# AUDITORY INTERFACES FOR ACCESSIBILITY

Using sound to improve the HSL metro ticketing interface for the visually impaired

Alexandra Jones
Alexandra.a.jones@aalto.fi

**Aalto University**
**School of Arts, Design and Architecture**

Aalto University, P.O. BOX 11000, 00076 AALTO
www.aalto.fi

**Master of Arts thesis abstract**

**Author** Alexandra Jones

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**Abstract**

Around 252 million trips by public transport are taken in Helsinki every year, and about 122 million passengers travel by Helsinki City Transport (tram, metro and ferry) in and around Finland's capitol. Given these numbers, it is important that the system be as wholly efficient, inclusive, and as easy to use as possible.

In my master's thesis, I examine Helsinki Region Transport's ticketing and information system. I pay special attention to their new touch screen card readers, framing them in the context of increasing usability and accessibility through the use of sound design. I look at what design decisions have been made and compare these with a variety of available technology that exists today, as well as what solutions are being used in other cities. Throughout my research, I've placed an emphasis on sonic cues and sound design, as this is my area of study. Everything is assessed against the requirements and perspective of Helsinki's public transportation end users who are blind and visually impaired.

I have used desk research, field research, user testing and stakeholder interviews in my methodology. I have put forth suggestions on how to improve the current system, taking into account the learnings from my research. I have looked at key points around people with disabilities and how sound can be used to improve accessibility and general functionality for all. I also hope to share this thesis with HSL and HKL, whom may use it to inform future optimization of their systems.

**Keywords** service design, sound design, accessibility, public transportation, interaction design

**Acknowledgements**

First and foremost, I would like to thank my professor Antti Ikonen. I don't think it's an understatement to say that without his dogged determinism, zen-like patience, and unwavering support and faith in my ability to finish this paper I surely would not have gotten this far.

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# 1 INTRODUCTION

*Sound gives to the consciousness an evidence of its existence.*

- Hazrat Inayat Kahn

In a world where the urban population is rapidly increasing, and the majority of people now live in cities, public transportation has solidified its role as an important part of a city's infrastructure. In my thesis, I examine Helsinki Transportation Authority's ticketing and payment system interfaces and explore the ways sound might enhance the accessibility of the newly installed ticketing kiosks and card readers. Greater accessibility would ensure public transportation in Helsinki was a more inclusive experience. I pay close attention to the ways that audio interfaces could improve the user experience for blind and visually impaired users in response to the current trend of implementing touch screen interfaces within public-facing, walk-up-and-use systems. These interfaces lack traditional tactile information; supplementing these smooth glass panels with audio could go some way to mitigate this oversight. It could help blind and visually impaired users move through a ticketing journey more efficiently and effectively with as little friction as possible. Can audio make up for the absence of, or even improve upon, physical buttons, braille, and other tactile informative features? Is sound an appropriate channel to convey meaning in these contexts?

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In the volume "Auditory Display: Sonification, Audification, and Auditory Interfaces", Gregory Kramer's text about creating and using sounds and sound frameworks to convey meaning, he talks about how the point of an auditory display is to help the user "monitor and comprehend" information (Kramer 1994, p. 1). He goes on to point out some overarching differences between speech and non-speech sounds, and the ways we as humans comprehend these two main categories of communicating information through audio. I discuss this in Chapter 2.2. I examine the strengths and weaknesses of each audio method, as well as how each is currently implemented in various ticketing machine systems around the world. I also look at other ways metro ticketing systems in other cities address accessibility via taking advantage of existing audio technology. In a wider sense, I look at how we as researchers and designers might develop more inclusive products and services by considering the needs of a broader range of users.

The current state of understanding around this topic derives knowledge mostly from the fields of industrial as well as sound and audio design. A large part of my research topic involves the use of touch screens. As touch screens have only been around for a limited time, and as blind and visually impaired users are a non-mainstream user group, it should be noted that secondary research and knowledge around this specific topic is relatively limited.

According to a 2015 report, the UN calculates that the world population is projected to increase by more than one billion people within the next 15 years, reaching a staggering 8.5 billion in 2030, and to thereafter increase further to 9.7 billion in 2050 and subsequently to 11.2 billion by 2100 (United Nations 2015, p. 2). This projection is relevant to the case for well-designed public transportation, as these systems can be considered a mainstay of many people's everyday lives. It is clear from the numbers that the amount of people riding public transportation will only increase as time moves forward.

Public transportation enables businesses to function by transporting their workforces, affects real estate values, and encourages economic benefit via the consolidation of services, thus allowing and encouraging innovation and growth. Furthermore, choosing public transportation over driving an automobile decreases traffic congestion and reduces the use of fossil fuels, thereby reducing carbon emissions and dangerous greenhouse gasses. In short, public transport provides benefits which increase peoples' choices, opportunities, and freedom, plus at the same time helps decrease humans' negative environmental impact on the planet.

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This example well builds up towards your topic introduction

Helsinki has a robust and well-connected public transportation network. It consists of busses, trams, ferries, commuter trains, and a metro that holds the distinction of being the northernmost in the world. This network spans the city and outlying areas and moves people back and forth across the capital in a clean, efficient, and comfortable manner. It does all of this whilst using an infrastructure that takes up a relatively small amount of space in the city. All of these factors add up to quite an effective mass transit system.

However, for people with disabilities, taking full advantage of public transportation can be a challenge. Wayfinding, purchasing a ticket, and physically using public transport vehicles are all potentially much more difficult challenges for someone with reduced capabilities. The substantial positive impact of public transportation is reduced if a particular subset of users is unable to participate in this beneficial system. Touch screen technology has taken hold so quickly that some users who might not fit a mainstream demographic have been left behind – particularly those with vision disabilities. I examine how this has happened within Helsinki's public transportation system later in this paper.

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## 1.1 The main idea: Using sound to enhance the accessibility of touch screens

In recent years, technology has brought about many changes in the way we live our lives. Many of the changes around us are meant to increase the ease and efficiency with which we complete everyday tasks. Every once in a while, a new technological innovation is introduced and is adopted by the masses. This is, however, fairly rare; successful radical innovation only occurs in any particular area about once every five to ten years (Norman & Verganti 2013). Touch screens can be considered one of these radical innovations, and they are now ubiquitous. This is an important point in the context of my thesis, as touch screens are the main way information is communicated in the new HSL ticketing machines and card readers.

A few short years ago, mechanical, tactile buttons were the most common way of interacting with a broad range of devices, from microwaves, to mobile phones, to the heating and air conditioning controls in one's car. However, today the new norm is the smooth, glassy surface of the touch screen. Designers like touch screen technology because it provides endless flexibility for on screen, interactive graphical user interfaces (GUIs) and beyond, thereby in many cases increasing efficiency and effectiveness of space.

While touch screens hold many advantages for the designers who create them as well as able-bodied end users, the lack of both tactile and mechanical feedback and consistent element placement presents new challenges to the blind and visually impaired user. I explore how sound could potentially help to fill this information gap. While sound is currently used to convey meaning – audio is already used to help people along in many critical contexts (for example, alarm clocks, smoke detectors, and telephones) - it could be a valuable asset in making touch screen technology more usable.

In some ways, this shift towards using sound to enhance accessibility in response to the switch to touch screen technology is already happening. Audio based assistive technology, such as Apple's Voice Over for Apple's mobile operating system, iOS (Apple 2018), has been developed to address the challenges that visual limitations present within the context of touch screen based smart phones. Of course, while this effort cannot be considered completely altruistic (Apple want this demographic to purchase its products), this technology seems to be transforming the lives of blind and visually impaired users for the better (Hatton 2014). In the context of personal devices, while these kinds of solutions are by no means perfect, they provide users with enormously improved ways to interact with on screen information. According to two of the visually impaired individuals I interviewed, Voice Over in particular has generally been very well received by the blind and visually impaired communities. Both individuals use this program extensively and skillfully themselves. However, Voice Over is a proprietary technology which is limited to only function with its

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own Apple brand operating system on personal devices.

While accessible solutions for touch screen interaction on personal devices has progressed, in the context of public systems it is a different story. It can be argued that using sound to communicate information holds great potential as an alternative to visually based communications within these public interfaces. Built-in, robust, and inclusive public facing solutions such as speech synthesis have been explored and, in some cases, attempted, but these implementations still have a long way to go until their efficiency and ease of use equal the innovations in personal computing, or even the default offerings which sighted users enjoy. Sound could potentially be pushed further and better utilized. Touch screens can be considered fairly nascent technology in a quickly changing area. There has not been a huge amount of research on the issue of blind and visually impaired users taking advantage of this method of communication. Furthermore, large enterprise municipal systems are historically less agile and slower to adapt to new technology, and also to the fine tuning and adjustments that technology might require once it has been implemented.

I discuss how some designers are already attempting to use sound to give the blind and visually impaired more access to touch screen communications in the public realm across various major cities later on in this paper in Chapter 4.

## 1.2 Motivation: The importance of inclusive design in public transportation

In 2017 in Finland, there were roughly 80,000 people who could be considered visually impaired (Iiris 2017). Many of these people rely on public transportation to get from place to place, as driving a car or other vehicle is not normally a viable option when one has limited visual capabilities. Being able to travel independently is important to one’s sense of freedom, autonomy, and overall mental wellbeing. It is also key in the ability to live a normal and active life. Transportation is required for many types of social, professional, and practical matters. HSL can play a key role in enabling the independence and well-being of visually impaired people by offering an inclusive infrastructure. Part of this could be using sound to improve the ticketing communication. This would in turn provide easier access to a safe and efficient way to travel within the Helsinki metropolitan area and would help this group to function more easily and equally within everyday society.

The additional challenges visually impaired users must overcome can inhibit and discourage them from using public transportation systems such as the metro. This can negatively affect their independence and quality of life. This problem isn't limited to ticketing, but also includes wayfinding and layouts, and integrated systems such as area maps, zoning, fare frameworks, and ways to get further general assistance. It is worth mentioning that while inadequate or ill thought out design in many of these areas might disproportionately affect disabled customers due to their potential further limitations and requirements, these design shortcomings negatively affect all types of passengers. The ultimate aim is to provide a service that is open and inclusive to all users.

The topic for this paper originally came from my professor Antti Ikonen's suggestion. I was having trouble selecting a topic, and the subject of the new ticketing system seem like an appropriate fit, given that interaction design has been a key theme in many Media Lab classes I have taken. The topic was also a suitable match for my professional experience. I have spent the last eight years working as a user experience designer, and part of that work has been assessing an ensuring that usability standards are in place, mostly in a website context. Part of my job is to make sure that systems are inclusive in their design and function. This experience has heightened my awareness of the challenges certain user groups face in everyday situations. It has given me a personal interest in accessible and inclusive solutions that decrease pain points while increasing usability and efficiency for all users.

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**Commented [15]:** which systems? (CS degree has an emphasis on systems thinking, hence the commenting on the word system…)

**Commented [16]:** good point and nicely said. Even though its a long sentence it rolls out nicely

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Additionally, I was attracted to the idea of a subject where my research and writing could potentially have a positive impact on people's lives. I would hope this paper can in some way lend a hand in helping to move things in the right direction in the context of raising awareness of inclusivity and increasing thoughtfulness within service and product design.

The topic is also timely due to the recent complete redesign of the two main components of HSL's ticketing system. The first of the two new components is the "walk up and use" kiosk-style ticket machines where transport users purchase or top up tickets. The second is the card readers, which have been controversially received by the public. The new card reader machines are currently being installed across the network, while the new ticket machines are also being installed, but are a bit behind the card readers; they were planned to be in place in 2018. The biggest and most immediately noticeable change the new machines utilize which differs from the old machines is the new digital touch screen interface, and the user flow. The reception of the new card readers by the general public has not been 100% positive, all considerations for visually challenged users aside. The user journey and flow of the ticket purchase and validation process has changed significantly. This has proved confusing and difficult for users who are accustomed to the original process of buying a ticket. Careful and thoughtful augmentation and enhancement the audio feedback for visually impaired users brings with it the very real possibility that usability and clarity would also increase for other users, and somewhat mitigate the confusion caused by the new user flow. This could only be a good thing for both the people who use HSL public transportation, and for the company itself.

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**Commented [22]:** users?

**Commented [23]:** this is an unfamiliar term for me for installing something, if I got it right thats what you meant?

**Commented [24]:** does this mean both: kiosks and readers?

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## 1.3 Work plan and research approach

I wanted to make sure I looked at this question from several different points of view, both theoretical and practical. I covered different methods of using sound to convey meaning, as well as practical ways of applying these methods in the context of public, self-service, “walk-up-and-use” style kiosks and card readers. I reviewed relevant papers and texts across a wide time frame in the area of sound within communication design, as well as sound in accessibility contexts. Some papers that were written quite some time ago still contain relevant information and insights. I also looked at existing technology and examined the current design of the HSL ticketing system, as well as several other similar systems around the world.

