if the users prefer pictorial buttons or textual buttons. At the end of the lifecycle, the comparison testing can be used to see how well the released product keeps up with the competitor's. The technique can be used during the whole product development lifecycle, but always with the definitive goal to establish which design is easier to use or learn, or to better understand advantages and disadvantages of different designs.

The basic methodology involves side-by-side comparison of two or more clearly different interfaces. Both performance data and preference data are collected for each of the interface alternatives and the results are compared. The technique can be conducted informally as an exploratory test, or as a more formal classical experiment, with one control group and one experimental group. If conducted formally, only one parameter should be altered. For example, keeping the content and functionality constant and altering the visual design or navigation scheme [26].

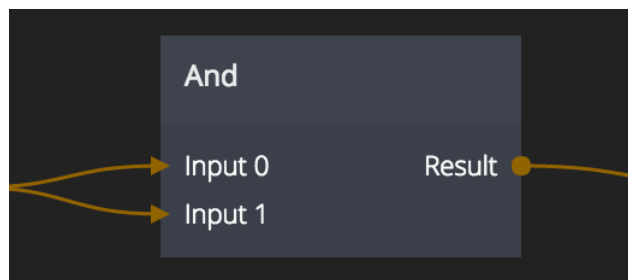
If conducted more informally as a more observational, qualitative study, several parameters may alter simultaneously. Although, the important part is to ascertain why one alternative is favored over another, and which aspects of design are favorable and unfavorable. When comparing in this fashion, one will inevitably discover that there is no "winning" design per se. Instead, the best design turns out to be a combination of the different alternatives and the best aspects of each design turns into a hybrid design [26].

It is also shown that, for exploratory tests, the best results and the most creative solutions are obtained by including widely differing alternatives, rather than very similar ones. This seems to work because of two major reasons: The design team is forced to stretch their ideas and conceptions of what will work, instead of continuing in the same old, predictable pattern. The result is maybe a design that redefines and improves the product in fundamental ways [26]. The other reason is that the participant during the test is forced to consider and reflect why one design is better and which aspects that are essential. It is always easier to compare similar alternatives, but harder to compare alternatives that differ greatly from each other. Because similar alternatives share the same framework and conceptual model, with only the low level details working differently. However, widely different alternatives

are based on different conceptual models and may therefore challenge the user on how the interaction with the system should be carried out [26].

## 2.6 Noodl

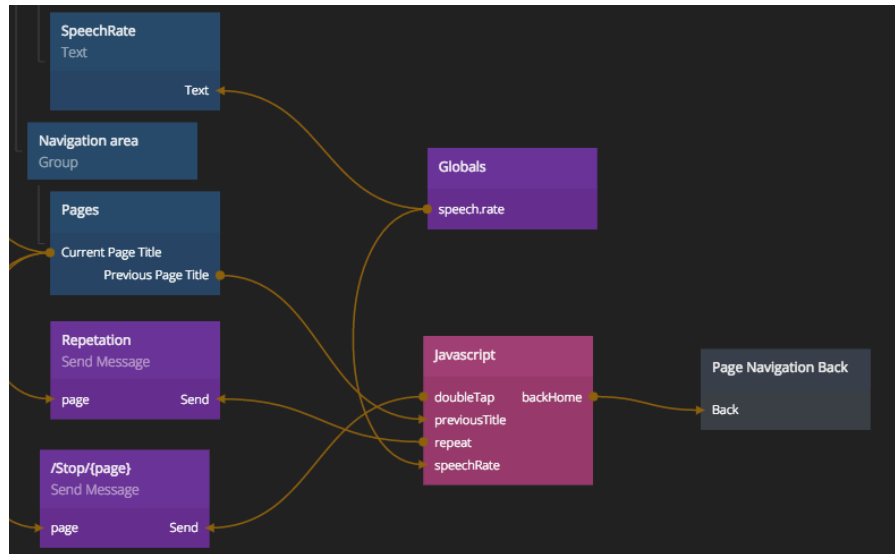
Noodl is a prototyping software developed by Topp design studio, based in Malmö [27]. It's a powerful tool for building interactive prototypes with non or minimum need for coding. The system is built up with components, one type for each of the functions. Some components have more logical functionality, while others only representing a static variable. Most components have the ability to connect an input and/or an output and thereby change or retrieve the stored value, see figure 2.1. In addition to components with data- and logical functions, Noodl provide graphical components with the ability to present information on a screen.



**Figure 2.1:** An AND-component in Noodl with two inputs and a resulting output.

Out of the box Noodl comes with a fair amount of already implemented and ready-to-use components. Those included components are often more than enough for a visual prototype. If that's not the case, Noodl offers the user to add their own Javascript-components and connect them in the network, see figure 2.2. A powerful feature we used frequently in this project. Since Noodl doesn't have any audio-components included, we had to use Javascript-components in our prototype for access to the audio-interfaces and being able to play sounds. Vibration and haptic feedback is another example of features that is not included and therefore has to be implemented with Javascript-components.

One of the large benefits with Noodl is the support for continuous testing and visualisation, during development. Using modern web technology built in under the hood, testing of the prototype is never more than a click away. With the web approach, testing on a mobile device can be conducted at the same level of smoothness as if it was made in a desktop environment. It also enables for cross-device prototypes. A prototype can be run on multiple devices sharing data with each other. Depending on what a user do at one device, the other devices in the prototype can be notified and react to the action. In our prototype we used this functionality by letting a mobile device vibrate and generate haptic feedback. Every time an alternative was read aloud on the main device, the mobile device was notified and reacted with a haptic vibration pattern.



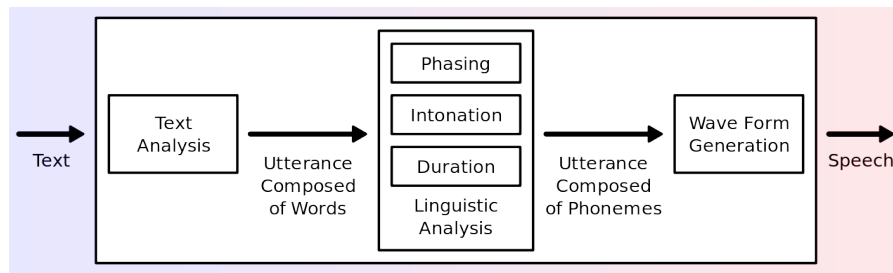
**Figure 2.2:** A Javascript-component taking text and rate as input, and read the result aloud to the user.

## 2.7 Text-to-speech synthesis

The artificial production of human speech is called speech synthesis. A computer used for speech synthesis is called a speech computer or speech synthesiser, and can be implemented in both hardware or software products. Text-to-speech (TTS) [28] synthesis is therefore a technique for generating understandable, natural-sounding artificial speech for a specific input text. The technique has been used in various types of applications, such as e-book reading, in-car navigation systems, and of course, voice-over functions for visually impaired. More recent types of applications are singing speech synthesiser, robots with the ability to communicate and speech-to-speech translation systems.

One can roughly say that a TTS system have two main components, text analysis and speech waveform generation. These are sometimes called front-end and back-end. The front-end has two major tasks. The first process is called *text normalisation* or *tokenisation*, raw text containing symbols like numbers or abbreviation are converted into the equivalent of written-out words. In the next step, the front-end assigns phonetic transcriptions to each word. The text is divided and marked into prosodic units, like phrases, clauses and sentences. This process is called *text-to-phoneme*. This linguistic information is then the output of the front-end component. This information is received of the back-end, the speech waveform generation component. Speech, in form of sound waveforms, are generated from the produced linguistic specification. Figure 2.3 generally describes a TTS system.

In our prototypes, we used the Web Speech API [30]. The API makes web apps able to handle voice data. The API has two components. The first is speech recognition, that via the *SpeechRecognition interface* provides the ability to recognise voice context from an audio input and respond appropriately. The second component is the speech synthesis, that via the *SpeechSynthesis interface* allows programs to read out text content loud. The reading part is normally done by the device's default speech synthesis, but it is possible to



**Figure 2.3:** Overview of a text-to-speech system [29]

change voice through a *SpeechSynthesisVoice* object. The component has also properties to adjust the language, speech rate, pitch and volume on different text objects. The API is compatible with most of the web browsers, but works slightly different on the different browsers.

