Accessibility of Music Production Software for the Visually Impaired

A study of developing an eyes-free audio application for a surface haptic interface

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Abstract

In the past three decades, the process of music-making moved away from operating analogue devices to using the software running inside of computers. While these advancements provide significant advantages, visually impaired people cannot fully benefit from this progress because some of the software tools are not accessible to them. The aim of this thesis is to explore the accessibility of music production tools for the visually impaired and propose an accessible eyes-free audio equalizer application controlled by a surface haptics interface.

To determine the level of accessibility of music production software, this thesis reviews industry practices and research concerning assistive technology in music production by analysing the most popular digital audio workstations' accessibility features. Further, online interviews with visually impaired music producers are conducted to find out about the way they work and their experience with using the software.

Finally, an equalizer with a visual display of the EQ curve for a surface haptic interface is designed and developed to explore a new human-computer interaction method that makes it possible to operate audio plugins eyes-free. Due to haptics feedback, the user can control the application in a non-visual way. To validate the application design and potential for improving the accessibility of music production tools, two tests with participants are conducted. The results show that it is possible to control audio equalizer only with haptic feedback. However, more development is needed to improve the user workflow.

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Chapter 1

Introduction

1.1 Motivation

Rapid technological advancement in the audio industry has changed the way music is recorded and edited. The process of music-making moved away from operating analogue devices to using the software running inside of computers. While some studios still offer analogue recording to a tape machine, most of the recording studios are now using Digital Audio Workstations (DAWs) in the recording process. This move towards digital technology resulted in a change that provides significant advantages such as unlimited audio edits and the availability of more tracks for recording. Ultimately, these changes made music recording much more affordable. It has allowed the democratization of music-making, and arguably, more people can now make and record music than ever in history.

Since the beginning of the 2010s, there has been a rise in the number of award-winning records made in home bedroom recording studios. Music producers and artists proved that there is no need for expensive equipment and a big studio to make a great sounding and successful record. In fact, only a computer with an audio interface is needed. For example, Billie Eilish recorded her album "When We All Fall Asleep, Where Do We Go?" in a bedroom studio together with her brother FINNEAS. The album received three GRAMMY awards in 2019, winning in categories

Album of the Year, Best Pop Vocal Album, and Best Engineered Album, Non-Classical.[1] All this is possible due to the technological advancements: with high computational power inside computers and affordable recording equipment.

This development has provided more accessible and easier ways of making music for sighted people. However, visually impaired engineers and music producers do not fully benefit from these advancements. One could even argue that they had more equal possibilities when working in analogue studios. They were able to find their way around using hardware equipment by remembering the interface layout and operating physical controls. The hardware interfaces that visually impaired music producers could explore with their hands changed into graphic interfaces on computer screens throughout the time. Recent years have shown that developers tend to use highly graphical interfaces that create potential problems for visually impaired users.

Companies developing audio recording software such as Logic Pro or Pro Tools have been working together with the visually impaired community and found ways to make the most of the main software features, such as audio editing or recording, accessible.[2] These efforts allowed visually impaired music producers to compete in the commercial market alongside sighted producers once again. However, the accessibility of the software is still far from perfect, and there are many challenges visually impaired music producers have to overcome in their workflow. Some software is accessible partially, and some software is not accessible at all, so visually impaired producers have to use different software.

In most cases, a screen reader is used for making the content displayed on the screen accessible for the visually impaired. The screen reader reads all the text information on the screen, and in combination with keyboard shortcuts, visually impaired users can use their computers in quite an effective way. However, having a screen reader read a lot of information can create problems when working with audio. This was also confirmed as a problem during the interviews with visually impaired producers, e.g. Cory Wilkins. In his email interview, he says: “This is a huge problem for me and I am seriously considering giving up most of my metering to mix almost

1. Recording Academy, *2019 GRAMMY Winners & Nominees*, 2020, accessed October 10, 2020, https://www.grammy.com/grammys/awards/62nd-annual-grammy-awards-2019.