My method also consists of qualitative interviews with blind and visually impaired users. Other research methods used included observational analysis, a walkthrough of the current ticketing kiosk with a blind user, and several walkthroughs of the current ticketing kiosk on my own.

The literature I used was obtained from various Helsinki and Los Angeles public and private libraries, as well as the Aalto University Harald Herlin Learning Centre. I also used research papers I sourced via Google Scholar and Google Books. My thesis advisor, Karoliina Tiuraniemi, was extremely helpful to start me off by recommending essential texts within the field of sound and sonification, namely *The Sonification Handbook*, edited by Thomas Hermann, Andy Hunt, and John G. Neuhoff. This text was central to my research and understanding of the field of sonification, its various sub-areas, and how this practice can be implemented. It also provided a thorough and robust bibliography of related written works which I was able to use to discover further material relevant to my topic.

The structure of my thesis is as follows: Chapter 2 looks at the history of audio in accessibility, as well as various current implementations of audio technology to assist visually impaired and blind people. It also discusses two existing semantic audio frameworks: earcons and auditory icons.

In Chapter 3 I explain my research methods and how I will examine the ways in which audio is used in other cities' public transportation ticketing systems. I also give practical details about the interviews and walk throughs I completed, and how I will examine Helsinki's current ticketing setup in the context of my topic.

Chapter 4 examines detailed findings from each city I researched. It explains how the systems work and what features and functionalities are present in each. I then explain the Helsinki system, and compare this against what other cities are doing. I also go through my four interviews in this chapter and talk about what visually impaired users themselves have to say about this paper's topic.

Chapter 5 is an overall analysis of my research and goes through several strategic methods and potential design solutions to enable meaningful access to audio. Chapter 6 discusses the research experience and how HSL currently addresses accessibility, and Chapter 7 reflects on what could have been done differently and the various limitations of my investigations, as well as what further research still might be done to contribute to the topic.

## 2 BACKGROUND

In this chapter I will provide a brief overview of the history of using sound in accessibility contexts, as well as profiling some current ways sound is used for accessibility. I will also explain the concepts of earcons and auditory icons.

Sound is used to communicate information in many different ways. We are constantly using multisensory input to understand the world around us. We use sound, combined with our other senses, to comprehend our relationship to our environment at any given moment. For blind and visually impaired people, this is a bit different: when one cannot see, one uses their other sense, including the sense of hearing, to locate where they are, who and what is around them, and what is happening nearby. While interacting with technology, sound cues

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often help one complete a task by providing valuable feedback in addition to visual information. Examples of this include an error state in a dialogue box, the sound of a dial-up modem, or Skype successfully making a connection. Other familiar examples might be the tones a phone keypad makes (tactile or touch screen based), or even the buzz of a door lock opening when someone lets a friend up to their apartment. These are all examples of how sound can be a useful tool for communicating information in a given context.

For visually impaired people, sound in particular can carry even greater importance when it comes to gaining useful information. Because access to visual stimuli and visual feedback is limited, or in some cases eliminated altogether, the other available senses become more important. These include touch, smell, and indeed, sound. Whist promising research exists, and medical breakthroughs such as those around stem cell research and electronic implants are taking place in the area of vision loss and visual impairment, there is still generally no viable way to fully and reliably replace the sense of sight. Audio can be a powerful and relatively easy way to supplement and support various interfaces in the absence of visual information. It has the potential to provide much meaning when thoughtfully placed in new contexts and used in certain deliberate ways.

In the report “Nonspeech Audio in Helicopter Aviation” (Houtsma 2003), Houtsma talks about how the ears and eyes are complimentary, as one can be doing one thing and the other can be doing something else. This is especially important in military aviation, because so much is demanded of the visual system (Houtsma 2003, p. 6). Due to this fact, he talks about some ways that meaning can be conveyed through sound rather than visual feedback, as visual bandwidth is not always available. The suggestion of expanding the uses and applications of sound to convey important messages in such critical situations as operating an aircraft in a military context is a testament to the potential effectiveness of these methods.

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maybe some resources could be presented?

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vision

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One worry of sound designers is that audio displays will interfere with speech communication (Kramer 1994, p.13). However, while it still should be considered, since the application we are talking about is purchasing and using a ticket for the Helsinki metro, this is not as great a risk and might be treated as an edge case. This is because the most common interactions with the machines are normally performed by one single person at a time.

## 2.1 A brief history of sound in designing for accessibility for the visually impaired

In this chapter, we will take a brief look at the beginnings of accessible design for visually impaired people using sound, and how the practice and technology has changed and evolved over the years. Because there is no complete theory of human audio perception, and because all humans are different, the development of auditory display approaches must be experimental and must be validated by evaluating the user (Kramer 1994, p. 119).

One of the first machines to use sound exclusively to help blind and visually impaired people was the Type-Reading Optophone (see Figure 1). This machine was invented by Dr. Edmund Edward Fournier d'Albe in 1912 and had a six-tone code that responded to scanned letter shapes. It used selenium photo sensors to detect black print and convert it into an audible output which could be interpreted by a blind person. Its stated purpose was to “enable the blind to see by ear,” (Scientific American 1920).

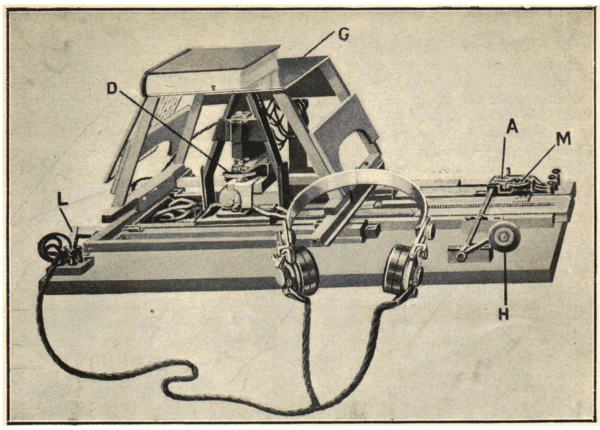


*Figure 1. Detail view of the type-reading optophone (Science & Vie 1922)*

*"A, switch for the electric lamp; D, perforated disk, placed in front of the lamp and driven by a small electric motor from the commutator M; G, glass plate, on which the image of slit placed above the disk; H, a crank, by which the operator can move the carriage with the lamp and disk from right to left; L, a line changer, which moves the pulpit, on which the glass plate with the book rests." Caption translated from Swedish.*

The device was updated and refined in 1922 (see Figure 1), and then again in the 1950s by the American Veterans Administration. In the 1960s, the Visotoner came along, which was similar in operation but used nine tones instead of seven. Finally, the Stereotoner was developed in the 1970s, which took the Visotoner further with a more complex tone system, possessing 10 tone channels and using a stereo output.

The same year, the New York Times published an article on the "Typophonia". This was also a device that also allowed "the blind to 'see' by ear" (Anon. 1920 p. 21).

Demonstrating a shift in communication strategy and major advancements in technological capabilities, screen readers were a different kind of audio solution. They came along at about the same time as the first DOS (Disk Operating System) personal computers and have evolved alongside them ever since. A screen reader is a device that transforms visual data on a screen into audio by digital means. Screen readers output on-screen text direct to audio speech, rather than outputting printed text to audio tones as the earlier

Optophone family of devices did. They started out as clunky and slow, but progressively got faster and easier to use. In the past, data and information was shown to the user via text on ASCII (American Standard Code for Information Interchange) terminals. This text was relatively simple for screen readers to convert to speech audio via speech synthesis software. However, when the user interface started shifting to graphical content, this interpretation of information became far more complex, and different solutions had to be developed, such as encoding detailed metadata within the images and within the operating system as a whole (I discuss this further in Chapter 2.3).

Today there are several well-known screen readers which are widely used by blind and visually impaired people to provide fairly quick and easy (though highly dependent on the user's skill) audio access to information. Freedom Scientific's JAWS (Job Access With Speech), which claims to be the "world's most popular Windows screen reader" (JAWS 2018), is software designed for Windows operating system users. Apple's Voice Over for Mac OSX and iOS (Apple's mobile operating system) (Apple 2018), is also very popular. Window-Eyes (Window-Eyes 2018), open source NVDA (NVDA 2018), Google ChromeVox for Chrome and Chrome OS (ChromeVox 2018), and Google TalkBack (Google TalkBack 2018) for Android devices, are also all various widely used versions of text to speech screen readers.

**Commented [AJ37]:** Include references for these applications as well, links to web pages introducing them.

In recent years, machine learning advances have enabled digital devices and software to not only translate visual information on a screen into audio, but to also utilize cameras and GPS to identify and communicate real world objects using sound. Aipoly Vision is an application which identifies objects, colors, and faces using one's native mobile camera, and then speaks the name out loud. Its AI is able to learn and improve as the application is used. Orcam is a wearable device which uses a camera to scan text, objects, and faces, and then translates that information through an audio earpiece to the wearer. AroundMe and

BlindSquare are navigation applications that work using GPS and audio output on one's mobile phone.

It should be noted that most of the tools used today depend on speech synthesis for information communication, rather than abstract or meaningful non-language sound. However, audio icons and earcons are two examples of meaningful non-speech sounds (see Chapter 2.3), though these frameworks are not used exclusively in an accessibility context.

There have been developments in technology used both in personal devices, as well as features within permanent interactive fixtures such as public kiosks in museums, transportation hubs and ATMs (Automated Teller Machines), for example. Some of the personal technology mentioned above can work in conjunction with the kiosks and fixtures, but often this is not possible. One reason for this is because of the vast array of different types of interfaces that exist in the public realm. There is a distinct lack of a global standard for usable and accessible interface design. Different countries, locations, and companies all use various types of interfaces, which are various ages, as well as maintained to varying degrees. Further, the visually impaired have many options to choose from for personal assistive technology. Because users have different preferences and needs, they use all different types of tools, and therefor there is no guarantee that public interface and personal technology will work together; one is not always compatible with the other.

## 2.2 Existing sound-based communication methods for the visually impaired

There are various ways sound is currently used to help people function in the world. These existing ideas and methods could potentially provide clues as to how sound can be used to communicate meaning. These methods can be broadly divided into speech and non-speech categories.

The differences between speech and non-speech sounds can be found in the origins of our understanding of the meanings they hold. As Kramer (1994, p.1) puts it:

> If the interface medium between user and system is speech, then the display is exploiting a learned repertoire of language and cognitive meaning. If the display medium is non-speech sound, the auditory display will exploit evolutionarily acquired environmental adaptations, including cognitive and preattentive clues.

Speech and non-speech sounds rely on very different sets of human knowledge. One is learned (language), and one uses acquired clues to leverage cognitive intuition (abstract and semi-abstract sounds).

If language for various required system actions and tasks has been assigned clearly and simply, and the user has a high competence in the language being used, speech sounds can be an accurate and easily understandable way to convey meaning. However, as we will see in the analysis of the LA Metro ticketing system, using language to can also be slow and cumbersome. Also, speech sounds require the user to be fluent in the language used. If I spoke no French, and the audio interface was in French and offered no alternate language selection, the systems would offer me little value and prove difficult for me to use successfully.

Both speech and non-speech sounds are easily used in conjunction with other methods of communication without interference of existing tools or skills. For example, if the user is directed to braille markings on the left side of the screen, they can initiate tactile exploration while the audio narration continues, and their button selections register with beeping sounds.

One potential problem with non-speech sounds is that their meaning is implied and depends on the ability to "*exploit evolutionarily acquired environmental adaptations,* *including cognitive and preattentive clues"* (Kramer 1994, p. 1). This can be much less clear than the specific meaning of words that make up a learned language. This is especially true if the non-speech sounds used are not carefully and thoughtfully designed and tested by skilled professional sound designers or similar.

Following, I discuss four distinct ways in which sound is used for accessibility purposes, though these are not necessarily examples from ticketing, touch screen, or public transportation contexts. Distinctions can be made between verbal and non-verbal cues. Use cases vary for each – some situations work better using one over the other. Learnings can be taken from each case.

### 2.2.1 Accessible pedestrian signals (APS)

An Accessible Pedestrian Signa (APS)l is "an integrated device that communicates information about the WALK and DON'T WALK intervals at signalized intersections in non-visual formats (i.e., audible tones and vibrotactile surfaces) to pedestrians who are blind or have low vision." (Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way; Advisory R209 2011).

APS is widely used around the world, helping blind and visually impaired users navigate intersections more safely. They use verbal and/or non-verbal audio cues to differentiate between WALK and DON'T WALK intervals, and have been installed at pedestrian intersections in Japan, Australia, and various European countries for at least 20 years. In the United States, they have been available for at least 25 years, but haven't routinely been installed because of both difficulty agreeing on their effectiveness, as well as noise pollution concerns.