In this thesis, we have only utilised the speech synthesis component of the Web Speech API. We have used Google Chrome as our standard browser and used that throughout the whole prototyping session. This let us do subtle changes on eg. the speech rate and analyse the results without worrying over inconsistency of the speech behaviour.

## 2.8 Haptic technology

The word haptic is taken from the Greek word “haptesthai” and means “of or relating to the sense of touch”. The term was redefined in the late 1980s to include all aspects of machine touch and human-machine touch interaction. The *touching* of objects could be done by humans as well as machines or a combination of both and the possible environment could be real, virtual or a combination of both. Moreover, the interaction could be independently or accompanied by other sensory modalities such as audition or vision [31]. Haptic technology can be defined as the science of adding touch sensation and control to interact with computer developed applications. With the help of haptic devices a user could get a sense of touch with computer generated environments, so when virtual objects are interacted with, they seem to be real and tangible. The function of haptic enables the user to interface with a virtual environment via sense of touch by applying forces, vibrations or motions to the user [25].

One of the most commonly know haptic feedback devices is the mobile phone, that through vibration patters gives the user haptic feedback. A good example of this is the “virtual keyboard” on a smartphone. As the user presses a key on the virtual keyboard, the smartphone answers with a fine subtle vibration to let the user know that the key has been pressed. The feedback is tried to imitate the real feedback you gain if you interact with a real, physical keyboard where the user could easily feel if a key has been pressed successfully or not.

There are many more haptic devices that mediate between the user and the computer. The Novint Falcon is a USB haptic device intended to replace the mouse in video games and other applications [25]. The falcon has changeable handles/grips that the user holds onto to control the falcon. It consists of three arms extending out of the device, with one motor connected to each arm. The user can move the grip in three dimensions, right-left

and forwards-backwards, like a computer mouse, but also up-down, unlike a mouse. The Falcon's software keeps track of where the grip is moved and creates forces that a user can feel by sending currents to the motors of the device. This is made at a rate of 1 000 Hz and will therefore provide a very realistic haptic interaction. The workspace of the Falcon is 12x12x12 cm. A picture of the Falcon can be seen in figure 2.4.

Another type of haptic device is a haptic vest, a wearable device that provides haptic feedback to the body of the user. The first vest were developed as early as 1994 by Aura Systems and monitors an audio signal and convert bass sounds waves into vibrations that can represent different in-game actions. The Aura vest can be seen in figure 2.4.



**Figure 2.4:** The Novint Falcon haptic device to the left. The Aura Interactor to the right

The application areas of haptics are many and increasing as the technology develops. Some of the areas are:

- *For visually impaired.* For example, by implementing a integrated touch screen in the haptic display device, the user can push on areas of screen to activate menus and icons which they can feel there. The ability to represent graphical information through haptic enables people with vision impairment to grasp the information.
- *Virtual information.* Most people understand and learn things better when education involves movement and touch. Traditionally learning consists of visual and auditory learning, but with haptic can this be combined with entirely different learning methods.
- *Medicine.* Haptic interfaces for medical simulations can be used for training of different surgical operations. It is also used in remote surgery, when the doctor perform surgery on a patient even though they are not located in the same room [25].





# Chapter 3

## Methodology

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This chapter contains the approach and different methods used during the thesis. The two major phases during the thesis were pre-study and prototyping. The pre-study phase consisted of a literature study, interviews and a workshop. The knowledge we gained during the pre-study were then utilised in the phase of prototyping. In the later phase, the prototypes were constantly evaluated after each iteration.

### 3.1 Pre-study

This section will cover methodology and tools used during the research phase. Starting with reading scientific papers in accessibility within human-computer interaction, and about entertainment systems within the airline business. We then carried out two interviews, and finished with a brainstorming session.

#### 3.1.1 Literature study

To collect necessary data and get a sense for where research in the subject stands today, a comprehensive literature study was carried out. The results became a significant part of the foundation for the theory in this project. Some material was given to us from our supervisors both from university and Tactel. Other resource materials were found using services from Lund University Library i.e. LUBSearch [32] and their extensive databases were of great usefulness during this part of the thesis.

We started with an expectation to find more interdisciplinary research in the field of aviation and accessibility. However, we quickly realised that it was not the case. Apart from a handful articles, some mentioned above, not much research has been performed in the field. Instead we decided to study the two areas separately, and extract the core learning's from them both.

The first field we focused on was accessibility within human-computer interaction (HCI). To get a comprehensive knowledge of how people with disabilities interact with computer systems. How they utilise their assistive technology, what they see as important factors in HCI, how the interaction can be made simpler for people with disabilities, what solutions are already implemented in today's IFE systems, etc. Within this field there was easy to find previous research. The challenge here was to sift in the large amount of data and subcategories. What could we learn from web, phones, public systems (ATM, ticket machines, parking meter etc.) and implement in our project?

With a wide research approach, it was possible to get inspiration from many dissimilar industries, combine these, and evaluate if they were applicable within the airline segment. Apart from systems that uses visual information, we were especially interested in systems that utilise sounds and haptics as communication techniques. During this phase, we also studied the assistive technologies within iOS and Android.

### **3.1.2 Interviews of experts**

A really efficient way to gain insight into a specific area, is to visit and interview people with experiences, experts. We have been striving to through the interviews, pick up ideas and solutions applicable for our project. From our meetings we have gained many insights of value, insights that underlie the rest of the project.

During this thesis, we mainly used a semi-structured interview approach. This approach allows the interview to be very flexible but still focused around the main subject. By changing the questions and the areas discussed during the interview session, one can easier address aspects that are important to the participant [33]. For example, during the interview with Ulf we used questions like: "How are you, as visually impaired, interacting with different computer systems?" or "How does a visually impaired feels when he/she needs to interact with a new system?" to get into the specific subject but still let the participant lead the discussion. The whole interview with Ulf can be read in the section below and all the questions can be seen in Appendix A.

#### **Ulf Larsson - visually impaired**

The interview with Ulf was executed as a semi-structured interview and the prepared template of questions can be seen in Appendix A. By allowing Ulf to sometimes speak freely, without severe directions, we believed that the discussion would be more fruitful. As Ulf was a man with opinions, this resulted in a very worthwhile discussion for us.

Ulf is around 65 years and has a vision impairment. Because of his vision impairment has he never been able to use the entertainment systems on a flight, despite his genuine interest in technology. Ulf has earlier been a representative of the national association for the blind in Skåne. He has been working with computer aids for visually impaired since the eighties. Through his consulting business Horisont [34], he produces special solutions for persons with vision impairments. Ulf has therefore a comprehensive knowledge within vision impairment and applicable solutions.

Ulf emphasises the fact that people with disabilities greatly prefer to use their own assistive technology to the largest possible extent. To use their own tools, that they know really well, gives comfort and a sense of reliability. A user with vision impairment has a

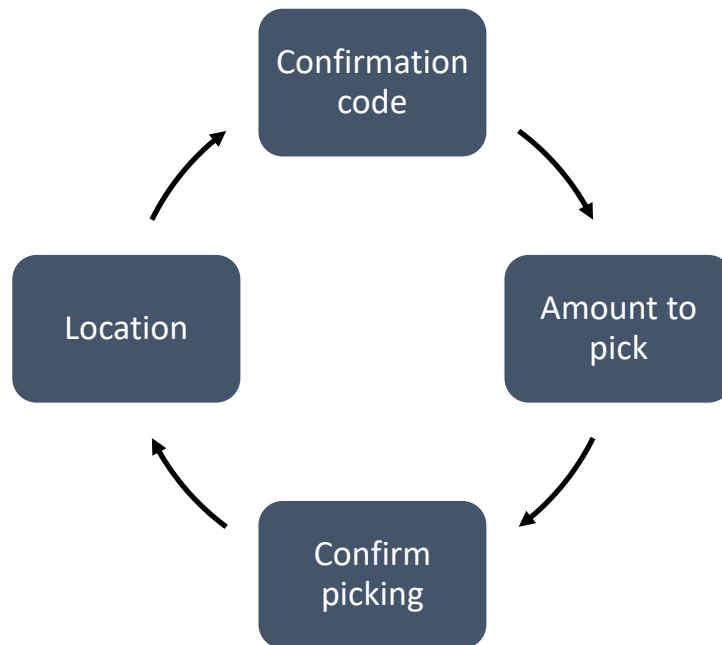
much steeper learning curve on graphical interface systems, because it is much harder for that user to gain an overview of the system. Ulf shows a concrete example by letting us observe when he uses his iPad. Ulf mainly navigate through the iPad with VoiceOver [35] and it's gestures. VoiceOver is a text-to-speech (TSS) system that gives auditory descriptions of each onscreen element. We discovered that the speaking rate that Ulf used was so fast, that it was impossible for us to follow the navigation. Ulf combines the VoiceOver function with the largest possible zoom to be able to distinguish what's displayed on the iPad. This technique makes it really hard to get an overview of the interface, but Ulf says it is the most efficient way for him to use the system. Because of the lack of visual overview, Ulf must know much of the system by heart, to be able to use it as efficient as possible. Hence is the cognitive effort generally much higher for a visual impaired user than for a fully sighted user interacting with a graphical interface system.