2. Slau Halatyn, *Music: Making DAW Software Accessible for Blind and Visually Impaired Audio Engineers and Musicians*, 2014, accessed October 10, 2020, http://www.avidblogs.com/music-daw-software-for-blind-and-visually-impaired-audio-professionals/.

completely out of the box with a console and outboard. Every time I have to dim a mix to listen to feedback from voice over, I lose focus on my mix, and that can make me a little angry if I am really in the zone." [3]

In some scenarios, the use of a screen reader has limitations. An alternative way of displaying information could help to improve the workflow of visually impaired music producers. Perceiving information through other sensory systems other than hearing can abate the problems and compliment the auditory perception.

1.2 Research overview

The following two research questions are going to be addressed in this work:

1. What are the current ways the visually impaired interact with music production software, and how accessible is this software?

There is a general lack of knowledge about visually impaired people's access to music production tools. Music production software accessibility features and the ways visually impaired people interact with this software will be explored.

2. Can a surface haptic interface serve as an eyes-free controller for music production software?

An eyes-free application prototype for a surface haptic interface will be developed. An experiment will be conducted to evaluate the effectiveness of the proposed method.

1.3 Objectives

Current industry practices and research concerning assistive technology in music production will be reviewed. A comprehensive overview of tools typically used by visually impaired musicians and music producers to interact with audio will be presented.

An application prototype for the haptic interface TanvasTouch will be developed in order to

3. Cory Wilkins, Email interview about DAWs conducted by Jakub Pesek. May 2020.

present a method for an alternative human-computer interaction with audio plugins for the visually impaired. An experiment with test subjects to evaluate this application will be conducted.

This study has both academic and practical value:

- academic: The study is one of the first to highlight the issue of inaccessibility of music production tools for the visually impaired.
- practical: It proposes an accessible audio equalizer application for a haptic interface that can be controlled eyes-free.

1.4 Thesis outline

This thesis is structured as follows:

1. Introduction provides background about the accessibility of music production software and presents a research overview and thesis structure.

2. Literature review gives a detailed overview of the accessibility of music production software and information about visual impairment and haptic technology.

3. Surface haptics application discusses designing the accessible equalizer application touchEQ for the surface haptic interface TanvasTouch.

4. Methodology outlines and motivates the parameters of the experiments organized as a part of this research. Further, it provides insight into the analysis of the data collected in the usability tests in order to evaluate the touchEQ application.

5. Discussion includes an interpretation and explanation of the study findings and reviews this research's limitations.

6. Conclusion offers closing remarks and lists possible directions for future works.

Chapter 2

Literature review

This chapter defines terms that are used in this study. First, the definition of disability and visual impairment and an overview of the existing assistive technology are given. Further, this chapter provides an overview of the accessibility of music production software. Interviews with visually impaired music producers provide insight into how visually impaired people use this software. Use of haptics in assistive technology is discussed at the end of this chapter.

2.1 Disability

A disability can be defined as "any condition of the body or mind (impairment) that makes it more difficult for the person with the condition to do certain activities and interact with the world around them."[1] According to the World Health Organization (WHO), almost everyone will experience difficulties of temporal or permanent impairment at some point in life.[2] WHO estimates that around 785 million people 15 years and older live with a disability, while 110 million people have very significant difficulties with functioning in daily life.

In the past decades, there has been a significant shift in the global understanding of disability.

1. Control Centers for Disease and Prevention, *Impairments, Activity Limitations, and Participation Restrictions*, 2020, accessed October 20, 2020, https://www.cdc.gov/ncbddd/disabilityandhealth/disability.html.
2. World Health Organization, *World Report on Disability* (2011), https://apps.who.int/iris/bitstream/handle/10665/70670/WHO_NMH_VIP_11.01_eng.pdf.

Because of the movements representing disabled people and research in health and social sciences, disability is now seen as a body condition and a human rights issue. Thanks to political initiatives such as the 2006 United Nations Convention on the Rights of Persons with Disabilities, many countries have changed their policies. They have shifted towards social and educational inclusion, recognizing that disabled people are disabled by the environment and society as well as their bodies.[3] In the past, the solutions provided by governments such as special schools or residential institutions segregated disabled people from the rest of society.

There are many types of disabilities, such as hearing loss, physical disability and vision impairment. Every disability presents different problems and barriers in daily life. The World Report on Disability by WHO suggests that many of these barriers can be avoided if governments adjust their disability-specific policies. WHO argues that governments need to work towards achieving goals such as higher involvement of people with disabilities, an increase of public awareness and understanding of disability, improving disability data collection, and enabling access to mainstream systems and services.