These systems can include various combinations of audio, visual, and tactile data, meaning they can provide information to people with multiple types of impairments. While tools such as canes and assistance animals can be very helpful, there are some tasks that require additional input and information, whether due to high task complexity, high risk of bodily harm, or a combination of both. The audio signal, whether verbal or non-verbal, can effectively convey a large amount of information which otherwise would be difficult to know. It can help users identify where the control button is located, where the crosswalk is and in which direction and how far away the opposite curb is, and at what point in time the WALK interval begins and ends.

Similar to other systems, APS is not a perfect standalone solution to the navigation challenges of the blind and visually impaired. Its usefulness and safety are strengthened when used along with other methods for decision making, such as listening for traffic and road noise, or using a cane to physically detect curbs and/or tactile warning markings on the ground.

APS is a good example of using audio earcons (discussed in Chapter 2.3.1) and speech synthesis to convey critical information to the user. In this case, the limitations of speech-based audio can be seen in language comprehension – if the language of the audio is not understood by the user, the message will not be understood (the "Don't Walk" command at a crossing, for example). However, combined with other audio cues, signals and signs, the chances of comprehension are greatly increased.

### 2.2.2 Bluetooth beacons for wayfinding

Despite the fact that they aren't as widely used at present, beacon technology is one way blind and visually impaired users are facing the challenge of navigation and wayfinding in unfamiliar, mostly urban locations.

Beacons are small physical transmitters, about the size of a hen's egg, which can be mounted in almost any location including on walls, ceilings or, for example, along a train platform. They are independent devices that constantly emit a UUID (Universally Unique Identifier) using Bluetooth 4.0 Low Energy (Cisco 2014). They work by broadcasting information relevant to that location via Bluetooth, which is then picked up by smart phones near the beacon which are running an appropriate application. The app then relays the relevant information to the user through audio, whether that information consists of descriptions, detailed directions, or warnings, so that they can safely find their way to their destination.

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In Strasbourg, France, more than 1,400 beacons have been placed around the city and are now being used by blind and visually impaired users to help them catch the correct bus, while in Wellington, New Zealand, the City Council has deployed 200 beacons in the central business district to assist blind and visually impaired people. The beacons work in conjunction with an app called BlindSquare, which speaks pre-programmed messages providing information such as details about buildings, facilities, products, and nearby streets. The beacon deployment was praised by the city's mayor as "a first for New Zealand" and "will build Wellington's reputation as a smart and accessible destination…(it) will welcome people with visual impairments to participate fully in the life of the city." (Wellington City Council 2016).

Beacon technology has the added potential of being profitable within commercial contexts, as it can be used to deliver advertising or contextual purchasing offers based on location or proximity to various sales points. Therefore, it might be pushed to further development and refinement more actively than some other assistive technologies.

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### 2.2.3 Screen readers for browsing the Internet or using a smart phone

One of the most established and widely used sound based communication methods for blind and visually impaired people are audio screen readers, which I discussed in Chapter 2.2: A brief history of sound in designing for accessibility for the visually impaired. To recap, they consist of a piece of software which is installed on a computer (or in some cases is part of the native operating system) and use speech synthesis to read out text and describe information on a digital screen.

### 2.2.4 Wearable devices

The current wearable space is an interesting one. While there are many solutions being developed using the native, integrated hardware in one's smart phone, there is still a space for autonomous devices that either work independently to, or indeed in combination with one's smart phone. As computers have become smaller, designs have become less cumbersome and easier to use within everyday life. The hardware and technology has also become less expensive, meaning scientists, developers, and researchers have had more opportunity to experiment with various ways to use wearable technology. It has also given the end user more affordable options, though many available wearable accessibility devices are still fairly expensive or even cost prohibitive.

OrCam's MyEye is a wearable device that uses a miniaturized camera to translates visual information to audio, which the user hears through an accompanying earpiece. MyEye runs using Artificial Intelligence and can identify objects via user gestures such as pointing to an object in view of the camera. The software can also memorize the faces of 100 people and 150 things, which the company claims is helpful when scanning a crowd for someone one already knows or searching a room for a particular object. The device costs $3,500 USD (Holton 2017), which unfortunately is a price which makes it too expensive to be a realistic every day assistive option for most people.

The BuzzClip is a wearable device which helps people with vision loss navigate their surroundings at a simpler level. It does this by using ultrasound to detect objects and

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obstacles in one's path. The device is primarily used to detect objects at head height, as these can be missed with a cane or even with a dog. This wearable device consists of a small clip (or clips – a user can wear more than one for multidirectional detection) that can be attached to clothing on various parts of the body. When an object is detected, the device "buzzes" and vibrates, notifying the user via both sonic and tactile feedback to watch out and navigate around whatever is blocking their path. It's a simple yet clever solution that doesn't offer a lot of specificity but might still help prevent someone walking into something and potentially injuring themselves.

### 2.2.5 Software Applications

In addition to physical devices such as beacons and wearables, there have been various applications developed to run on a smart phone which use sound in some way to help blind and visually impaired users. While screen readers might fall under the category of software, I am using the term "application" to specifically describe mobile applications, or "apps" for short. Many of these don't use sound exclusively – most of the time they are paired with use of the phone's hardware such as the camera or speaker in order to do their job.

LookTel is an app that identifies money denominations instantly and in real-time, specifically in places where the bills are the same dimensions and have the same physical qualities. It then speaks the denominations out loud, enabling quick identification of bills. It supports 21 languages, can recognize bills when they are moving, and does not require internet to function.

TapTapSee, Aipoly, and Seeing AI all use a user's phone's native camera hardware to capture an image and identify the object or person in that image, and then speaks it out loud.

BeMyEyes and Aira help blind and visually impaired users take advantage of a network of sighted users as surrogate "eyes". The blind and visually impaired users contact a random sighted user in the app's global network by video call, and then point their camera at what they are trying to identify or need help with. The images are seen by the sighted user and they are able to describe and advise on what the blind person is trying to identify.

BlindSquare is an app which integrates with the popular social location discovery application FourSquare, which uses crowdsourced information which lives in the app's database, as well as the phone's GPS system, to help users navigate as well as figure out what businesses and landmarks are around them. This information is announced out loud to the user using text to speech synthesis.

## 2.3 Earcons and auditory icons

"Sonification" is defined as the use of non-speech audio to represent information (Penn State College of Arts and Architecture 2015). Earcons and auditory icons are both existing sonification concepts in which sound attempts to convey meaning in two different ways. Both are already commonly used in existing ticketing setups to some extent as I have seen in my field research. "Sonification" refers to the fact that these methods involve non-speech audio, as opposed to speech synthesis, where either a text to speech engine dynamically converts written words into speech, or there is simply playback of chunks of recorded speech which is non-dynamic. Both earcons and auditory icons do not involve linguistic speech to convey meaningful information, but attempt to do this via other methods, detailed below.

It should be noted that most of the tools used today depend on speech synthesis for information communication, rather than abstract or meaningful non-language sound. The reason for this might be that the learning curve might be greater for non-speech sound. In the article "Auditory Icons, Earcons, and Speech", Wayne Staab states that the link between the audio signal of a non-speech earcon and the event it signifies must be learned and is "not a natural immediate understanding of the sound intention" (Staab 2014), though the audio

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display can exploit "evolutionarily acquired environmental adaptations, including cognitive and preattentive cues" (Kramer 1994, p. 1). In spite of this required initial effort, the potential return for upfront commitment could be greater communication speeds once one is familiar with the given lexicon.

### 2.3.1 Earcons

The word "earcon" was first used in 1985 by D.A. Sumikawa an article titled "Guidelines for the Integration of Audio Cues into Computer User Interfaces" (Sumikawa 1985). It is quite similar to the word "icon". This is not by chance; it indicates the similarities and parallels which earcons have with traditional graphical visual icons. A graphical icon is a universal, simple and easily recognizable image which is representative of concise information. Blattner, Sumikawa, and Greenberg (1989) define an earcon as "nonverbal audio messages used in the user-computer interface to provide information to the user about some computer object, operation, or interaction." (p.13). Like a graphical icon, they quickly and efficiently present information within a succinct package. This package is a synthesized sound which is usually abstract, and which has little or no relationship to what they are meant to represent. Because of their abstract nature, there is a concerted and necessary learning process involved. Though some earcons are culturally well known (examples: the NBC jingle, sirens on emergency vehicle, etc.) this can be a challenge to someone who is unfamiliar with their meaning, since they don't have any direct connection between sounds and real-life objects or processes. In spite of this, if thoughtfully and skillfully designed, earcons can convey meaning in an abstract way in spite of a lack of knowledge to what a certain sound means.

Most existing sounds in use in the Helsinki ticketing machines, and indeed in ticketing machines in other cities worldwide, can be considered closer to earcons than

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auditory icons. The sounds most often employed are various abstract beeps and chimes which do not relate to real world, literal sounds generated by physical actions.

The most ubiquitous among these earcons may be the beep that accompanies a button push, as was used extensively in the old-style ticketing kiosk machines in Helsinki. Interestingly, this is not the case on the new machines. There is no sound to indicate a successful button push. It could be argued that this feedback is important on touch screen devices not only for blind and visually impaired users, but for all users, as there is not only no audio feedback, but no tactile feedback either, making it more difficult to discern if input has been registered or not.

In fact, the minimal audio feedback currently on the new machines is even less than what the previous machines provided.

### 2.3.2 Auditory Icons

Auditory icons are brief sounds used to indicate an event or action, which carry meaning through a natural association with a real-world action and the resulting sound this action produces (Gaver 1989).

Gaver (1989) was the first person to coin the term "auditory icon". He developed what he called a "Sonic Finder" system for Apple Computers, which used auditory icons to convey meaning. In this system, he used sounds that emulated the process of moving an item over a hard surface and dropping it into a metal receptacle to help users understand and navigate the process of moving a file to the "Trash" folder on a graphical desktop computer operating system.

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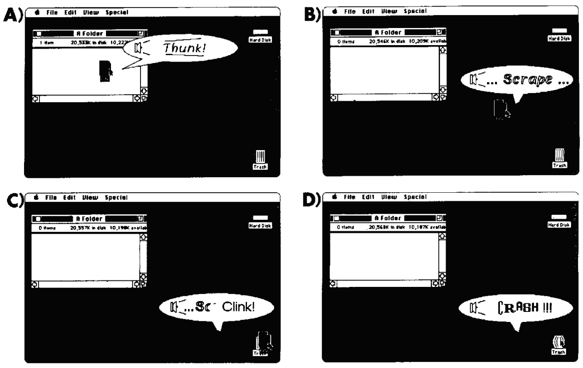


*Figure 2. Deletion of folder in Gaver's (1989) 'Sonic Finder' Graphical User Interface*

Another example could be an auditory icon for the action of depositing a coin into a machine. This “deposit” action could trigger an artificial, pre-recorded, stereotypical sound of a metal coin dropping onto a hard surface, which would then be played back to the user through a speaker in the machine. The idea would be for the sound to be an auditory caricature, perhaps with exaggerated characteristics, which clearly represents the physical concept of a “coin”, and for the user to know that the machine registered the coin because they hear the successfully triggered sound, and also because they naturally associate the sound of a coin dropping with the coin which they just deposited into the machine. The power of the auditory icon lies within this intrinsic association, which is based on previous learned experience. This means that there is a good chance the user will already be familiar with the meaning and will not have to learn it from scratch before using and understanding it. (Houtsma 2003 p.7).

Auditory icons often work in conjunction with visual displays which reinforce the information given. To use the previous example, the action of depositing the coin into the machine and hearing the sound of a coin dropping might work together with a numerical visual display showing the amount of money still needed. Without this visual display, a blind or visually impaired user would be at a disadvantage and would have to keep track of the amount of money deposited. However, they would still be able to use the auditory icon to know that each coin they deposit has been registered by the machine.

# 3 RESEARCH METHODS

## 3.1 Examining auditory interfaces within other public transportation systems

For the purposes of this paper, I examined how sound is used in public transportation ticketing interfaces in New York City, Tokyo, Los Angeles, and London. I chose these four cities because I believed they would give a good overall cross section of data across a varied selection of geography and cultures (Europe, North America, and Asia). I wanted to make sure each city's system I examined had a large, robust and established transportation system. This was so that there would be more likelihood of research being undertaken when the systems were designed, and enough people using the designs over a long enough period of time to ensure they work to a decent standard. I also wanted the chosen systems to be unique in relation to each other, to hopefully see various types of efforts made towards inclusive design, and to examine different methods and effectiveness of using sound to help with each location's unique ticketing journey.