The great enlargement of the interface has, as previously stated, a negative impact on the possibility to gain an overview, according to Ulf. If a user doesn't know their position in the interface combined with the capacity to only see one or a few application/options, it can be really inconvenient to find the desired service in the system. To avoid this, a system needs to have a clear structure, intuitive user flows and the ability to get an overview, despite the enlarged interface, which is hard to accomplish according to Ulf.

Ulf also points out the importance of consistency within a system for a user with visual impairments. The consistency within a system gives the user a feeling of security as they use the system and reduce the chances for the user with visual impairment to get lost navigating in the system. Ulf once again returns to his iPad for an example. He shows the importance of that the physical home button has the same function. Despite if you are navigating in the interface, using one of the built-in applications, or using a third-part application. The home button-function, to always take the user back to the home screen, gives the user a sense of security as they use the iPad. Ulf compares it with an insurance, because how lost the user might be, the user is always one button from knowing exactly where in the system they are. He addresses the difficulties in troubleshooting inside an application for a user without the ability to see everything on the screen. To react on an unfamiliar pop-up warning box might therefore be hard, and an easier solution could be to start over by pressing the home button and then redo the procedure, says Ulf. Another aspect of consistency is when applications are changed after an update. To change place for a specific function inside an application can be seen as a small thing. Although, for a visually impaired user can this lead to serious consequences. A user with a visual impairment knows the application and its function much more by heart, compared to a normal user, and will therefore have to adapt more after changes. Ulf gives an example, where visually impaired users have thought a specific function within an application has been removed, when it's actually just had been moved into another category in the application.

## **Fredrik Hagfjäll - Experience of Voice-directed warehousing system**

Fredrik has been working at a warehouse for almost two years. His daily tasks included picking and packaging of goods, and prepare it for delivery. The picking process was performed solely working with a forklift. The picker therefore has to keep track of orders and articles while at the same time drive the truck correctly and in a safe manner.



**Figure 3.1:** States of the voice-controlled picking system.

To assist the workers and increase the production rate, the warehouse has an audio-based picking system. The system consists of a computer with a database of current orders, and personal headsets communicating wirelessly with the computer handling orders. In the end user’s perspective (Fredrik’s perspective) the system is completely voice-based.

The system has four states when picking an article, see figure 3.1. Through the headset information is given of which corridor, shelf, and storey the current article was located, and the amount to be picked. The picker confirms that he/she is at the correct location by stating a confirmation-code placed at the shelf. When the correct confirmation-code is given, the system tells the amount of articles to be picked. The picker picks the articles from the shelf and then confirms the accomplished task by stating a “Done”-command. The system then automatically responds with the next article to be picked.

Fredrik tells us that both he and his colleagues had an overall positive experience of the system. To his knowledge, there was no difference between ages, previous background etc. regarding the experiences of the system. The few complains concerned the system’s ability to recognise voice in noisy environments, especially in the freezer section of the warehouse.

For daily use and in the ideal use case, Fredrik tells us that the system works well. The simplicity with only a few commands available made it very easy to learn and to work with. Although, for the experienced user who wanted to use not advanced features the simplicity could be a repressive factor. As illustrated in figure 3.1, the system has only four states accessible and is therefore very strict and limited. There were no opportunities to work with the system in any other way than described in the figure. For an experienced picker, it would be more efficient to receive both location and amount before arriving to the shelf, a case that is not supported by the system.

Another trade-off with this simple approach is the ability to get an overview. There is no functionality to see the quantity of remaining articles to pick, which is bad according

to Fredrik. To never know which articles to come strongly inhibited the opportunity for the worker to individually plan the picking process, which Fredrik believes is bad. If the picker for some reason ends up in the wrong state, ie. confirms picking before the article is picked, the headset offers no function to go back. Instead the process must be interrupted until the picker manually can check reverse the order through with a stationary computer.

Fredrik tells how the system itself is very self-explanatory, it uses short sentences to instruct the user. Phrases like “*Please state the confirmation code*” or “*Go to corridor A, shelf 45, depth 2*” is used. This kind of language makes the learning curve for a new user very low. For an experienced user though, this could be superfluous and repressive for the production rate. For this type of user the language and amount of words used could be held to a minimum.

### 3.1.3 Workshop

The final step of the pre-study phase was a brainstorming [36] workshop, that we hosted. The goal of the workshop was both for us to sum up all our knowledge and research work, but also to include other people in our work and to get an opportunity to hear their opinions and ideas.

The participants were employees from Tactel’s office in Malmö, where the workshop was held. The workshop was introduced with a short presentation of the subject and the insights from the previous weeks of research. Since we expected the participants to have a fairly high level of technical experience, we decided to put most focus during the introduction on the user experience field. We demonstrated what in our opinion was the most valuable and interesting insights from interviews and previous research.

The second part of the workshop was an idea-generation activity. Together with our supervisor at Tactel, we formulated three problem scenarios. One problem regarding how people with hearing problems can take in sound based information. The second problem is focused on stress and how some people have a propensity to get stressed in new and unfamiliar situations. The third, and last problem, is about TTS and how visually impaired experience visual information.

The participants were allowed 15 minutes for each problem to freely brainstorm for potential solutions and ideas and put on Post-it notes. We encouraged participants to perform the brainstorm quietly on to start, and opened up for some light discussion during the last minutes of each problem-session.

When time was up, participants were invited one at a time, to share their notes by placing them on the whiteboard. This allowed for a brief description of each note, and an opportunity to ask clarifying questions. Pictures from the session can be seen in figure 3.2.

## Execution

We used a 3-step methodology from the design consulting firm IDEO to gather our learnings and convert them to insight statements [37].

1. Everyone captured their insights and ideas on Post-its. All ideas, possible as impossible, were encouraged. These Post-its were then gradually posted on the whiteboard [38].



**Figure 3.2:** Pictures from the brainstorming session. All the ideas were gradually posted on the whiteboard that can be seen in the left figure.

2. Once all Post-its has been shared and explained, if so needed, the next step was to identify themes. In search for common attributes and similarities, the notes were grouped together. The goal was to find themes and headings on the types of insights [39]. The ideas that came up during the hearing problem scenario were posted under the hearing category, etc.
3. The last and most difficult step in this method is the transformation from themes and groups into insight statements. Trying to find the core insights by rephrasing themes and headers into statements. The goal was to find statements summing-up previous research in succinct phrases [40]. This step was solely made by us administrators.

#### **Problem scenario - Hearing**

*Timing is important when communicating information, right information at the right time. On the other hand, too much interruptions for information can be a disturbing factor. A greater part of the information is also fresh and unique for the occasion/situation. Speaker-systems are often used to communicate this type of information, especially in the transport-industry. Is there any alternative methods to include those with hearing disabilities, and at the same time give extra support to users with regular hearing-function?*

**Problem scenario - Cognitive**

*Many people have a propensity to get stressed in new and unfamiliar situations. To make a decision, or selection between alternatives can be hard, due to difficulties of visualising options. Unexpected changes i.e. delays, change of alternatives in a decision can also be a factor of stress. What are the opportunities to increase the comfort for this type of passengers, and maybe also for experienced travellers.*

**Problem scenario - Visual**

*TTS is the most popular tool for blind users to experience visual information. Gestures are used for navigation, while the text is read aloud. Even though, a large part of the experience is lost. What are the alternative solutions? Any complement to TTS?*



To illustrate the loss of experience using TTS, the visual problem was presented in two parts. Participants were first presented to an audio-recording from a Swedish news website read aloud with TTS. The participants were then presented with the same recording, but this time with the visual website alongside.