2.2 Visual impairment

This research focuses specifically on visual impairment and visually impaired people's access to music production software. The vision impairment ranges from partial sight loss to no sight at all. There are many different types of eye conditions that result in various forms of vision distortion. A person who is registered as legally blind does not necessarily need to have full vision loss. For example, there are eye conditions that result in a very narrow vision, a perception of light and shadow, or a lack of central vision. Some people are born blind or are born with some form of visual impairment, which is gradually getting worse over time. Some people have a condition that develops later in life. While visual impairment affects people in all age groups, sight loss is closely related to higher age, with people aged 50 and older representing 82% of all visually impaired.[4]

3. World Health Organization, *World Report on Disability.*
4. World Health Organization, *Global Data on Visual Impairments 2010* (2010), https://www.who.int/blindness/GLOBALDATAFINALforweb.pdf?ua=1.

Legal definitions of visual impairment vary in different countries. In this thesis, the term visually impaired is used to describe blind and partially sighted people together, in line with a definition by the European visually impaired Union.[5]

The World Blind Union estimates there are more than 253 million blind or visually impaired people worldwide.[6] According to WHO, more than 285 million people are blind, of whom 39 million are visually impaired.[7] In Europe, an estimated 30 million people affected by a partial sight loss or a visual impairment which means that 1 in 30 Europeans experience a sight loss.[8] In the Netherlands, there are between 220 000 to 320 000 people with visual impairment, of whom 33 000 to 45 000 are blind.

Vision loss affects people in everyday activities and has a dramatic impact on their quality of life. In Europe, the average unemployment rate of blind and visually impaired people in the productive age is more than 75 per cent.[9] In the Western world, visually impaired people usually have access to government support through social benefits systems. Other forms of support that can help make life easier for the visually impaired include local organizations, rehabilitation, support in education, and assistive technology.[10]

2.2.1 Assistive Technology

Assistive technology helps people with a disability to live a healthy and independent life and makes it possible for them to be better included in society. Based on WHO estimates, more than 2 billion people will need at least one assistive product by 2030.[11] Visually impaired people can often be recognized using assistive tools such as a white cane and guide dogs for getting around independently. This section will list some of the technology commonly used by visually impaired people in everyday life and in human-computer interaction (HCI).

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5. European Blind Union, *About blindness and partial sight*, 2020, accessed October 24, 2020, http://www.euroblind.org/about-blindness-and-partial-sight/facts-and-figures.
6. World Blind Union, accessed February 18, 2021, https://worldblindunion.org/.
7. World Health Organization, *World Report on Disability*.
8. European Blind Union, *About blindness and partial sight*.
9. **ibid**.
10. European Commission, *People with disabilities have equal rights: the European Disability Strategy 2010-2020* (Publications Office of the European Union, 2010), accessed October 28, 2020, https://ec.europa.eu/eip/ageing/standards/general/general-documents/european-disability-strategy-2010-2020_en.html.
11. World Health Organization, *Blindness and vision impairment*, 2020, accessed October 20, 2020, https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment.

2.2.1.1 Screen readers

A screen reader is a software program that uses a Text-To-Speech (TTS) engine to translate on-screen information into a synthesized speech or output it to a braille display. A screen reader is controlled by keyboard commands and tabbing over visual elements because visually impaired people generally do not use mouse to navigate in the user interface. The user can instruct a screen reader to perform tasks such as reading a word, reading a line or a full screen of text, finding a string of text on the screen, or announcing the cursor's location.[12]

There are multiple screen readers for Windows and macOS, such as JAWS or Narrator for Windows and VoiceOver for macOS. Screen readers for Android and iOS devices are also available.[13] Most screen readers offer similar features and are efficient for interacting with a text. However, they have limitations when it comes to displaying graphic visual representations of information. For example, if the screen reader detects an image without a description tag, it might skip the image entirely.[14]

2.2.1.2 Braille tablets and displays

Some visually impaired computer users use refreshable braille displays to read the text output. These hardware devices convert the screen reader's output into braille characters, which are displayed by raising and lowering different combinations of pins in the braille cells.[15] Braille displays, as seen in Figure 2.1 (image by Humanware[16]), are often used in combination with synthesized speech output from the screen reader. The price of braille displays varies based on the number of characters it can display, ranging from $600 to $10 000.