To learn how sound is used in each of the four different ticketing systems, I performed exploratory research using a combination of methods, including both primary and secondary research. I was already quite familiar with the ticketing systems in New York and London due to previously living in both places and using public transportation on a regular basis. I was able to use my previous knowledge, along with the help of videos and reading, to inform some of my research, as going off of memory alone is not reliable enough for the purposes of this paper, especially for small details. I watched many different YouTube videos of instructional walk-throughs for using the machines to purchase and use tickets. All of the cities I chose to examine are large and popular tourist destinations, and there was a good amount of video content to look through. Most of it was aimed at helping tourists learn how to purchase a transportation ticket and navigate public transport. Some videos were made by the companies or municipal bodies that controlled the ticketing machines, so could be considered "official". I didn't have previous knowledge of the Los Angeles metro ticketing system, but as I am currently living there, I was able to easily examine this system first-hand. For Tokyo, I neither had first hand access nor previous experience, and could not examine the systems in person due to the large distances and logistical constraints. Therefor I relied on desk research; I learned about how the ticketing system works in Japan through YouTube videos, articles, blog posts, and posting questions on online message boards at accessible-japan.com (Accessible Japan 2017). All of the cities had official websites for their transportation systems, and each of these had helpful official information and tutorials as well.

### 3.2 Interviews and walkthrough

I performed qualitative research via interviewing four different visually impaired users of the Helsinki Metro. Three of the interviewees were introduced to me through academic connections, while the fourth is the mother of a friend of mine. All interviews were somewhat informal discussions around my topic. Three took place in public places and one at the individual's home. They each lasted about an hour and were loosely guided by a series of questions I had prepared in advance.

I also did an observational walk through with one of these users, Pekka Järvinen*, in order to hopefully identify and highlight specific pain points in the current ticket buying journey which could potentially be mitigated using audio cues. This particular individual has fairly severe loss of vision in both eyes and had no previous experience using the ticketing machines or card readers in the Helsinki Metro. We conducted the walk through at Rautatieasema metro station. I gave him a task and a goal, accompanied him to the location of the machine, and then observed what happened. I took a video recording of the walk through, however Pekka did not wish for it to be included here. Therefor it has not been included in this paper's associated media. I also took written notes.

### 3.3 Current Helsinki system analysis

I was able to do a detailed, first-hand evaluation of the Helsinki system, as well as additional research via current articles, blog posts, and YouTube videos. Through some of these articles, and from talking to colleagues, teachers, and designers, I also learned about general public opinion of the new Helsinki system.

It should be noted that until recently, HSL offered free travel via a special pass to those passengers with a qualifying disability who applied and provided sufficient proof via a doctor's note. The qualifying disability for visual impairment was "Visual disability, very severe (disability category at least 15 = 75 %)" (HSL 2017), but that option has now been removed from the application form. Now the HSL website states that "Visually impaired passengers accompanied by a guide dog or using a white stick do not have to show their Travel Card season tickets to the card reader." This presumably means that these passengers no longer have to apply for the special pass, thus enabling temporary visitors to travel, as well as other users from out of the area for whom it would be unreasonable to expect to go through the application process.

# 4 RESULTS

## 4.1.1 New York City

The New York City subway's public transportation ticketing kiosks were designed by Antenna Agency and deployed in 1999 (Figure 2). They have remained largely unchanged since their initial introduction almost 20 years ago.

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*Figure 3. Antenna Agency's early prototype of the New York City subway ticketing machine. (Masunaga 1999)*

The main kiosk interface consists of a touch screen as well as several slots to input money or cards, plus a keypad and ticket a dispenser. Each section of functionality is grouped by color (Figure 4).


*Figure 4. A New York City subway ticketing machine (NYC ticketing machine n.d.).*

The machine provides no audio feedback when tapping "buttons" on the touch screen interface to input information. However, notably, the machines include an "audio" option as follows: the kiosk has an audio jack, where users can plug their own compatible audio headsets in. They are then verbally "walked" through the process of buying or topping up a ticket, much in the same way as a screen reader would work for a personal computer. The Official Accessibility Guide 2008 published by the Mayor's Office for People with Disabilities says the following:

> Customers with visual impairments may use an audio feature that prompts them through the use of the machine. To activate the audio feature, press 1# on the vending machine (you must use your personal headset, such as those used with tape players, to access the feature). Braille instructions are located at the base of

the screen. (The Mayor's Office of Accessibility for People with Disabilities 2008, p.20)

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The second part of the ticketing system, the barrier, makes the New York City user journey fundamentally different to the journey in Helsinki. The New York system has a barrier, whilst the Helsinki system does not have a barrier at all. Second, there is one flat fare in NYC rather than a zone system, so the issue of working out selection of proper payment for the specific journey to be taken is eliminated. Helsinki, however, does use a zone system, which means that the ticket selection process is more complex. Also, the way the New York City card reader "reads" the user's card and deducts the fare is very different. NYC users must slide the card through a horizontal metal slot located to the right of the barrier, with the magnetic strip facing to the inside. One corner of the card is flat, to help users use touch and sight to orientate the magnetic strip in the correct, readable position (see Figure 5). In Helsinki, a contactless system is used.

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*Figure 5. A MetroCard used on the New York City public transportation system (MetroCard n.d.).*

The system in New York produces one single tone when the user swipes their card (Figure 6). This exact same tone is produced whether the card is read successfully or unsuccessfully, though upon closer inspection, I noticed that an unsuccessful swipe produces two instances of the same tone.  However, they are so close together that it's difficult to hear any separation.  I had never noticed it before.


*Figure 6. A woman swipes a MetroCard at an entrance turnstile (Anandolu Agency via Getty Images)*

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### 4.1.2 Tokyo

While researching Tokyo's metro system and its accessibility for blind people, I came upon the following excerpt:

> When it comes to facilities for the blind, Japan generally has a very advanced system. At subway stations and on many major sidewalks in Tokyo, raised dots and lines on the ground guide blind people through intersections and subway platforms. In some cities, streetlights chime a theme when the signal turns green east-west, and chime another for north-south. Even Japanese yen notes are identified by a slightly raised area in their top corners -- the ¥1,000 note has one circle in a corner, while the ¥10,000 note has two. And finally, many elevators have floors indicated in Braille, and some hotels identify rooms in Braille. (Frommer's 2017).

It is good to hear they accommodate the blind and visually impaired in these ways, but does this extend to using sound, too? Tokyo has one of the most extensive urban railway networks in the world. Over 40 million passengers use 882 interconnected rail stations to get around the city (Bataraga 2017). 282 of these are subway stations, which is what we'll be focusing on as we examine their current ticketing system.

The train lines are run by different companies, each requiring different tickets and possibly requiring transfers between lines with different owners. Also, various ticket types (such as commuter or monthly passes) sometimes need to be purchased on designated machines – depending on the machines offered at the location one is at. The different types of machines are mainly differentiated by their color; most of their other attributes are the same.

Like many interactive public "walk up and use" systems these days, Tokyo's ticketing kiosks present a mixture of both touch screen and tactile interaction (Figure 7). However, they also have large amounts of text in multiple languages and characters, plus various keypads, buttons, and currency and card inputs and outputs.


*Figure 7. A ticket machine in a Tokyo metro station (okapianda.hatenablog.com 2013)*

The fare system in Tokyo is also relatively complex, though this is an issue most users are able to mitigate by using the yellow “fare adjustment” machines (Figure 8).


*Figure 8. A fare adjustment machine in a Tokyo metro station (Tokyo Metro, Year unknown).*

The Tokyo ticketing kiosks often have a speech mode (some with English [Figure 9] though most of the time only in Japanese), as well as a call button on every machine which will connect the user to a member of staff over the unit’s intercom (though again, the staff members do not always speak a language the user understands).

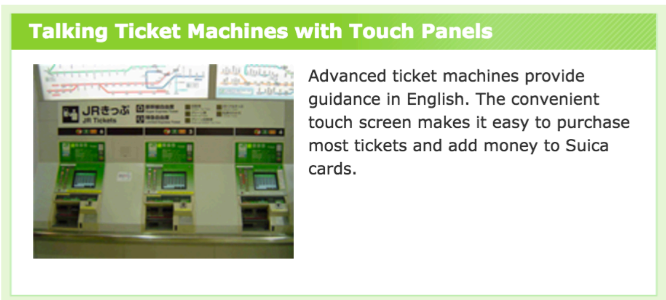


*Figure 9. A screen grab from East Japan Railway Company’s accessibility page on their website at <http://www.jreast.co.jp/e/customer_support/accessibility.html>*

Users must tap in and out with their cards (if using a card), or if using a paper ticket, at the beginning of their journey they must feed the paper ticket into the barrier while making sure to retrieve it.

*Figure 10. Turnstiles and tactile floor markings in a Tokyo metro station (The Expat's Guide to Japan 2016).*

This is because they must also feed the ticket into the barrier when exiting to enable the exit barrier to open and let them out of the system.

*Figure 11. Looking backwards towards the entrance turnstiles in a Tokyo metro station (Japanamal, Year unknown).*


*Figure 12. Ticket slot at entrance turnstile in a Tokyo metro station (Japanamal, Year unknown).*

One option which the main card vendors offer is a “sound effect” service. The service lets the user know when it is time to top up the value on their card. When it is activated, the user’s card will make a different sound when going through the barriers, depending on the amount of money left on it. If there is less than ¥1000 on the card, the gate will beep three times (instead of the usual two) to let you know it is time to charge. If you have a commuter pass, when there are fewer than 15 days remaining, the gate will beep twice (instead of once) so you don’t forget to renew. This service must be activated by asking ticket staff at a station and requesting *onsei annai* (音声案内, literally translated as “Sound of the case”) (The Expat's Guide to Japan, 2016).

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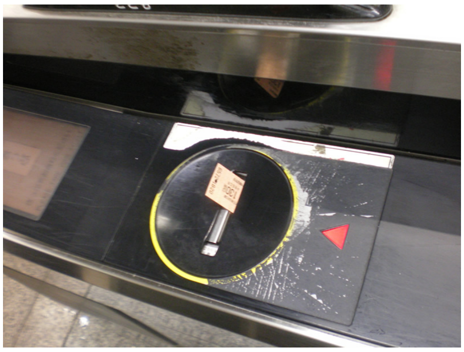

*Figure 13. Users must remember to retrieve their paper ticket before moving off from the entrance barrier gate, as they will need it to exit on the other end of their journey. (Japanamal, Year unknown).*

Some stations have audio and tactile maps for navigation around the station area (Figure 14).

*Figure 14. A tactile map in a Tokyo metro station http://www.transportforall.org.uk/about/blog/access-to-transport-in-tokyo*

One interesting use of sound on the Tokyo metro is that once a user has successfully purchased and validated a ticket and is on the train, the arrival at particular stations is announced with jingles unique to each location (King 2018). In this way, for regular commuters it is easy to hear when to get off the train.

### 4.1.3 Los Angeles

Similar to the New York transit system, the Los Angeles Metro uses flat fares, so no need for the user to calculate how much to pay. The Transit Access Pass (TAP) card is a form of electronic ticketing used on most public transport services within Los Angeles County, California, and also in many systems around the world (including in Helsinki). This reusable plastic card is required to ride the metro and can be loaded with time or value using cash or payment card. It is purchased and reloaded using the TAP vending machine “walk up and use” style kiosks.

The kiosks provide audio information, as well as information in braille about some of the labels and buttons on the machine (Metro Los Angeles 2016). At the moment, they do not utilize touch screens.

*Figure 15. A ticket machine at a Los Angeles metro station (Jones 2018).*

All interactive buttons on the machine are mechanical and tactile. The tactile information specifies which button is which using letters, however they do not include tactile information to specify their actual functions, as all of their functions are assigned on screen and can change dynamically from screen to screen (Figure 16).

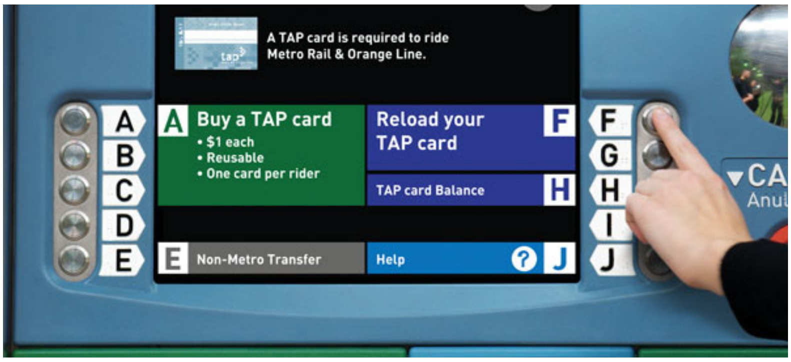


*Figure 16. Close up of interface on a Los Angeles metro ticket machine (LA Metro 2017).*

The standard audio feedback on this machine is triggered when a user presses any of the mechanical buttons. It is a uniform "beep" sound at a neutral tone which is the same sound as the default "ding" sound on the Microsoft Windows 95 operating system. This is most likely because the software that the kiosks run is built on top of this operating system. This "ding" denotes a successful system registration of a "button push". While there is this audio indication of a successfully registered button push, there is no further information within this audio feedback (correct/valid or incorrect/invalid action). Also, there is a point when the user is required to touch the TAP card to the reader. There is a visual indication whether this is successful or not (a red or green light on the reader pad), but no audio indication that the card was registered or not registered.