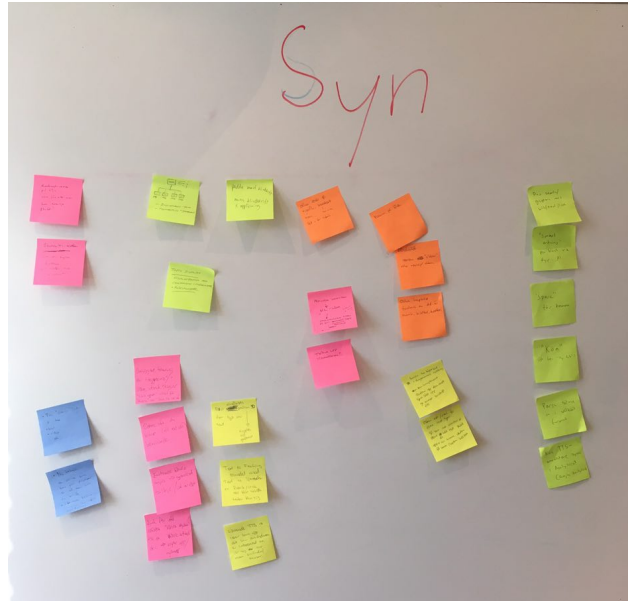
**Post-workshop**

The workshop ended up to be a very inspiring session where many interesting ideas were presented and discussed. To summarise this ocean of ideas for continued work, we had to group the notes together. Inspired by the 3-step method used in workshop, we started to look for similarities between the notes. Similarities used to construct themes and headers from the notes. Starting from a board with almost 100 notes, we were able to construct 15 core themes and ideas from the workshop. In figure 3.3, one can see all the posted ideas for the visual problem scenario.

**3.2 Prototyping**

Apart from learnings and knowledge gained during the project, a part of the result consisted of applications. This section will present the prototypes developed during this thesis.





**Figure 3.3:** The results of the brainstorming. Ideas to the visual problem scenario

Instead of building one larger prototype we, together with our supervisors decided to make a number of smaller prototypes. This approach allowed for faster iterations and more focus on the core task in each prototype.

### 3.2.1 Iterative design

The methodology is based on a cyclic process of the stages prototyping, testing, analysing and improving a product or process. With the latest test results in mind, changes and refinements are made. The ultimate goal of the methodology is to improve the quality and functionality of a product. The approach with iterations is taken from the agile software development methodology. Where the work is divided into small increments, that must be delivered in short time periods. This enable the customers, or in our case, the potential end users, to evaluate the product and provide necessary feedback during the whole prototyping process [41].

Due to that our working progress contained both market research, prototyping and evaluating, the choice to work agile came naturally. Every iteration ended with a small test, the results were analysed, and then shaped the upcoming iteration.

### Iterative testing

The final phase of each iteration consisted of a test- and evaluation session. Every test session was performed with a small group of participants. In order to improve the result, tests were executed in a fashion to simulate the real conditions for a potential end-user. The order in which the different alternatives of a prototype were tested for a participant was counterbalanced to avoid the *Transfer of learning*-effect [26].

To ensure unified tests in all iterations a basic testplan was developed, see Appendix

B. With a uniformed testplan used in every iteration, we could easily see the progress how changes and adjustments was received by potential users. Both qualitative and quantitative data were collected during tests. Each task was timed from start to acceptance criteria. We also had a short questionnaire participants were asked to fill after testing. The questionnaire was a based on the commonly used System Usability Scale(SUS)-score [42], with some customisation to better suit our situation. Participants were asked to rate each question between 1-5, (1 = strongly disagree, 5 = strongly agree). The four presented questions were:

1. It was easy to use the system.
2. The interaction felt intuitive/logic.
3. Methods of interaction was comfortable to use.
4. I think most users would learn how to use this system in very short time.

By adding the values, a total score for each design alternative/prototype appeared. Knowing the score was of low statistical accuracy, it could at least give us a hint of which design the users preferred.

In addition to the more general questionnaire, more comparison-specific preference data were collected during some of the tests. By letting a participant test two different alternative designs/functions and then ask for their subjective opinion it is possible to start a fruitful discussion. With the comparison-technique it is much easier to have a worthwhile discuss of the pros and cons of the two different designs with the participant and reflect over the best design together. Compared with letting the participant only try one design and solely relate to that design during the discussion.

### **3.2.2 Evaluation**

As mentioned previously, both quantitative and qualitative data from test were collected. Since the quantitative data primarily consisted of time data for how long it took for a user to preform each task, a total-, median- and deviation value could be calculated from those values. The qualitative data consisted of interview notes taken during and after the test, but also a numerical result from the SUS inspired questionnaire.

The difficult task for us was then to find a conclusion from all this data, and take a decision if and what to be adjusted in next iteration. The decision process often started by looking at the quantitative result. On the parts where we used comparison testing, this was a bit more straight forward since we always had two values to compare against each other. Many of our test persons had never used any system like this before, so a lot of thoughts and spontaneous opinions came up during the test sessions.

The detective work was then to map all test data together. Could opinions from interviews be connected to a numerical result in the quantitative data? This phase of the evaluation consisted of much discussions, our supervisor at Tactel was a great resource of advice and support here.

Some of the feedback we received in earlier interactions was reused and transformed into interview questions. For example, if many users complained about the voice speed in the system, we adjusted the system and but also added it as a question or discussion point

for future test sessions. With this method not only the prototype, also the test process was developed and improved between iterations.

# Chapter 4

## Results

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This chapter will cover and describe our results. The result consists primarily of two prototypes, prototype 1 and prototype 2. Where the major part of time was spent on the prototype 1.

### 4.1 Prototype 1

Our prototype was a simplified IFE system consisted of TTS and haptic feedback. The content was read and every available option that was read was enhanced with vibrations. Early in the process we decided to go for a simple layout with only a maximum of 4 options available at the same time. We grouped the options in a 2x2 layout that can be seen in figure 4.2. The system is controlled by a remote that will be explained later in the chapter. The layout of the interface can be seen in detail in figure 4.5 and figure 4.3.

Even if the system is designed to work for a user with no vision, it has also been designed with low-vision users in mind. High-contrast colours has been used to assist this group of users. Colours on the screen are also reused on the remote for increased clarity and recognition.

A known drawback with this design is the limited amount of alternatives available for showing. Only four alternatives can be presented simultaneously. This enables for a very simple system as the cognitive load on users can be kept low. The challenge here is to find a balance between amount of showing alternatives and keeping the cognitive load as low as possible. We have tried to keep the structure of the interface as consistent as possible. The 2x2 layout of buttons goes through the whole system, except for some special pages (e.g. movie search, movie playback).

The two versions has different keyboard layouts of six respectively two buttons. Although, they are shaped from the same keyboard, a simple Delcato numpad that can be seen in figure 4.1. By using the keyboard as a base it was easy to adjust it as we wanted. For example, by removing all the remaining unused buttons the keyboard become more

customised for the system and we avoided the issues that might come with it. Another positive aspect of the simple Delcato numpad is the good feedback it gives after each click.

To include one more sense apart from hearing, haptic feedback was used. In our prototype this was implemented with a smartphone, which vibration-motor was triggered from the system. The vibration-pattern became a subject to intensive testing since it was harder than we first expected to find a both informative and simple pattern. After being adjusted in every iteration, we landed in a version with single haptic impulses every time an alternative is read.

One function we were especially interested in was the search method. To explore this, we implemented two different methods in the two versions, where the search goes from A to H. The search method in the version with six buttons is structured so that the alphabet is gathered in groups. The size of the groups was then adjusted to our 2x2 layout and thus will the first available option be **A-B**, the second option **C-D**, the third option **E-F** and the fourth option **G-H**. For example, to search for a movie that starts with the letter D, one has to enter the second option where all movies that starts with a C or D are presented. In the other search method the alphabet is read out loud, from first letter to last. When the desired letter to search for is read, the user double tap to select that specific letter and will then find all elements that starts with the letter.