12. American Foundation for the Blind, *Assistive technology products*, 2020, accessed November 1, 2020, https://www.afb.org/blindness-and-low-vision/using-technology/assistive-technology-products.
13. AbilityNet, *An introduction to screen readers*, February 2019, https://abilitynet.org.uk/factsheets/introduction-screen-readers.
14. J. Hogue, *Accessible Images "Out Loud" - Insights*, January 2019, https://www.oomphinc.com/insights/images-alt-tags-out-loud-experience-oomph-inc/.
15. American Foundation for the Blind, *Assistive technology products*.
16. Humanware, *Brailliant BI 40X braille display*, accessed March 5, 2021, https://store.humanware.com/media/catalog/product/cache/2/image/9df78eab33525d08d6e5fb8d27136e95/b/r/brailliant__bi40__x__-__front__view-lr.jpg.

Figure 2.1: A braille display with 40 refreshable cells with a cost of $3,995

Blitab is a device with similar functionality to braille display but it offers more features. It is a tactile Android tablet combined with a smart braille interface that can display 14 rows of information. It can convert visual images into simplified tactile images or generate a tactile version of a map.[17]

2.2.1.3 Other technology

Another tool often used by the visually impaired is the magnification of information displayed on the screen. Software tools such as Dolphin Guide enlarge any text and graphics to a desirable scale. The enlarged area can also be highlighted with colour to make it easily identifiable.[18] Furthermore, operating systems typically allow adjusting system features such as font size, icon size, colour scheme, and screen resolution, which can help some users. Partially sighted people commonly use these tools.

Controlling devices by voice commands is another potential form of human-computer interaction. With the improved functionality of voice assistants, the popularity of these devices is rising, and large companies such as Google and Amazon are starting to add features that benefit visually impaired users. For example, Amazon's Echo Show smart screen has a feature that allows the user to ask questions such as: "What am I holding?" The Echo uses camera input and machine learning to recognize what the person holds in hand and then communicates this information via the TTS engine.[19]

17. Blitab, *Feelings get visible - World's first tactile tablet*, 2020, accessed November 4, 2020, https://blitab.com/.
18. American Foundation for the Blind, *Assistive technology products*.
19. Tech Xplore, *Amazon smart display 'eyes' aid visually impaired*, 2019, accessed November 3, 2020, https://techxplore.com/news/2019-09-amazon-smart-eyes-aid-visually.html.

Emerging technology such as location-based virtual audio guides in immersive audio and wearable haptic devices can be used for navigation in public spaces and also for interacting with digital devices. However, many of these interfaces are still in the early stages of development, and they are not yet available for consumers. If these devices fulfil their promising potential, human-computer interaction for the visually impaired can become more comfortable and efficient in the near future.

2.2.2 Conclusion

Assistive technology presented in this chapter helps visually impaired people with the accessibility of computers and other digital devices. However, the display and interaction with graphical on-screen information remain mostly unsolved problems. This might change in the following years, thanks to novel interfaces and larger companies' attempts to consider impaired users' needs when developing their products.

One of the issues of assistive technology is the high cost and the resulting financial barrier for acquiring these devices. This might be caused by the fact that these devices are developed specifically for a relatively small visually impaired community. The development and manufacturing costs need to be covered by a much smaller sales number than with general consumer devices. Implementing accessibility features into technology created not only for the visually impaired community but also for sighted users has significant benefits. Prices of these devices are likely to be lower, updates will be more frequent, and in the long term, it is the most sustainable solution to accessibility issues. This way, both visually impaired and sighted users can benefit from technological progress.

2.3 Accessibility of music production software for the visually impaired

A digital audio workstation or DAW is a software application used to create music, sound design, sound effects, podcasts or any other situation where a complex manipulation with audio is needed. Modern DAWs are designed to replicate the analogue processes involved in recording, mixing and processing audio signals into a final piece.[20] In current music production practice, it would be unusual for a recorded or electronic musical work not to be mediated by a DAW at some stage of the music making process.[21]

Music producers can choose a DAW based on their needs and genre-specific preferences. Some DAWs are more suited towards electronic music production, others are more popular with engineers who record bands and live audio. This section provides an overview of the accessibility features for the visually impaired of the most commonly used DAWs. It additionally focuses on what developers are doing regarding making their tools accessible for visually impaired music producers. Accessibility features of six commercially available DAWs are examined. Furthermore, four visually impaired music producers were interviewed to find out about their experiences using music production software. Finally, an overview of the accessibility of music production plugins and hardware interfaces such as MIDI controllers is provided, followed by a review of music production education for visually impaired people.