There is an "audio" button on the kiosk, which offers an alternative audio experience for using the machine. It features an initial narration of the kiosk's features and their locations and uses the tactile number keypad for input (Figure 17). I talk more about this narration process in Chapter 5.1.


*Figure 17. PIN pad on a Los Angeles metro ticket machine (Jones 2018).*

Once users have loaded value or time onto their reusable TAP card, they only have to touch in with their card at the entry barriers, and if transferring between lines or onto buses, touch the special transfer reader with their card. If the TAP card is not valid for travel, when the user touches in the barrier will emit two high pitched beeps and will not unlock when one tries to walk through the turnstile. Otherwise, it will emit one neutral beep and the turnstile will swing freely when one pushes through it, admitting entrance. Users do not have to touch out when exiting.

### 4.1.4 London

London's Underground system is extensive and complex, though perhaps not as complex as the systems in Japan or New York City. Every day in London 1.3 million journeys are made by disabled people (London Assembly, 2016, p. 6). Approximately 175,000 Londoners currently live with sight loss. (Royal National Institute of Blind People 2017).

The London Underground operates using a zoned fare system which dictates how much a journey will cost. There are also different fares depending if one travels during peak or off-peak hours. However, the user does not have to worry about how much to pay when using a reusable Oyster card (similar to other systems' reusable cards), as the correct fare is automatically calculated and deducted. This is because users are required to touch both in and out when they begin and end their journey on the Underground, so the exact time and location of both the beginning and end of the journey can be identified, and the correct fare deducted at the end of the journey upon touching out (Figure 18).


*Figure 18. Entrance turnstile in a London Tube station (Time Out London 2014).*

The ticketing kiosks on the London Underground are similar to other kiosks we have discussed in that the machine's interface is mainly touchscreen-based, meaning there is an absence of tactile input buttons for main functionality (Figure 18).


*Figure 19. Ticket machine in a London Underground station (Chronicled 2015).*

The kiosk does not offer an audio option, though there is sometimes a help button within the visual touch interface; this depends on the machine and version of software it is running.

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## 4.2 Helsinki

In this section I take a close look at how the Helsinki system currently functions, both regarding the physical kiosk and the ticket reader, and interactions with hardware which are required in order to navigate through the complete ticketing journey.

### 4.2.1 How the Helsinki ticketing system works

The Helsinki ticketing kiosks have been around for years and are now in the process of being replaced. On HSL's website, they state that "The current Travel Card system needs to be renewed as the life cycle of this kind of systems is at most 10-15 years. As it is getting difficult to get spare parts and components for the current system, the system can no longer be maintained." (Helsinki Transport Authority 2017). This replacement of the physical and mechanical ticketing infrastructure has provided HSL with an opportunity to renew how the system actually works as well. The new card readers look and function completely differently from the old ones they have replaced. In addition, there have been significant changes to the user flow and required interaction sequence.

In order to use the Helsinki metro, one must somewhat understand both the ticketing logic as well as how to use the physical ticketing machines. Fares vary depending on your journey distance and ticket type, and the fare calculation requires an understanding of how the fare system works, familiarity with or the ability to reference information about zone areas and borders, and how to use the HSL machines. In the current setup, the majority of this necessary information is primarily conveyed through on-screen, visual means, putting blind users or users with visual impairments at a significant disadvantage.

**The logic**

There are several things the user must do in order to successfully purchase and use a ticket for the metro. Users must first locate a ticketing kiosk. Next, they must decide what their goal is out of the available options. This information is normally communicated visually on screen. The user can complete one of four main tasks at the kiosk: 1) Purchase a paper single or day ticket (good for one to seven days) 2) Top up time on an existing travel card 3) Top up value on an existing travel card or 4) Check the status of existing travel card.

If purchasing a ticket, it can be time or value based, and may cover single or multiple fare zones. The simplest scenario is when one is travelling on a pre-paid time-based season ticket on a reusable plastic travel card within the allowed zone, as one does not technically need to interact with the machines at all. With this type of ticket, a passenger may board the train freely but must present a valid travel card or ticket to fare inspectors when requested to do so.

If the ticket type is a single use paper ticket, the only interaction is at the ticketing kiosk, where the ticket must be purchased shortly before travel. There is no need to interact at the card reader if using a paper ticket.

Using a value ticket stored on a reusable plastic travel card is more complicated. In this case, some might say the system is potentially less user friendly than other systems, because value fares are not automatically calculated by the system (unless one is using a season ticket within the allowable zone[s]). Rather, the onus is on the user to calculate and pay the correct value fare or risk getting a fine. The user must first purchase the ticket at the ticket kiosk or from an HSL service point. Then at the time of use, once at the card reader, one must select the correct ticket type from a list (which requires knowledge of the journey's zone details), then select the number of tickets to purchase, and then validate the ticket on the card reader's validation point. There is never any requirement to touch out upon exiting the journey, regardless of the type of ticket used.


*Figure 20. A new style Helsinki ticketing kiosk and card reader (HSL 2017).*

**The Machines**

Users interact with two separate machines (Figure 20) which work together, but which are used at two different stages of the journey. Tickets are purchased at the larger **ticketing kiosk**, where the user can add value or time to a reusable travel card or purchase a single or day paper ticket. The smaller **card reader** is in a different location from the ticketing kiosk, usually at the entrance to the platform. This card reader is where, if using a value ticket (arvolippu) on a reusable travel card, the appropriate fare is selected**.** The user must choose the correct options on the screen (on the new style card readers), and then validate the card below on the machine's validation point, so that the correct fare is then deducted. If using a time-based season ticket (kausilippu) stored on a travel card, the user does not have to validate their card on the card reader, which makes this option much simpler as it completely eliminates the physical interaction with the second machine.

HSL ticketing kiosks are located in metro stations, tram platforms, and other key locations around Helsinki. The card readers are present on buses, inside of trams, and at the entrance to ferries and the metro system, but the location of the card reader depends on what mode of transportation is being taken, whether that is the metro, bus, tram, or ferry.

In the next few years all of the old ticketing kiosks where you buy your tickets, and the readers where your fare is deducted, will been replaced with new kiosk machines and card readers, both with new interface designs which have implications for low or no vision users (Figure 21).


*Figure 21. New (left) and old (right) style ticketing kiosks in Helsinki, found at Kalasaatama metro station at the time of writing in April 2017 (Jones 2017).*

The old-style ticketing kiosks have tactile buttons and many different slots and hardware pieces (Figure 22).


*Figure 22. Old style Helsinki ticket machine with tactile buttons (ЭКОНОМНЫЙ ПУТЕШЕСТВЕННИК (Russian; English translation: The Economic Traveler 2013).*

The new kiosks use touch screens for the main user interface, and the tactile buttons have been removed. There are no braille markings or tactile ridges for touch purposes, which means that there is little useful information that visually impaired and blind users can understand to help the, with the purchase process. Also, given the screen-based interface buttons and other elements are dynamic, there is no way to use memory to remember where particular functions are, as they are not constant like physical elements are.

However, one of the most baffling pieces to this puzzle is the fact that the new machines actually come with built in functionality to help blind and visually impaired users. The manufacturer’s website states that this style of ticketing kiosk features “Multilingual Audio assistance with dynamic voice synthesis” (Parkeon 2018). Some of the machine’s features include the ability to: “Clearly advise passengers with colored pictograms, visual indicators, buzzer and audio assistance for visually-impaired travelers (status of validation, information regarding smart card validity, season ticket status, balance, list of contracts, recent transactions).” (Parkeon 2018). With these features readily available at the flip of a switch, I wonder why they have not been put into use yet.

### 4.3 Interviews

I interviewed four Finnish adults who are visually impaired and who all use the Helsinki Metro. I wanted to get an idea of their experiences of and feelings about the metro’s ticketing system. I hoped to uncover insights and points of view I hadn’t thought about myself, as well as possibly validate or challenge my previous ideas or things I had learned around my topic. I am not visually impaired, and it is impossible to truly put myself into a visually impaired person’s shoes, so to speak. I try to practice user centered design and believe that talking directly to the people one is trying to design for is crucial. The insights they provide are very important in order for the resulting design to successfully fulfil its purposes.

By choosing to interview four different blind and visually impaired users of Helsinki’s public transportation system, additional challenges were brought to light which hadn’t previously been considerations for this thesis. While many are outside the scope of this paper’s research, they are worth noting nonetheless. Furthermore, various personal methods of using technology for navigation and everyday task completion were discussed and demonstrated, several utilizing sound as the main medium for communication. These technologies are notable in their potential to assist users with behavior which might otherwise be inconvenient or impossible, such as using the mobile Internet or wayfinding.

The conversations I had during my user interviews gave me new insights into ideas and experiences. The user interviews highlight certain problems that currently exist and the questions and solutions I should be looking at from a real-world perspective.

### 4.3.1 Mikko Herranen – Musician and visually impaired HSL user

Mikko Herranen is a Finnish musician living in Helsinki. He is visually impaired and uses public transportation as well as taxis to get around the city. We talked about the tools and methods he uses to facilitate these actions, and the things he thinks could be done better within the transportation system. HSL lets people with certain degrees of impairments apply and register to ride for free (this is discussed later in Chapter 6.2). Mikko does not have to pay for a ticket due to the degree of his visual impairment. Therefore, we didn't speak too much about the ticketing system, but discussed the broader insights he offered which point to certain methods that could be helpful in purchasing and using a metro ticket.

Commented [AJ57]: remember to explain this for the reader too. Why does he not have to pay for the ticket?

The first thing I asked him was about how audio plays a part in his day to day navigation of the city. He replied that "The main tool for us blind people today is iPhone…it's not "phone", but it's…precisely iPhone. It's iPhone because there is lots of apps for iPhone which have been done [created] for the blind,". He acknowledged that there were apps developed for other mobile platforms too, but in his opinion, there are not as many, and they do not work as well. Apple's phone comes with the speech synthesis program Voice Over integrated as standard, and Mikko says that this built-in software in particular is very helpful and works well for his needs.

Mikko also mentioned an application I profiled earlier in this paper called BlindSquare. He said that BlindSquare helps provide the information he needs to navigate the city. BlindSquare "describes the environment, announces points of interest and street intersections as you travel" and is "self-voicing, announcing points of interest, intersections and user-defined points through a dedicated speech synthesizer." (BlindSquare 2017). Speech synthesis is actually a theme throughout our conversation about audio solutions for blind and visually impaired people. Almost every tool or idea for improvement we discuss uses some sort of speech synthesis to convey information. He says that one very helpful thing would be to have bus stops which announce what bus is arriving. Another would be to have stops announced on the buses. Yet another suggestion would be if eastbound metro trains announced the terminus, so that one would know whether the train will be travelling the Mellunmäki or Vuosaari branch. Again, none of these suggestions deal directly with the ticketing system I am examining; however, they do show that in Mikko's case, audio communication through speech could be a clear and effective way to communicate critical information.

### 4.3.2 Pirjo Koivusalo – Visually impaired HSL user

Pirjo has macular degeneration, which is a degenerative eye disease. She currently has limited vision, though this will progressively degrade over time. She told me that she mostly uses the bus in Tampere, and then, mostly only routes that she is very familiar with and travels often. Though this is not the same system as the Helsinki Metro, she still must purchase tickets and/or top up her travel pass. She said that confirmation beeps are important to her understanding of what is going on during the payment process. However, overall she finds self service solutions challenging, and mostly tries to deal with a real person when making transactions regarding transportation tickets.

Similar to Mikko, Pirjo mentioned that audio speech announcements would be very helpful, both at bus stops to indicate what bus is arriving and in how many minutes, and also on busses to indicate the upcoming stop. At the moment, she must make sure that there are other people around to ask for this information. Sometimes she will sit next to the bus driver after requesting that they let her know when her stop is. This method works sometimes, but not always – there are times the bus driver forgets.

Also, interestingly, Pirjo said that she prefers to take in information by reading (using assistive tools including a magnifying glass or a monocular) rather than listening. Of course, not everyone in the user group relevant to this paper has enough sight to read visually, but the same point could apply to reading braille as well.

It is also clear that her choice of tools is tailored to her individual needs and preferences and reflects a possible preference for mostly non-digital solutions. She is a user with some vision, who uses analogue tools. Both of the other two visually impaired individuals I spoke to use a white cane, but do not generally use analogue magnifying tools.

### 4.3.3 Pekka Järvinen* – Usability expert

Pekka is an accessibility expert living and working in Helsinki. He is also visually impaired himself, so he is in a unique position to give feedback on accessibility and usability issues. He feels strongly that experiences should be designed to be not only accessible, but also useable – that is, they should not only be possible for people to use, but using them should also be "pleasant, efficient, and effective" for everyone.