In the prototype it is possible to anytime trigger the repetition function. when triggered, the repetition will always start with the option 1 and finish with option 4.

An essential function within the prototype is the return function. This function looks the same within the two versions and so does the corresponding button. The key with a ← symbol will always let the user go back and jump one step up in the level hierarchy. When pressed, the system also gives the user a feedback in the shape of a short electric notification sound. The sound works as a location awareness sound because depending on what level in the navigation hierarchy you are in, the pitch of the sound is changed. We picked a suitable sound and adjusted it into four different versions with linear increased pitch. The pitch of the sound gets higher as the user is deeper into the navigation hierarchy.

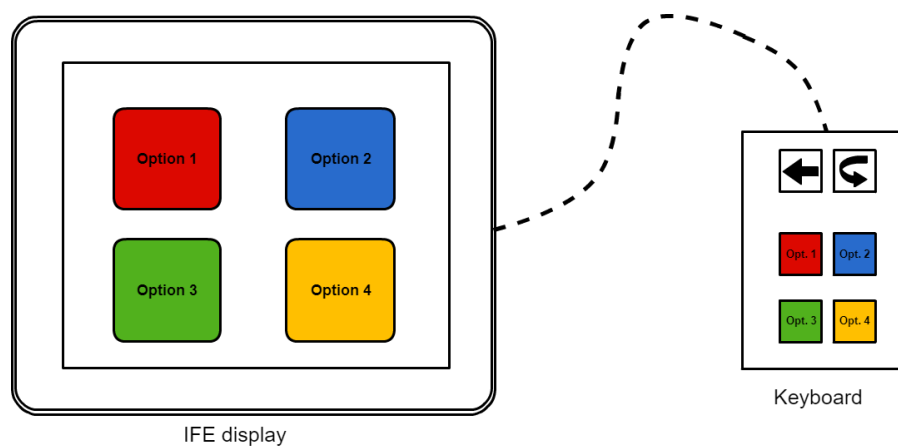
Another auditory feature is the sound played in the background in different situations to enhance the specific information and experience. We implemented this in two situations, the weather information of transit and weather information of destination. For example, at the transit where the weather is warm and sunny. The background is filled with birdsong and a smooth breeze to further more enhance the feeling of a warm and sunny day.

### 4.1.1 Version with 6 buttons

The goal when designing the prototype was to find a simple mapping that easily could be represented in both a physical and a non-visual way. Our choice fell on a basic 2x2 layout with coloured buttons. The mapping between the control and display can be seen in fig 4.2. We fell for this layout due to it's very simple design. Inspired in how complicated and complex current available IFE-remotes tends to be, we wanted to do something different. The navigation layout for this version can be seen in fig 4.3.



**Figure 4.1:** The keyboard numpad used for the two versions used in prototype one.

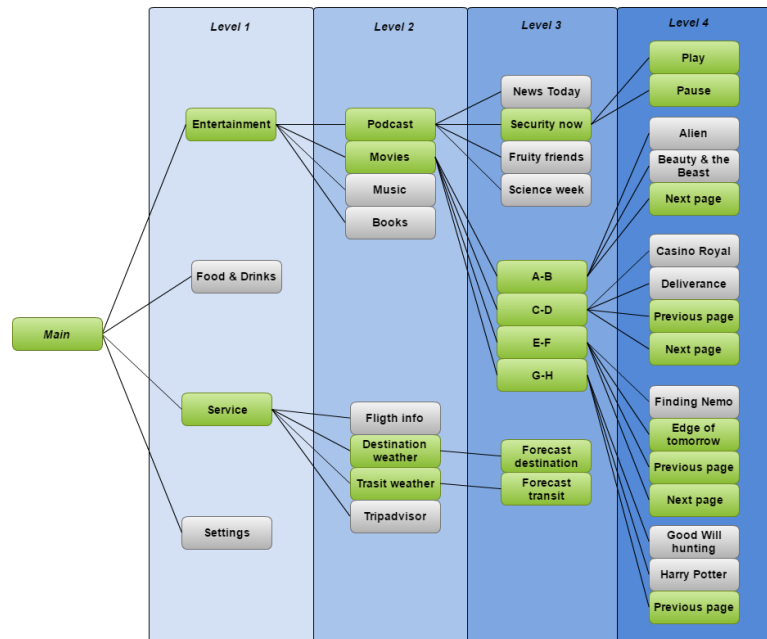


**Figure 4.2:** Conceptual sketch how mapping from the graphical screen is reused on the physical remote.

## Customised buttons

During the first iterations and tests the keyboard was mounted with labelled buttons, coloured paper pieces pasted on the original keys. Our intent with this solution was to aid low-vision users with high contrast colours, easy to distinguish. Also for users without vision impairments the coloured buttons could be a support, since mapping between colours on the remote is reused on the screen.

A drawback with this approach was even though we had removed unnecessary buttons, blind users still had problem to distinguish between the keys. We had to increase the tactile feedback for this group of users. Our solution here was to design and 3D-print tactile plates



**Figure 4.3:** The navigation structure of the version with six buttons.

to attach over the keys. Braille characters were used for the numerical keys. Other keys (enter, repeat, return) got a similar design as their 2D versions, but with an elevated effect.

Due to technical limitations, we were only able to 3D print in white plastic. Knowing that much of the mapping metaphor disappeared without coloured keys, this was a priority we did. In a future version, the plates would have been painted.

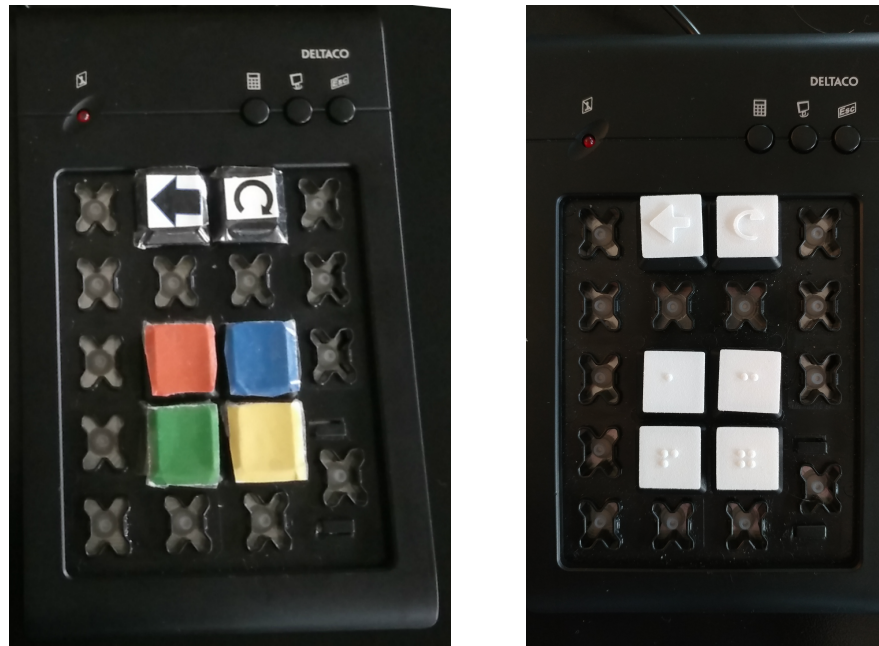
## 4.1.2 Version with 2 buttons

The idea to this version started to grow during the first iteration, in the quest for a simpler interaction with a reduced amount of button. Inspired from iOS voice-over where gestures and multiple taps are used to differentiate the actions. We redesigned the remote to only include two buttons, an enter/select-key and a back-key. The back-key was a single action button and trigger the return function within the system.