2.3.1 Visually impaired and music production

Visually impaired people often have an outstanding analytic hearing to orientate in space,[22] which is developed over time and helps compensate for their sight loss. Visually impaired people develop better hearing and notice a broader range of sounds and pitches, especially those born blind.[23]

There is a general lack of sources about visually impaired people's access to DAWs. Only a few resources and tutorials are available for visually impaired music producers, and users often ask for advice in online forums. While some of these questions are posted by visually impaired music producers themselves, others are posted by their friends or teachers who have a visually impaired student in their class, asking for help regarding what software the student should use. The lack of general awareness about the accessibility of music production software makes it difficult for

20. Ken C. Pohlmann, *Principles of digital audio*, Sixth Edition (McGraw-Hill, 2011).

21. Michael Terren, "The grain of the digital audio workstation" (PhD diss., 2019), 2–15, https://ro.ecu.edu.au/theses/2201.

22. Mats E. Nilsson and Bo N. Schenkman, "Blind people are more sensitive than sighted people to binaural sound-location cues, particularly inter-aural level differences," *Hearing Research* 332 (February 2016): 223–232, https://doi.org/https://doi.org/10.1016/j.heares.2015.09.012.

23. Catherine Wan et al., "Early but not late-blindness leads to enhanced auditory perception," *Neuropsychologia* 48 (September 2009): 344–8, https://doi.org/10.1016/j.neuropsychologia.2009.08.016.

visually impaired people to start with music production. Thus, a thorough review of available software is presented in this thesis.

2.3.2 Assistive technology in music production

2.3.2.1 Screen readers

The functionality of a screen reader has already been described in Section 2.2.1.1. Currently, screen readers are the primary tool for making music production software such as DAWs or plugins accessible. While the screen reader enables access to most of the DAW features, it is still a significant challenge to make accessible software where there is a need for a graphical display of information, such as EQ curves or 3D panning positions. Currently, available screen readers cannot display non-textual information. Visually impaired people have to rely on the developers to tag their graphical interfaces with proper descriptions so the screen reader can read the description, but this is not always the case. An example of an equalizer that relies heavily on graphical display is presented in Figure 2.2.

Figure 2.2: Graphical user interfaces are not accessible for visually impaired users

The screen reader is reading the information displayed on the screen in a synthesized speech, and in some scenarios, it might disrupt the music producer's workflow. A visually impaired music producer Cory Wilkins thinks that listening to the screen reader's output is sometimes disrupting and presents problems to his workflow. He says: "[...] having voiceover be too present when I mix. This is a huge problem for me and I am seriously considering giving up most of my metering to mix almost completely out of the box with a console and outboard."[24] This issue was mentioned by several visually impaired music producers. A solution that can diminish this problem is to set the screen reader's audio output to different speakers from the main speakers used for monitoring and mixing. This is working well for Héctor Mestre, a visually impaired music producer who runs his own studio. He says: "I use the voice over on my computer through the computer monitor, not the recording or mixing monitors. I choose to do that because it does not get in the way of the main monitors when I am mixing I can separately turn down the volume on the computer if I want without affecting what I am mixing in the moment."

These screen reader limitations suggest that in some situations, a different type of human-computer interaction, such as haptics, could be implemented into the music production workflow. Even though the accessibility of DAWs was significantly improved in the past decade, there are still some functions of the software that are not accessible by the screen reader. Making music production software accessible is a challenging process that requires rethinking the way information is rendered and interacted with. Therefore, a discussion about information display is essential for improving accessibility for visually impaired music producers.