Like Mikko, Pekka is a keen user of Apple's VoiceOver software, and finds it very helpful in browsing the web or using his mobile phone, but he had an interesting opinion on using audio for communication means. He told me that many people he's talked to who are blind and visually impaired "think of themselves as more visual than auditory…that's why they, for example, like to use a braille display…if you're on a website or doing something that needs accuracy, for example, paying your bills…they want to use a braille display because they want to "see" what's happening there." Pekka says that a lot of people would rather have a tactile experience. He also mentioned privacy concerns with audio solutions. We spoke about the possibility of using an audio jack along with a speech synthesis system, such as some ATMs use. We also discussed Bluetooth iBeacons, and specifically their implementation in the Itakeskus shopping center. iBeacons are used in conjunction with other things like tactile floor markings, as well as ambient sound. Pekka says the beacon technology is not yet accurate enough to be considered truly usable (against his metrics of "pleasant, efficient, and effective").

The main takeaways from my conversation with Pekka were that any solution for the ticketing system should be as usable as possible, that not everyone prefers the same solution to get something accomplished, and most interestingly, that most blind and visually impaired people he has talked to prefer "seeing" via braille over audio information.

Pekka and I met a second time, where we did a walk-through review of one of the old-style ticketing machines. Pekka's task was to top up his travel card. In spite of characteristics such as certain areas of high screen contrast, and him being able to tell where the travel card goes since the color and size of the card matches the color and size of the target area on the machine, he was ultimately unable to successfully complete the full task, as there was simply not enough information available to him as a visually impaired user.

### 4.3.4 Timo Jokela – Usability and UX professional

Timo Jokela is a sighted usability and UX professional currently working in Helsinki. He has examined the new HSL ticketing system and believes there is more work to be done to make it truly usable for both able bodied users and those with disabilities.

Timo and I discussed a bit about the planning and design stages of the system. He believes that usability was not specifically required by HSL, in this case. The new interface was generally not received well by the public. Some of this can be attributed to change bias, but some can be traced to the lack of usability designed into the system. This was in part due to what he believes was a lack of concrete usability requirements in the design contracts.

Our conversation brought up interesting questions such as who is responsible for making sure a system is usable and accessible, what roles do outside contractors play in this issue, and at what stage in the design process should these issues be considered. Also, what happens when the system ends up being inaccessible for certain groups? These questions are important, but outside the scope of this paper's focus on using sound to address accessibility for blind and visually impaired users.

## 5 ANALYSIS

In this chapter I discuss the findings from my research relating to the four cities I examined, as well as what I discovered investigating Helsinki's own system, and the findings from both speaking to stakeholders and undertaking observational analysis.

### 5.1 Auditory interfaces in other cities' ticketing machines.

There were certain audio-based methods I saw used in multiple cities. These included the use of speech synthesis through a dedicated headphone jack, audio feedback in the form of simple beeps when information was inputted into the machines via user interaction (or when a travel card was read by the machine), and options to call for assistance via a button and two-way audio speaker.

Overall, speech synthesis seems to be a popular and effective option. In New York City, where users have this option to guide them through the process of purchasing a ticket, one drawback is that the user must have additional hardware (compatible headphones or headset) to use this feature. In Los Angeles, a similar speech synthesis feature is offered, however there is also the possibility of using the built-in speakers if one does not have headphones or does not choose to use them. Tokyo is the only city on the list that offers a function to call a real person for assistance directly from the kiosk. Not only can the user call for assistance, but he or she can converse with the person via two-way audio.  I can see how users of this feature might potentially face some challenges, for example audio quality or background noise in a metro station might make it difficult to hear. There also might be possible language barriers. Then again, it might offer valuable and effective help to many people as well.  All cities on the list supplement audio elements with braille markings except for London, offering braille information makes sense to provide a recognizable entry point to the respective audio experience.

**New York**

The New York City is the 8$^{th}$ most populous city in the world with a population of 8,550,405 as of 2015 (NYC.gov 2015). Accordingly, it has one of the most complex and extensive public transportation systems in the world.

In New York, it was interesting to learn that there is no audio feedback when users input information into the machine's touch screen interface, which is where the bulk of interaction takes place. The only audible feedback seems to be when the tactile buttons on the number keypad (including the "enter" button) are pushed. Perhaps this is done because entering one's personal PIN in order to pay is seen as a critical step for the subway system to receive payment, even if the user has purchased the wrong ticket. This sounds like quite a cynical and perhaps farfetched theory, however it is still a possibility, even if implemented subconsciously by the designers. Perhaps there is a tendency to view entering payment information as higher up on the hierarchy of importance, given there is generally a heightened concern for security during this part of the transaction. While adding audio feedback for touch screen "button" interaction would not be enough to make the screens accessible to fully blind users, in the case of low vision or partially sighted users, at the very least a beep or click could be useful in confirming that their input tap was registered by the machine. Further, even with fully sighted users, this could be a useful feature to let one know input has been registered. Possible reasons why this feature has not been included could be that the beeps or clicks could be disruptive to others in the vicinity (thought this seems unlikely, given the noisy audio situation from the gates), or that it would confuse users on adjacent machines, as they might think the confirmation sounds from another machine are coming from their own machine, thereby rendering the feedback unhelpful and even confusing.

Neither New York City Subway's touch screen interface nor London's touch screen interface interactions utilize audio, other than, as mentioned above, in the form of beeps when the tactile number keypad is engaged (for instance, to enter one's PIN for a payment card). In Tokyo, the touch screens do give audio feedback, in the form of a single loud beep. In Los Angeles where the ticket machines do not use touch screens, the tactile selection buttons also give audio feedback in the form of a single loud beep when they are activated.

Regarding the speech synthesis walkthrough feature which uses the machine's tactile number keypad and requires headphones; this solution could potentially work well, however the major drawback is that the user must have their own external equipment in the form of compatible headphones. In other words, the user must have knowledge of the requirements beforehand. Even though there is braille to identify various components of the kiosk, without a pair of compatible headphones, blind and visually impaired users would still be unable to use these machines independently, as they would not be able to navigate through the on-screen journey to complete the desired ticket purchase.

Also, regarding contactless payment versus sliding a card through a horizontal slot at the barrier, it is easy to see which one is more straightforward to use. Despite the fact that in New York, one corner of the payment card is "cut off" so one can use touch to figure out if it is in the right position, this action still requires much more time, effort, agile precision, and skill than Helsinki's contactless touch system does, as the contactless system requires much less accuracy of gesture and placement.

As we are focusing on audio, let us examine the tone that is used when one slides the card through the reader slot. It is the same tone regardless of if the swipe has been registered or not, though an unsuccessful swipe sounds two tones, rather than one. However, the two tones are so close together that it is quite difficult to notice the difference at all. This similarity in tone is unhelpful for blind and visually impaired users, as very little differentiating information is carried by the sound playback. This is also a missed opportunity to use the existing audio to communicate clear, helpful information which could be imparted by carefully designing the triggered sound. For example, the tone could be lower and/or shorter when the card is swiped unsuccessfully (a "card not read" tone), and a higher pitched, gentler and more flowing series of tones stepping upwards on the musical scale to represent a successful swipe (a "card read, you can proceed through the turnstile" tone). The sound, perhaps made up of multiple tones in different pitches (or even the same pitch as it is now) could also have very clear separation and rhythm in between tones.

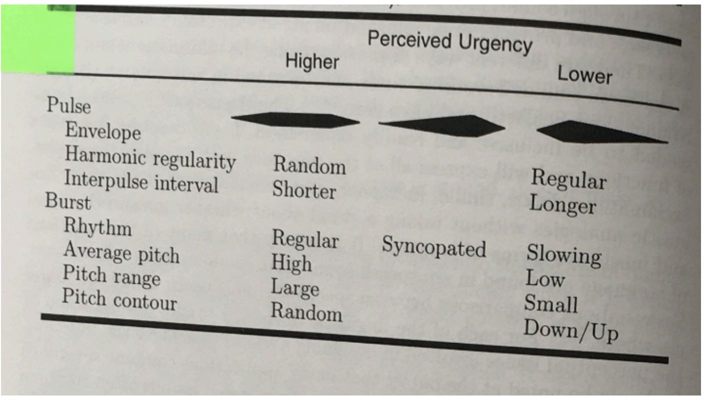
> **Commented [AJ58]:** Karoliina: or something entirely different? if the difference is in only in the length and pitch of the sounds, a lone user will find it hard to remember the absolute pitch of a single note. the human ear is better at comparing relative pitches (or lengths) than remembering absolute values. Of course, the difference is obvious in case there are many people entering the subway at the same time – which might always be the case in NY anyway. Just a thought.


*Figure 23. A potential successful swipe sound (Jones 2018).*


*Figure 24. A potential unsuccessful swipe sound (Jones 2018).*

One can see the repercussions having the same sounding tone for a successful and unsuccessful swipe has on sighted users: many people will try to walk through the turnstile barriers, expecting the turnstile arm to swing freely. However, they will be stopped abruptly by the metal arm of the barrier when it holds fast due to an unsuccessful swipe. This problem is compounded for users with sight issues, as this "walking forward" action is the only sure way to discover whether the swipe was successful or not, due to the poorly designed sound cues and general lack of common knowledge about what they mean.

There could also be a separate sound for other system statuses, for example, if there is insufficient value on a card which is being used for a value trip. Of course, if we are considering non-verbal cues (which could be beneficial for cross-language communication), the matter of quickly learning, or even already intrinsically knowing what the various sounds mean is crucial. It would be beneficial to examine what kinds of sounds naturally invoke what emotions and implications. Engineering and designing the nuances and connotations of the sounds would most likely benefit from input from a professional sound designer, and from resources such as Kramer's Table of Perceived Urgency (1994):



| | Perceived Urgency | | |
|---|---|---|---|
| | Higher | | Lower |
| Pulse | | | |
| Envelope | | | |
| Harmonic regularity | Random | | Regular |
| Interpulse interval | Shorter | | Longer |
| Burst | | | |
| Rhythm | Regular | Syncopated | Slowing |
| Average pitch | High | | Low |
| Pitch range | Large | | Small |
| Pitch contour | Random | | Down/Up |

*Figure 25. Table of Perceived Urgency, (Kramer 1994, p.82)*

**Tokyo**

In spite of Tokyo's advanced facilities for blind users, right away it is apparent that there are still some things working against metro riders in this city. First off is the fact that the many different types of ticket machines can only be differentiated by their color; the machines other attributes are the same. Beyond being confusing for able bodied users, this obviously could be even more of a problem for someone who cannot see well, or even someone who is simply color blind.

Also, despite the fact that the Tokyo metro is known for being fairly accessible, at first glance these kiosk interfaces can seem more complex that many others due to the multiple languages, fonts, symbols and types of buttons and knobs which make up the interface.

Fare adjustment machines: The very fact that these machines exist is a testament to the complexity of the fare system and the frequency at which users are unable to calculate the correct fare for their journeys. Rather than addressing the larger task of simplifying the system as a whole, they have decided to put a sticking plaster on the issue, further complicating the original problem. And for blind and visually impaired users, figuring out how to use an additional machine is one more significant challenge to overcome.

Another potential issue is that users must tap in and out with their cards This means there are more required steps than in other transport systems (though Tokyo's is also more secure against fare evasion).

One interesting option is a "sound effect" service. The service lets the user know when it's time to top up the value on their card. This provides a quick and useful audio cue for all users, but is especially helpful for blind people or people with vision issues who might not be able to read the small digital display on the barrier which indicate how much money is remaining on the card. This sonic device is used in New York as well, but there it is implemented so poorly that it is all but useless. The clarity of the separation of the tones is lacking so much that it is difficult to hear the difference between positive and negative feedback. Further, even if the clarity was improved, few people are aware of the meaning of the tones. In Tokyo it is an "opt-in" service, which indicates that if one has consciously selected to use it, one most likely is aware of its meaning.

**Commented [AJ59]:** Karoliina: in the final version, make sure that the pictures are not following each other as there should be text in between. the other option is to make one photo collage and combine that as one picture. Two pictures side by side is still ok.

**Los Angeles**

One unique thing about the LA Metro kiosks compared to the other systems I have profiled in this paper is the fact that they do not utilize touch screens.

Regarding the audio navigation option that is offered to users: while in theory this feature is commendable for the effort the designers have made (many other systems do not offer any audio navigation option at all), and for the fact that the method does not require the user to have headphones in their possession to use it as in New York City, in practice the Los Angeles Metro's implementation is rather clunky and difficult to use. This is a good example of a system being accessible but not usable, as discussed in my interview with Pekka Järvinen* in Chapter 4.3.3. For example, there is an option to increase or decrease the volume of the audio, which is useful as the subway environment is often noisy. However, the feature is poorly implemented as it does nothing to indicate the range of the volume choices, or where the user is currently in that range. Further, when one reaches the loudest level (which is impossible to know), pressing the relevant button again takes the user back to the quietest option, at which point they must move through all of the volume levels once again. If one would like to set the loudest option, it is rather hit-or-miss. One must use the keypad to incrementally increase or decrease the volume. Once maximum volume is reached, it cycles back to the quietest option and again starts to increase; there is no way to know where you are on the audio's scale of loudness other than the volume relative to the last tone one has heard.