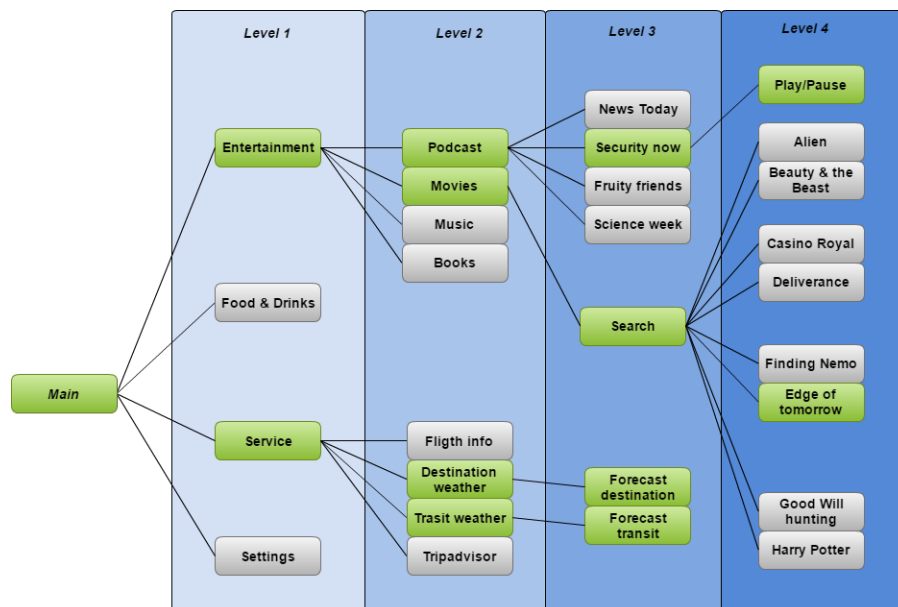
The enter/select-key in this version is what really differ the two version apart. As in the version with 6 buttons, available alternatives are read aloud to the user. However, the user navigates in the system by double tap the enter-key when the desired alternative is read. To trigger the reading of alternatives/repetition, the enter-key is pressed once. To make a double tap, the enter-key has to be pressed twice within a time interval of 600 ms. The navigation layout for this version can be seen in fig 4.5.

### Customised buttons

Similar to the version with six buttons, we used printed paper logos in the first iterations. In later iterations 3D printed tactile plates was attached to the keys, similar to the other version. Since the keys in this version varied in action, according to current system state, selection of icons was harder. For the return/back-key we reused the icon from the 6-button



**Figure 4.4:** L; First prototype of the physical remote. R; Final version with 3D-printed tactile keys.



**Figure 4.5:** The navigation structure of the version with two buttons. Object in grey are not implemented in this version.

prototype. Regarding the enter/repetition-key we kept the double size and went with a neutral halfpipe-shape. Our expectations, later approved in tests was that the divergence within shape and size would be enough to distinct the keys from each other.





**Figure 4.6:** L; First prototype of the physical remote. R; Final version with 3D-printed tactile keys.

### 4.1.3 Test data

Results from the three tests. Each test has a table over average time taken for each task and total time, and a table over the score of the questionnaire. Each test had the total number of four test participants, all without impairments.

#### Iteration 1

Results from the test after the first iteration can be seen in table 4.1 and table 4.2.

**Table 4.1:** Results from test 1. Average time over the 3 tasks and the total time, in seconds.

Task	6-Button Version (s)	2-Button Version (s)
Task 1	51	50
Task 2	56	39
Task 3	17	28
Total time	124	116

**Table 4.2:** Questionnaire results from test 1. Average value from 1-5, where 1 is strongly disagree and 5 is strongly agree.

Question	6-Button Version	2-Button Version
Question 1	4.25	4
Question 2	4	2.5
Question 3	3.5	2.75
Question 4	3.5	3
Total score	3.81	3.06

#### Iteration 2

Results from the test after the second iteration can be seen in table 4.3 and table 4.4.

**Table 4.3:** Results from test 2. Average time over the 3 tasks and the total time, in seconds.

Task	6-Button version (s)	2-Button Version (s)
Task 1	40	49
Task 2	27	58
Task 3	13	32
Total time	80	138

**Table 4.4:** Questionnaire results from test 2. Average value from 1-5, where 1 is strongly disagree and 5 is strongly agree.

Question	6-Button Version	2-Button Version
Question 1	4.5	4
Question 2	3.75	3.25
Question 3	4	3.75
Question 4	4	4.5
Total score	4.06	3.88

### Iteration 3

Results from the test after the third iteration can be seen in table 4.5 and table 4.6.

**Table 4.5:** Results from test 3. Average time over the 3 tasks and the total time, in seconds.

Task	6-Button version (s)	2-Button Version (s)
Task 1	49	44
Task 2	33	34
Task 3	25	24
Total time	105	101

#### 4.1.4 Final testing

The final testing was done on potential end users. The four participants were either blind or severely vision impaired. We achieved a wide range of ages within the participants, the youngest was 19 years and the oldest 65 years.

Subjective opinions from the tests were summarised and refined in the list below:

- All four pointed out the good and slimmed layout with only four choices presented at a time.
- All the participants understood relatively quickly the 2x2 mapping between the presented choice and the six buttoned control. 2 participants understood it immediately and the rest approximately halfway in in the test.

**Table 4.6:** Questionnaire results from test 3. Average value from 1-5, where 1 is strongly disagree and 5 is strongly agree.

Question	6-Button Version	2-Button Version
Question 1	4.25	4
Question 2	4	3.75
Question 3	3.5	4
Question 4	4.25	4
Total score	4	3.94

- Even if all the participants are daily users of VoiceOver or similar assistive functions, they expressed the unfamiliarity of listening so concentrated when using a system. Especially when using the version with two buttons. Or as a participant expressed it: “The fewer the buttons, the more complicated it becomes to make a choice”.
- The fact that the screen, voice and partly control are homogeneous and provide the same function simultaneously, will according to the participants lead to:
  - Facilitate and shorten the learning of the system, if the user are able to distinguish some of the content on the screen.
  - Gives the opportunity for a second person to help the user navigate in the system.
- The opinions of the vibrations in the system diverged among the participants. One of the participants did not notice it at all and the participants who did notice them experienced them as redundant. They considered the spoken voice to be enough and that you already listen so carefully to the interface that any other input was unnecessary.
- All participants emphasised the lack of feedback when entering an option in the interface. As a user, when entering a option, there is no feedback and the user will instead hear the next four options available inside the entered option. The participants wanted some sort of confirmation that they had entered the correct option.
- There was no winner between the two different search methods. Both were considered as good alternatives, but also time consuming and sensitive to errors. They are especially time consuming and sensitive to errors when taken into consideration the fact that the methods only went from *A* to *H* and not provided the whole alphabet. Another feature within the search that the participants missed was the function to simply browse between all available elements.
- The preferred version between the participants was the version with six buttons. This was because they believed the mapping between the screen, voice and control were more obvious, easier to use faster with better opportunities to speed up the TTS-voice for more advanced usage, and the other version to be more cognitive exhausting.

- They all, however, expressed that the best possible solution for them would have been to connect their own smartphone to the system and control the interface through their own phone. They are so familiar and comfortable with the assistive solutions from Apple or Android that they want to use them in a as large extend as possible.

## 4.2 Prototype 2

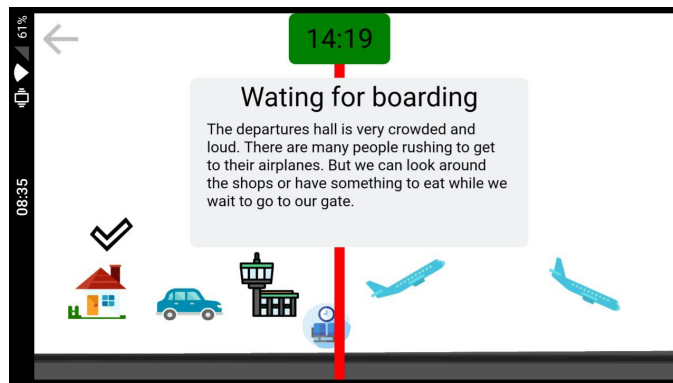
With this prototype we was trying to aim for another group of users, compared to the first prototype. This prototype consists of three different concepts, all with the aim to ease the flight experience for a passenger which is inexperienced, easily stressed and/or suffering from fear of flying. All of the features and design choices in this prototype origins from the workshop at Tactel.

### 4.2.1 Timeline

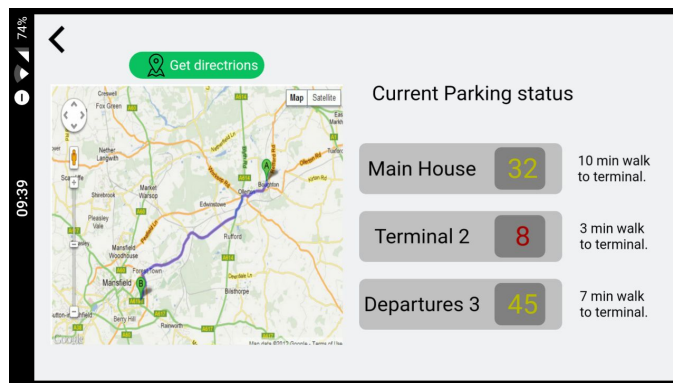
The process of travel, especially when travelling by plane includes many steps and procedures. Much information has to be captured, remembered and processed at the right time. Our goal with this prototype was to gather all relevant information a user may be needs during a trip and put it in one unified system. We wanted to create a concept where sources of information during a travel situation has been dramatically reduced, and presented in a more user-friendly way.

The massive amount of information presented to the user during travel can easily result in increased stress-levels. “Right information presented in right time”, was our vision during the development. The system will assist the user with filtering and only present information relevant in the current situation. Information is categorized in time of usage, instead of the more classical approach of grouping on the type and level of abstraction. Therefore, detailed information and selections can be presented side-by-side with more abstract information, if they are relevant in the same time-span.

As the headline suggests, this concept is based around a timeline-metaphor. At startup, the user is presented with a graphical timeline with timestamps and checkpoints corresponding to the users current trip. The red marker seen in figure 4.7 can be dragged over the screen to see when events are scheduled to occur. The text field in the center of the screen adapts to where the marker is located. The idea with the text is to prepare a stressed or inexperienced traveller on what to expect. The text is written in a simple and guiding manner, inspired from Aer Lingus visual guide for autism travelling [43]. In addition to the chronological overview provided by the timeline, the system has functionality to provide more detailed information. This is where the situation-based filtering previously mentioned comes in. By tapping the icons on the timeline, the user is presented with detailed and updated information related to the selected situation. For example, tapping the house will result in an interactive packing list, tapping the vehicle icon will return directions and current parking status at the airport, see figure 4.8.



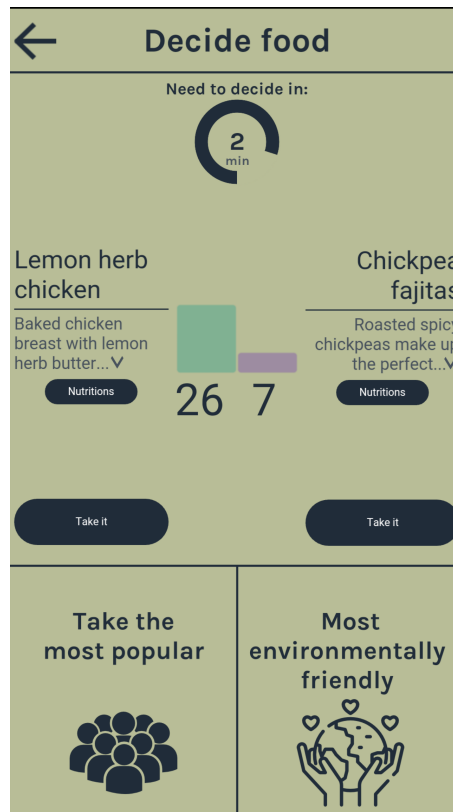
**Figure 4.7:** The timeline-view with marker, describing text and checkpoints illustrated with objects.



**Figure 4.8:** Transit view when user has selected car as form of transport. Directions and current parking status are shown.

## 4.2.2 Decision making

As a passenger during a flight you face different decision situations. These decisions can however be related to stress, and may be further exacerbated in the case of fear of flying, and lead to a very demanding and unpleasant journey for the passenger. This concept is made to assist the passenger during the decision of what to eat and can be seen in figure 4.9. The concept gives the passenger necessary but digestible information together with available options, to make the decision of what to eat as simple as possible for the passenger. The prototype shows time left until the decision has to be made, descriptions of the available meals and in real time what the other passengers choose. There is also two shortcuts in the bottom as you can pick the most popular one or the most environmentally friendly one.



**Figure 4.9:** Information and options displayed to facilitate the decisions for the passenger.

### 4.2.3 Information and notification

This concept is based on the difficulty to register and process the sound based information during a flight.

The information is traditionally given by the pilot as he speaks the e.g weather information through the speakers. However, this concept displays the same information in rolling text at the top of the screen, simultaneously as the information is passed through the speakers. The three animated centred circles just below the text offer the user to either drag it down to extend the information, or drag it up to remove it. This can be seen in figure 4.10.

If the information is extended, it is displayed in a pop-up window that can be seen in figure 4.11. The pop-up consists of more detailed information where the information also is visualised together with explanatory pictures. In the figure 4.11 the destination is Rome and today's weather is then further visualised with an animated sun over a widely known landmark, in this case the Colosseum. The pop-up window is then removed by dragging it upwards.



**Figure 4.10:** The information displayed simultaneously as the sound based information .



**Figure 4.11:** The pop-up window with extended information.

# Chapter 5

## Discussion

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### 5.1 Haptic feedback

The impact of the haptic feedback in the prototype 1 was a big disappointment for us but also a big lesson. The fact that so few of the test participant even took notice of the vibrations despite our attempts to enhance its effect taught us a lot. At the first iteration, we believed that the vibration would come intuitive to the user and that the users would by themselves understand that every spoken choice in the interface was associated with a vibration. Yet, none of the participant even noticed or had a thought of the vibrations. Even our supervisors, that knew that the system would contain vibrations, did not noticed them. We experimented with different vibration patterns and the location of the vibration device (from that the user held it in one hand to be under the numpad device and thus made the whole device vibrate) but without better result. After each test we asked the participant specifically about the vibrations and how they experienced it. We believed that by starting a discussion about it we could quickly learn about how to best design the pattern of the vibration and the timing of it. Although, we had to early in the iterations change goal of the vibration from how to best design it, to just make it noticeable at all for the users. The big lesson learnt was how extremely much focus the audio within the interface required from the user.

One thought we had on the design of the haptic device was to further reuse the 2x2 layout (see figure 4.2). By having 4 haptic devices in a vest, the devices could be placed at a users back with the 2x2 formation. Each of the four given options would then have a haptic device vibrating on the back of the user, with the first option always trigger the vibration of the device in the left upper corner and the second option the right upper corner etc. But the fact that the human back are not as sensitive as the hand, our participants didn't even notice the vibrations in their own hands, and that our vibration devices are smartphones with relatively weak vibration. We decided to not implement this idea. This would, however, with stronger and more precise vibration devices been a possible next



step in evolution of the prototype to make it better.

## 5.2 Audio

We had a vision about doing the prototype 1 interface even more auditory advanced with the help of multiple spatial sounds. We wanted to utilise the basic idea of spatial auditory interface, that in addition to the content of the sound signal, also use the position of the sound signal to hold some information to the listener. The meaning or functionality of an auditory icon can change when its spatial position is changed. A hierarchical menu could therefore be represented with spatial sounds describing their physical properties and dimensions. We liked the idea of spatial sounds and investigated different applications to help us create spatial sounds. After some research we decided to try Unity. Although, after doing some tutorials and tried different demo plug-in applications, specialised in making 3d-sound in the program, we decided that the experience of the spatial sounds was not good enough for further use in our prototyping. We thought that the sound wasn't distinguishable enough to use in a interface menu. It is more suitable in, for example, a game environment where you can move yourself closer and further away from the sound source and more easily get the perception of how the sound is getting more intense or more vague. Another aspect of multiple spatial sounds is the aspect of Head Related Transfer Functions (HRTF's). To be able to effectively deliver the sound through headphones (which is essential during a flight with many fellow passengers) the audio has to be filtered with HRTF's to add the information on the spatial position of an arbitrary sound. The filter functions are measured separately for each ear of the listener and the spatial sound get more accurate if this settings are done carefully.