The other problem with the audio option is that it takes more than four minutes to get through a complete instance of the interface description alone, before reaching any options for actions. There is not a clear way to skip this, and that time does not include making any actual transactions using the audio mode. Realistically, one might not have that much time to spend on a ticketing transaction if they are trying to get somewhere or catch a train. They also might feel pressured if there are people waiting to use the machine behind them (this is very likely, unless they are travelling late at night or very early in the morning). The other problem is security and privacy, given that with most transactions one would be using some form of payment method, whether that is cash or card. Using the audio mode, anyone in the area can hear the transaction that is being completed, potentially putting the user at risk. There is an option to use headphones, and also to turn the screen off for increased privacy while in audio mode, but this does not help people who might not have come prepared with headphones, and who must use the built-in speakers on the machine.

**London**

London's ticketing system uses some audio, but as with other systems, it seems that the sound element was not particularly thoughtfully designed. Most of the audio feedback is not utilized to its maximum potential through things like tone, volume, and even sentiment. However, the basic audio is at least a step up from the new HSL ticketing machines, which do not provide any audio feedback when interacting with the screen. The caveat here is that not all London ticketing machines use the same interface; some are silent and do not give audio feedback for touch screen interactions at all.

One thing I found strange about the ticketing machines in London, was the lack of braille markings on the machines. While braille is not itself audio related, it can serve as an important starting point into an audio experience. Take, for example, the speech synthesis narration I discussed at the beginning of this section. Having audio narration is well and good, but if there is no way to figure out that this exists (through, for example, a notice on the machine in braille), then the feature isn't very helpful. I emailed the machine manufacturers at Protouch Solutions about this and they replied that their designs comply with ADA regulations, but did not directly respond to my questions regarding the lack of braille on the machines.

The fact that as in NYC, users do not have to manually calculate a value fare due to touching in upon entering and touching out upon exiting is also interesting. This means that a huge cognitive load is taken off not just visually impaired and blind passengers, but everyone who uses the system. Again, this point is not directly related to audio communication, but it does greatly simplify any audio communication that must be had because the payment system is made much less complex. A simpler system means simpler communication requirements all around.

Similar to other cities, the sound design in London uses flat beeps to indicate an interaction has been registered at the ticketing machine. As in other locations, they could take the opportunity to more finely tune the audio cues and sounds to more specific meanings. In New York, at the barriers two beeps mean a barrier ticket swipe was unsuccessful, yet due to poor sound design and no communication explaining this to users, its meaning, and therefore its value, is lost. However, in London, a similar system is in place when using a ticket at the gate: if a ticket swipe (or "touch" in London's case) is not valid, the barrier emits three distinct, quick beeps of the same tone which are a clear, sonic indication of the card failing to register. If the registration is successful, there is one beep.

## 5.2 Problems with the new Helsinki system for the visually impaired

Before talking about the user interface, I would like to touch upon overarching and significant changes that have been made to the user flow and required interaction sequence. HSL's decision to reverse the order of actions required to validate a ticket or pay a fare has resulted in a great amount of frustration and confusion by users (Jämsen 2016). They have failed to adhere to the principle of consistency, and this has resulted in unnecessary friction when trying to use the system. As much as it affects able bodied users, it will affect non able-bodied users even more so.

The new machines have also done away with tactile buttons, instead opting for touch screen technology. The reasoning for these changes, according to the HSL website, is that "the new system and card readers will be more flexible in terms of adding new fare zones," and that "it will be easier to expand the Travel Card validity area to new municipalities", (HSL 2017).

These are valid reasons to change the current system to something more suitable to the current and future needs of HSL. However, if we look more closely, we see that perhaps these advantages in flexibility and the way HSL has decided to implement these changes is coming at a higher cost to certain users of public transportation, including blind and visually impaired users.

In order to have an efficient system, one has to first look at the overall user flow and make sure it is organized in the optimal way as this will have an impact on the efficacy of more granular design systems within the flow, such as the user interface which this paper focuses on. Like many devices these days, the main interface on the new HSL machines is based around a touch screen. While they are usable to many people and flexible for designers, touch screens present a challenge for blind and visually impaired people due to their lack of tactile feedback. A smooth field of glass does not provide useful information. Audio can be a good alternative way to convey information, but the audio feedback in the current system is minimal.

**Ticketing kiosks, card readers, and sound design**

In the context of blind and visually impaired users, the old-style ticketing kiosks have a few things going for them over the new ones. The old kiosks use tactile buttons to select and navigate through the screens, and they also use an audible short tone whenever a button is pressed and registered to the system. This audible tone is always the same – there is no positive or negative audio feedback; it is neutral, and simply lets the user know that their button press has been registered. This is the only sound cue that the machine provides during the process.

**Video of old style ticket machine interaction audio feedback. (Den S 2013). <https://www.youtube.com/watch?v=pYFdcsfRjR4>.**

This machine provides minimal audio feedback to the user; there is scope to do much more with the medium of sound in order to make the process easier to understand.

Touch screens have become ubiquitous in everyday life for most people. From smart phones to public kiosks to televisions, they can be found in all kinds of places. Product designers like them because they enable a flexible interface with infinite possibilities of presentation and design, without having to rely on external controllers such as a mouse or tactile buttons that are static and cannot be changed. Organizations like them because the information they present can be changed and updated as needed, and this can be done relatively quickly and inexpensively. While touch screens have simplified life for many stakeholders, eliminating hardware and enabling direct interaction with content, some user groups are missing out. Where the mainstream user group might benefit, other minority user groups are put at a great disadvantage. For blind and visually impaired users of systems that require input and interaction, using touch interfaces can be particularly challenging. When this is also in a new or unfamiliar setting and context for these users, the challenge becomes even greater.

As such, one big issue is that the new style ticketing kiosks do not provide audio feedback for touch interactions.

**Video demonstration lack of audio for touch screen interactions on the new Helsinki ticketing kiosks can be found here: <https://youtu.be/s9cNlk3IK0M>.**

The new style card readers have been created using smooth glass touch screens, and designers have gotten rid of the four old style, large tactile plastic buttons that were previously used to select a journey type. These new readers do not give any audio feedback at all, other than when one touches the card to the validation area at the end of the selection process, at which point the machine audibly beeps to notify the user the action has been registered. The machine does emit a lower "beep" sound if the action can't be completed.

**Video demonstration lack of audio for touch screen interactions on the new Helsinki card readers can be found here: <***https://youtu.be/s9cNlk3IK0M*>.

## 5.3 Potential ways to use sound to enhance the user experience

The lack of sound in the user interface (UI) and wider overall ticketing experience presents a large opportunity to use audio to communicate meaning and logic to enable greater comprehension throughout the process of purchasing and using a ticket. This would ultimately greatly assist in the tasks that the user is aiming to fulfil.

Given the various ways sounds has been used in other places, and the existing frameworks which are currently being utilized around the world, it is clear that there are many ways sound can be used to improve the user experience for users of the new Helsinki metro ticket machines and card readers, and specifically for those who are blind and visually impaired.

One simple potential use of sound to help the user complete their task would be to play a sound when any key is touch-activated and registered on the machine. This would be, in a sense, a "skeuomorphic" nod to the mechanical audio feedback a tactile keyboard would provide ("skeuomorphism" being "interface objects that *mimic* their real-world counterparts in how they appear and/or how the user can interact with them." [Interaction Design Foundation, 2017]). Using audio to register keystrokes, in combination with good visual contrast ratio of color, and large font and button size among other things, could help with cognitive comprehension of text input for all, but especially for users who can't see as well.

Commented [AJ60]: Please explain this term and reference it as well.

Another concept I considered was a universal earcon framework made up of a fixed number of audio components. There does not seem to be any currently established universal audio framework for conveying simple meaning. Is this something that is viable enough to explore as a solution to the accessibility issues brought forth by touch screen technology? The framework would function almost as a simplified language of its own. Each short abstract sound would have its own basic meaning, and multiple sounds could be used together to augment the meaning of the individual sounds. As it would be created and tailored for simple interactions via touch screen, it could include the following sorts of commands:

**Table of simple commands and functions**

| Command | Function |
|---|---|
| Start | Begin the process of purchasing a ticket |
| Finished/End | End the process of purchasing a ticket (in case there was the option to perform additional tasks) |
| Move forward | Go to the next step |
| Move backwards | Go to the previous step |
| Enter/Select | Commit a command or confirm a selection |
| Cancel | Cancel an input or transaction |
| Confirm | Confirm information that has been communicated |
| Undo | Undo previous action |
| Error | Communicates a problem or issue (and what that problem is and ideally how to resolve it) |
| Help | Offers options for assistance |

*Figure 26. Table showing simple commands in a theoretical audio framework (Jones 2018).*

These earcons would most likely not be successful on their own unless the audio framework was very detailed, in which case the learning curve could be too steep to be useful. Therefore, they would be used alongside a simple overall physical design, instructions in braille on the machines, braille markings on inputs, outputs, and keypads, speech synthesis, and certain physical gestures on the touch screen such as swiping and tapping. The earcons would effectively reinforce tactile actions and information during the process of purchasing or adding value to a ticket, as well as validating it for travel.

The ticketing machines and card readers could also both register user input selections using specially designed sounds: neutral earcon sounds for neutral button pushes, and loaded earcon sounds for a successful purchase, incorrect input, correct input, cancelation of process, time out of process, etc. The card reader could have special earcons for successful ticket tap for travel card, successful tap for value card (possible use of auditory icon “coin” sound to indicate value has been deducted), unsuccessful ticket tap due to insufficient funds, unsuccessful tap due to non-registration of tap, notification when value ticket is low, etc.). There might be an option for an integrated screen reader with speech synthesis and language selection (including Finnish, Swedish, and English), as well.

I checked the International Organization for Standardization website (International Organization for Standardization, 2018) to see if a standardized audio framework similar to the one I describe already exists, and it seems it does not. Standardization would be helpful, as if implemented, increased consistency means increased efficiency. There would of course be a learning curve, however if blind and visually impaired users learned the sounds and their meanings, the result would be a more usable experience for them. The framework could also be utilized in other contexts where interaction is necessary, functioning similarly to the ISO’s international graphical symbol library. If specific meaning was universally agreed upon and known due to ubiquitous use and clear, thoughtful, intuitive design, an audio framework of earcons could be useful well beyond the context considered for the topic of this paper.

It might be considered a very simplified, universal, abstract language. Of course, if it became too complex, it could be argued that it would become too difficult to learn and possibly too close to the concept of spoken language as we know it, and that would beg the question: why not just use speech synthesis?

There should be braille markings on all parts, labels and buttons of the kiosk, and follow up information on the ticket kiosks to direct how and where to touch in on the card reader. A “help” option and two-way audio communication to station staff could be very useful in the case that the user comes to an impasse and needs further assistance. Also helpful, and something previously stated but deserving of reiteration is audio output confirming machine registration of inputs, for example, audible “beeps” when keys are tapped, etc. The card reader should implement braille, audio speech synthesis, earcons, audio icons, and language selection together to offer a more usable solution.

### 5.3.1 Provide paired tactile and audio feedback

Non-verbal audio feedback can be provided to indicate how controls operate. Tactile indication can be provided by requiring a gradual increase in physical force to activate a control, followed by an acute decrease as it is activated (such as the pressing of a button or knob). Audio feedback can be provided through abstract sounds such as clicks or beeps. For multiposition controls, feedback should be used to indicate the current position, status, or progress, and additional information can be given on the overall process (“Option number one *of four*”, “Volume level 3 *of 11*”, etc.).

Abstract sounds, including earcons, must be thoughtfully designed to convey the correct message, even if that message is limited in complexity (on/off, error, confirmation of input, successful completion of task, etc.). Some of these messages can use musical convention: if we take the well known Windows 95 start-up sound created by Brian Eno as an example, he has used a musical phrase that moves from lower notes to higher ones, ending on a high note and leaving the user with a feeling of “opening”. This makes sense in the context of what that sound means: “Your computer is starting up”. Though it is fairly abstract, it contains enough information to convey meaning: it is clear that it is the beginning of something; that the machine is turned on, is completing its start-up processes, and is ready for the start of your session. It is also a short yet unique musical phrase, which makes for a memorable experience.

If the message is that a task was successfully completed, the associated audio feedback should be positive. A “positive” sound is a fairly abstract concept, and could be many different things to different people, but generally it might be something higher pitched and gentler sounding. In contrast, an “error” sound might be something lower, shorter, and more aggressive sounding, putting forth a more negative connotation and therefor letting the user know that something needs attention (i.e. a payment card needs to be removed from the card slot), an incorrect input has been made (i.e. an incompatible option was chosen), or something needs immediate action (i.e. the screen is about to time out).