Our auditory interface in prototype 1 consists partly of speech, but also of different assistive sounds. Some of these sounds are played in the background in different situations to enhance the specific information and experience. For example, when a user gets the weather information, if the forecast predicts sun and a hot day, the background is filled with birdsong and a smooth breeze. We experimented to partly find a suitable sound for the current situation. But also to get the sound noticeable enough without taking to much of the space and thus disturbing the user from getting the primary information that is spoken. In our prototype, this feature is only implemented in the weather information service for transit and final destination. Although, we experimented with sounds for more situations. For example, we tried to implement it in the entertainment section, so when a user entered *entertainment*, the background was filled with the sound of popcorn popping. However, we didn't find a sound suitable for this and we also believe that it is hard to find one sound that gives the correct association for all the passengers. One has to consider many parameters as the age of the passenger, cultural differences and nationality to find a sound that gives the proper association to all the passengers. To get the desired results, the testing has to be comprehensive on all the different passengers which is both time consuming and expensive.

## 5.3 Button layout

In the beginning of the development of prototype 1 we only had one button-layout in mind, a version with six buttons, see figure 4.4. From what we had learned during our research we decided that this was in theory the best design, matching as many criteria as possible. Simple and intuitive mapping from screen to control and dedicated actions for each button was two of the main advantages with this design.

When testing this design in combination with the visual screen this layout worked well. The mental mapping we had aimed for worked as expected. However, since the system was designed for no- and low-vision users a majority of the testing was performed with the test person not able to use the screen. With no visual guidance, the screen-to-control mapping we had designed for didn't work. When not being able to see the screen, test persons had harder to understand our design with coloured buttons in a 2x2 layout. Some participants testing the system without a screen said that the layout made it harder, due to the increased cognitive load put on the memory when the visual guidance was disabled. With this in mind we realised that we had to develop a design where the users visual ability did not affect the experience.

From the development of the 2x2 layout, an idea of a version with minimal amount of buttons was born. Inspired by available TTS-systems on the market today, i.e. iOS, where users navigate with gestures and multiple-taps, we created a design where user used the same key for multiple actions. A single press to trigger the TTS functionality and a double press to select a desired alternative. The back-button was kept with unchanged functionality.

In addition to using less buttons, this version goes away from the 2x2 mapping and instead presents the four alternatives in a sequential order. This design reduced the load on the users short-term memory, however more users were dependent on a repetition of alternatives using this version compared to the first one. Users also stated that using one button for multiple purposes was more difficult to get used to.

### 5.3.1 Testing

The iterative design and development process we used consisted of a lot of testing. To ensure a rapid and efficient development, testing has to be performed during the whole timespan of development. For a trustworthy and somewhat statistically valid result, we tested the system on new test participants every iteration. With exception for our supervisors, all test persons used in the testing were new and unaware of the system before testing. The majority of the test persons have been full vision users and therefore outside the primary target group. The lack of test persons with reduced vision was a weakness we were aware of in the beginning of the project. Therefore we did a conscious decision to test with simulated conditions in the beginning and thereby save the few valuable test persons within the target group until the final iteration. A challenge was therefore to determine how feedback from an inexperienced user with full visual ability, should be weighted against feedback from user within the target group.

Our method of always using new test persons in every iteration had both pros and cons. In a scenario where this system is mounted in an airplane, we can see that the majority of users will use it very seldom with only a few hours per occasion. The usability for an

inexperienced and new user is therefore of highest priority. Testing with new users every time gives us valuable data how the current version is handled by this group of users. A downside is that we lose the ability to investigate how experienced users would interact with the system.

The two search-methods was evaluated with comparison testing. Not included in the initial test-plan, but later turned out to be a useful method to increase the feedback received in test sessions. Opening up discussions and giving the user two versions to think comparative about. While test persons with experience within voice based systems, compared the prototypes in relation to the previous systems they have been using. For a test person with no previous experience within this kind of systems this was not possible, thereby the comparison was an useful method to give test persons something to relate to and discuss around.

## 5.4 Physical remote control

We decided early in the design process that we wanted a physical control as a part of the result. We have found both in literature studies and our own interview data confirming that a physical navigation device can increase the usability for users with visual impairments. With the rapid development in touchscreen interfaces there is a risk of leaving some users behind.

What we weren't prepared for when we started this project was how well developed the modern tools for low vision users are. All the users we interviewed within this group was using the iOS VoiceOver and was thereby able to access the same content as a user with full visual ability.

The low vision users we tested our prototypes on were mainly positive to our approach with a physical navigation device. However, it was stated that a tighter implementation with tools available on the market today has increased the usability. This confirms what Ulf said in an early interview (Ch. 3). With more advanced tools comes with the price of a higher curve of learning. When developed speed and trust to a tool, you stick to it as much as you can. With all types and unique takes on impairments available, it's impossible for a small project like this to cover them all. To implement current standards, and thereby allowing the user to their own physical device of choice seems like the recipe for success.

## 5.5 Prototype 2

Because of the limited time in the thesis, this prototype was devoted significantly less time. The three concepts were made with the foundation in the results of the workshop and in corporation with our supervisor from Tactel. Because of the limited time, there was no room for us to thoroughly test the concepts on users apart from our supervisors. We therefore lack of test data for this prototype. This is not optimal, but we still didn't want to exclude the prototype from our report and because of the lack of testing, we don't have any conclusions drawn from it.

# Chapter 6

## Conclusion

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In this thesis, we have designed and evaluated accessibility support within in-flight-entertainment systems available in the market today. The focus has been on usability for users with reduced or no vision. Interactive text-to-speech prototypes with physical controls were developed to evaluate different methods of interaction. User centred design has been a key factor during the process where testing and development has been alternated with an iterative approach.

During the development, usability test was performed to measure both quantitative and qualitative data from test persons. The result showed an overall positive feedback for the concept with a dedicated physical control. However, we underestimated how much focus an audio based interface required from the user. Which resulted in none or very little notice and help from the haptic feedback in the prototype, despite our experimentation with the feedback.

Even though our prototypes were given much positive feedback. The preferable approach, suggested by participants with reduced vision, was to in the IFE system implement support for their smartphones, to let the users control the system through their phones. Vision impaired users are very familiar and comfortable with their own assistive tools, which is an important factor to consider when designing accessible systems.



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# Appendices



# Appendix A

## Questions template for first interview with Ulf

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Prepared question for the first meeting with Ulf:

1. Ulfs background and knowledge of assistive technologies.
2. How are you, as visually impaired, interacting with different computer systems?.
3. How are your customers interacting with touch screens?
4. What kind of assistive technologies exists? If possible, do you always prefer to use your own?
5. Ask Ulf of his previous experiences of IFE systems and his general opinions. Show him the IFE system we brought from Tactel and his opinions about it.
6. How does a visually impaired feels when he/she needs to interact with a new system?
7. General guidelines of computer interaction as visually impaired. Both from design and interactive perspective
8. To what degree are TTS used? Do you use it even if you have a mild vision impairment?
9. How are the accessibility within IT developing? Google vs Apple.



# **Appendix B**

## **Test scheme for iterative testing**

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# Test scheme for iterative testing

## Preparation:

Introduce the test person (TP) in the hardware used in the test.

Make sure that the TP understands how the interaction device (remote) works.

Explain that both sound and haptic feedback will be used in this test.

Explain the mapping on the remote. How decisions are split up into four options, and how this mapping can be found on the physical remote.

Describe how the remote is used to navigate in the system (how options is read aloud and which buttons to press to select an alternative)

Task	Sub-task	Accepted when
Find weather at destination & transit	<ol style="list-style-type: none"><li>1. Navigate to Service</li><li>2. Find and receive info regarding whether at dest.</li><li>3. Navigate backwards</li><li>4. No. 2 for transit dest.</li></ol>	TP has received and understood current forecast for both the final destination and transit destination.
Find and play the movie "Edge of tomorrow"	<ol style="list-style-type: none"><li>1. Navigate to Movies.</li><li>2. Search for correct letter.</li><li>3. Play "Edge of tomorrow".</li></ol>	TP has started the correct movie.
Find and play the podcast "Security Now"	<ol style="list-style-type: none"><li>1. Navigate to Podcasts</li><li>2. Select the correct podcast</li><li>3. Play podcast</li><li>4. Pause podcast</li></ol>	TP has played and been able to pause the podcast using the pause button (not by pressing the back-key)