### 5.3.2 Add voice output

Add voice output to speak the instructions. This can be achieved using either pre-recorded audio or speech synthesis. Speech synthesis, whilst more flexible, is often of much poorer quality and may be difficult to understand for some users and in noisy environments. However, text to speech synthesis is more flexible and often more accurate than using pre-recorded .WAV files or similar formats. Pre-recorded files that are created in a studio sound nicer, but if something needs to be changed, it’s much more difficult to do. Text to speech synthesis reads the on-screen text as it is generated, depending on what functions the user selects.

If voice output is likely to be intrusive or if the instructions give away sensitive personal information, allow the audio to be turned off during a user session and provide a standard jack socket for connecting an earphone. Inserting a jack plug should switch off the output to the external loudspeakers.

Depending on the use, text to speech can be a time consuming solution to communicate meaning. If the information to be conveyed is complex beyond binary, the detail and preciseness of spoken language may be required.

### 5.3.3 Develop a separate audio menu

If the terminal relies on visible correlations between changing prompts and unlabeled buttons, users may still not be able to know which button is associated with each prompt. In this case, it may be best to develop a separate audio menu which prompts the user to press a number on the keypad for each choice. This can be done along the lines of telephone Interactive Voice Response (IVR) systems which ask the user to "press 1 for this option, press 2 for that option" etc., or the speaking ATMs which have been developed. Both the New York Subway and the Los Angeles Metro offer a solution similar to this one.

## 5.4 Further thoughts

Compared with visual design, audio design can be a challenging medium to work within the context of user interfaces. This is due to several factors including space limitations, intrusiveness, active attention demand, and unfamiliarity.

For example, voice interface technology is one area that could be explored for public applications like the ticketing kiosk, assuming the hardware was fast enough, and the voice recognition technology was accurate enough - though obviously, privacy and security are concerns. These concerns could be mitigated by use of headphones, though inputting data such as payment details verbally would still leave open the possibility of other people hearing, and therefore would be prone to privacy issues.

Another difficulty is that people generally prefer visual information over audio, even if they can only see a limited amount. This is due to the fact that it is much easier and faster to visually scan or take in a large amount of visual information and filter it quickly to focus on what one is looking for, whereas audio might be more difficult to do this with. This aligns with the feedback from my interview with Pirjo Koivusalo in Chapter 4.3.2. Even touch gives the user more control than audio does. Audio is linear and also temporal, so it is more cognitively taxing because the user must remember things. They are counting on recall rather than recognition. It is also more difficult to selectively focus on one bit of sound, unlike visual information. Using audio to support and reinforce visuals would be one thing, but to replace visuals all together with audio is much more demanding of the user's brain power. For this reason, any audio elements must be thoughtfully designed to make them as easy as possible to use, and so they work well alongside visual cues which sighted users are able to take advantage of.

Additional benefits of using sound within the public transportation context include making the experience better for additional user groups, such as international visitors who may not speak Finnish, people with various learning impairments, or people who might be able bodied and cognitively sound, but might simply be multitasking and not paying as much attention to key visual indicators due to ongoing activity on smart phones or other devices, or due to any number of other distractions.

Sonification is one of the most relevant areas to examine when looking at ways to use sound design to improve experiences for blind and visually impaired users of public transportation in Helsinki. According to Kramer, "Sonification is the use of non-speech audio to convey information." (Kramer 1998 p. 33). It is an interdisciplinary field which combines multiple learnings and inputs from the areas of "human perception, acoustics, design, the arts, and engineering," and requires collaboration between experts in these subjects in order to fully realize its successful and effective potential in various applications, which are wide reaching. These include new ways of comprehending the increasingly vast amount of data to which we have access, artistic expression, education and learning, and accessibility issues. In the context of this paper, sonification can be examined in light of the sounds which convey information in the process of travelling within HSL's system, determining current location and intent of self, and interacting with ticketing kiosks and card readers.

# 6 DISCUSSION

## 6.1 The research experience

The research segment of this project was quite interesting for me. Not only did I learn a lot about the academic publishing world and how to access and navigate it, but I found that there is a large body of work about human computer interaction written over a fairly lengthy period of time. In comparison, I found that information around touch screens was comparatively light, as was information around the idea of exclusively using sound to communicate information. This makes sense, as touch screens are a newer technology, and communication through sound is a rather niche subject.

My methods of desk research, user interviews, and field research seem fitting for this project. As this is my first time writing a research paper, I learned the value of having a robust reference management system in place from the beginning. Given the large amount of written material, I found it was easy to lose track of ideas and references, and much more difficult to organize content retroactively. I would have paid closer attention to initial organization of my reference materials before I started writing if I had the opportunity to do it over again. Also, regarding primary research, figuring out a strategy to make sure all information was captured proved to be an important task. I'm glad I used audio recordings for my interviews, as I'm sure I would have missed some important insights had I not used this method. I also wondered about the interviews themselves. Since they were conversational in style, they cannot be compared to each other. If I had the opportunity to do it again, I would include a standardized set of questions which I'd have asked every participant, in addition to the more free-flowing conversational portion in order to have some sort of consistent baseline to measure against.

It would have been beneficial to examine each city's ticketing system in person. Also, a standardized walkthrough with several visually impaired users (in a perfect world, this would be the same group of visually impaired users) would have given the most accurate and robust results. This would have clearly shown the differences in each station's systems and would have offered insight into particular methods of operation that were successful and not successful. However, this was not realistic for this project. Of course, unfortunately I had neither the time nor resources for this approach, and perhaps it would be outside the normal scope of a master's thesis eve if I had. I did not have the budget to travel to each city myself, let alone bring the same group of users to each location for a walkthrough. The video content I found online was a fair stand in. I was also able to make contact with several blind users in Tokyo via an online message board, thereby learning about their personal experiences with that system.

I would also have liked to further explore potential experimental frameworks for communicating sound through meaning, and perhaps even develop a prototype of this framework to test. However, again this fell outside my time restraints as well as the scope of this paper.

While overall my research methods seem to have worked well, there were some drawbacks. For example, though there is a wealth of relevant amateur video tutorial content which exists regarding ticketing machines in the cities I profiled in this paper, many of the videos I found were unusable for my purposes. This was mainly because in many cases, the live machine sounds were inaudible due to musical soundtracks added to the videos during editing, or due to poor quality sound recording or loud ambient sounds within the stations.

Also, I have obviously not examined every public facing kiosk in existence. There may be solutions implemented somewhere which work well and which I am unaware of and haven't been exposed to in my research. I also would have liked to interview more people, but it proved fairly difficult to find visually impaired users in Helsinki, and furthermore, those who were confident and willing to be interviewed in English (Pirjo Koivusalo was in fact, interviewed with the translation help of her daughter).

My argument for accessible ticketing systems in Helsinki also might not be as strong as it could be if it were made in other cities with larger populations. This is because the user base I'm concerned with is a very small number of people who make up a small percentage of the Finnish population (which itself is small) and could reasonably be considered an "edge case" by decision makers. A counter argument to my assertion that the Helsinki metro ticketing systems should be more accessible might involve the approach the city of Helsinki has currently taken regarding the matter, which I will discuss in the next section.

The manner in which I wrote this paper was probably not ideal, as it was completed in starts and stops over a long period of time and years after my coursework had been completed. I imagine it is more useful to write a research paper when things are fresh in your mind, and when you can give your full concentration to the task.

I also think my topic could have been defined better and possibly ring-fenced more strictly. I feel like the vast majority of my struggles stemmed from not having a totally clear and strict idea of my topic. Sometimes I was thinking about touch screens, sometimes I was thinking about communication through sound, and sometimes I was thinking about physical interfaces. There are many relevant pieces to this puzzle, and I found it hard not to jump around between them. I would probably have benefitted from deeper research into a more specific area, rather than looking at several different facets of the problem less closely.

I wanted to research and write about a topic which carried the possibility to affect positive, real change. The interviews I've done in the course of my research have had a profound impact on my feelings about this topic. Talking first hand with those who faces these challenges every day is quite a convincing exercise. It brings the topic to life and drives home the fact that the issues I am examining affect real people in very tangible ways. My hope is that my finished paper will provide insight on how and why designers might more seriously consider the needs of blind and visually impaired people. Moreover, I hope that this thesis raises awareness of the wide variety of users of a given system, and encourages more thoughtful, inclusive design within all contexts.

**Commented [AJ61]:** This goes more under the Discussion, not so much the conclusion.

## 6.2 HSL's current solution of free travel

Clearly both the old and new ticketing machines are lacking in their ability to reasonably serve blind and visually impaired users. One could say the city has been somewhat pragmatic in their present solution, which is to offer free travel to this group. This circumnavigates any and all issues with purchasing and validating a ticket, as the user doesn't interact with the machines at all and only has to show a badge to anyone in authority who asks. One problem with this approach is that blind and visually impaired users who are not normally resident in Helsinki cannot be reasonably expected to have this badge. It must be applied for through HSL, along with a doctor's note proving the condition is genuine and severe enough to warrant the badge.

While HSL's current method works to some extent, it ignores the fundamental problem of their offer of a system that is not fully accessible to all. One could argue that HSL does not currently treat blind and visually impaired users with equal consideration as able bodies users and has not considered them in the design process. It does not seem they are implementing fundamentally inclusive design practices. In my view, offering free travel is not a true solution.

As far as using sound in place of visual feedback, there is a certain control one has when one is actively reading as opposed to listening, which is passive. With reading, you can start and stop whenever you'd like, and you may go as fast or slow as is comfortable for effective comprehension and comfort. This is not the case with audio, where the primary control is to activate the flow of information (yet once it starts, it is out of the user's control until it finishes). The issue of the perception of personal control is an interesting one to consider.

# 7 CONCLUSION

In this study I was trying to examine how to use sound to mitigate the repercussions that touch screen interfaces have on users with low or no vision, and specifically in the context of the Helsinki Metro. Looking at the results of my research and interviews, I concluded that the current new ticketing system cannot be considered to be usable by blind or visually impaired people. I wanted to find out if there might be any reasonable solutions to this issue, perhaps even being implemented in other cities.

I learned that indeed, the current Helsinki ticketing system is not reasonably usable by persons with moderate to severe visual impairment. There is existing functionality which is used in other systems in other cities, including both sound cues and speech synthesis, which can be effective ways to communicate meaning, albeit not perfectly. The methods can be cumbersome and lengthy. Nevertheless, this functionality, which is imperfect yet better than nothing, could be fairly easily included in the Helsinki metro ticketing system, especially given the built-in hardware in the new ticketing kiosks that only has to be activated. This would ultimately offer a more inclusive and usable ticketing experience to the metro's users.

One possible solution could be the inclusion of various types of sounds to communicate meaning and information. These could be a combination of speech sounds, audio icons, and earcons, and could work in conjunction with other assistive systems, devices and technology.

During my research, I concluded that thought there may be current workable solutions in place in certain cities, these solutions are not in place in Helsinki. They also do not provide an equal user experience as able bodied users enjoy, and hence I do not believe that there has been a satisfactory answer to the needs of blind and visually impaired users in these ecosystems.

While audio is a powerful medium which is able to carry a substantial amount of information, it would seem that using sound exclusively to convey meaning around the fairly complex series of interactions necessary to purchase and use a metro ticket in Helsinki might not be the most effective way to go about things. Rather, audio might best be utilized in conjunction with braille, tactile ridges, and other physical indicators which provide tactile feedback. These additional features would work alongside and in addition to the touch screen panels in order to augment the experience to be usable for blind and visually impaired users.

## 7.1 Limitations of study

There were certain limitations to this study. I believe it would have been advantageous to have done several more walkthroughs of the Helsinki ticketing system with different people. Ideally, I would have liked to have done this with at least four other users. Jacob Nielsen, a well-known usability consultant, claims that five is the "sweet spot"; the optimal number of users to test in order to get the most information with the least amount of effort and resource.

After the fifth user, new information diminishes drastically. You will be “observing the same findings repeatedly but not learning much new.” (Nielsen 2000).

## 7.2 Further research

The idea of an abstract framework of simple sounds to denote meaning, similar to earcons but more developed, is a topic I think could be further explored. Of course, this kind of solution is contingent on standardization and user uptake. Nevertheless, I think it would be worthwhile to see if this might be a viable solution, or perhaps part of one.

There are other directions one could go towards related and adjacent research, which might hold ideas for new solutions to this challenge. They could encompass future conceptual solutions, as well as ideas that have already been developed such as augmented and virtual reality (augmented and virtual reality), spatial sound design, proximity sensors, and other currently nascent technology.

**Commented [AJ62]:** Is this really within the scope of your thesis, or does it reach already too far?

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