2.3.2.2 Hardware interfaces

One of the solutions to accessibility issues are hardware interfaces. Software control elements can be mapped to physical controls of interfaces such as MIDI keyboards or other MIDI controllers. Héctor Mestre thinks that for a visually impaired music producer, a hardware interface is essential in order to achieve an efficient workflow but he has not yet found an ideal interface for his studio. He believes that a multi-purpose hardware controller unit with knobs and buttons would make his workflow better. He suggests that this kind of device could behave as a compressor, limiter, EQ, or reverb, changing the functionality based on the user's needs.[25]

There are examples of existing hardware interfaces where the manufacturers created their tools with accessibility in mind. The Komplete Kontrol MIDI keyboard, designed by Native Instru-

24. Cory Wilkins, Email interview about DAWs conducted by Jakub Pesek. May 2020.
25. Héctor Mestre, Email interview about DAWs conducted by Jakub Pesek. May 2020.

ments, is an example of such an interface. It offers visually impaired music producers features for better interaction with software, especially virtual instruments (VST). "Thanks to the touch-sensitive rotary encoders, and auditory feedback provided by the buttons on the Komplete Kontrol keyboard range, the software can detect when the user's fingers are resting on them, then give auditory feedback – synthesized speech – of the current value, and do so continuously as it is adjusted."[26] These features allow users to browse through sound libraries and alter sounds with high accuracy. Interfaces such as Komplete Kontrol are great tools to empower visually impaired music producers. It allows them to access features they could not access before, such as preset browsing, parameter editing, and using the scale and arpeggiator engines. Plugin developers can work with Native Instruments NKS standard and make their plugins accessible through the Komplete Kontrol.

2.3.3 Digital Audio Workstations

According to an online survey conducted by ask.audio in 2018, which had more than 30 000 responses from DAW users, the most popular DAW is Ableton Live (20.52%), followed by Logic Pro (19.20%), Pro Tools (16.13%), and Cubase or Nuendo (10.43%).[27] While these numbers may not be a completely accurate representation of DAWs' popularity, they can be used as an indication of the different DAWs' respective usage for this section's purpose. Even though these DAWs might be the most popular with sighted music producers, some less popular DAWs might be more accessible for visually impaired music producers. For this reason, Reaper by Cockos and Sonar by Cakewalk are also considered in this chapter.[28] A list of DAWs included in this study is listed in Table 2.1.

26. Hollin Jones, *How KOMPLETE KONTROL is empowering visually impaired musicians*, August 2018, accessed March 5, 2021, https://blog.native-instruments.com/how-komplete-kontrol-is-empowering-visually-impaired-musicians/.

27. Rounik Sethi, *Top 12 Most Popular DAWs (You Voted For) : Ask.Audio*, April 2018, accessed May 14, 2020, https://ask.audio/articles/top-12-most-popular-daws-you-voted-for.

28. Adil Ghanty, "Native Instruments - Komplete Kontrol Accessibility A Guide to Musical Creation for Visually Impaired Musicians," June 2017, https://www.golden-chord.com/docs/documents/accessibility-user-guide-gdchd1004.pdf.

Developer	DAW	Website
Ableton	Live	https://www.ableton.com/
Apple	Logic Pro	https://www.apple.com/logic-pro/
Avid	Pro Tools	https://www.avid.com/pro-tools/
Steinberg	Nuendo	https://new.steinberg.net/nuendo/
Cockos	Reaper	https://www.reaper.fm/
Cakewalk	Sonar	https://www.cakewalk.com/products/SONAR/

Table 2.1: List of popular DAWs, their developers and websites

2.3.3.1 Live

Despite being one of the most popular DAWs, especially for electronic music production, Ableton Live does not offer a lot of accessibility features to users. Live's latest version 11.0 is not accessible for screen readers, making it almost impossible for visually impaired people to operate the software. One of the features Live offers is screen zooming and colour schemes that can be customized based on the user's preferences. These features might help some users with partial sight loss, but as of now, there is no option for visually impaired users to access Live in a way that would make the workflow usable.

Ableton offers a hardware controller, Push 2, designed specifically for close interaction with Live. Using Push 2 with Live can make some features more accessible because users can take advantage of hardware knobs and pads. However, much of the displayed information is still visual and therefore, interaction with the on-screen information is needed. With no auditory feedback from the screen reader, Live is not accessible for visually impaired users.

2.3.3.2 Logic Pro

Logic Pro is a DAW developed by Apple, and it runs on macOS machines only. One of Logic Pro's most significant advantages is the VoiceOver integration that Apple has implemented in recent years. Users report that all essential functions in Logic Pro are accessible and that even more advanced features such as automation of volume are accessible. Logic Pro comes with a bundle of stock plugins and virtual instruments developed by Apple that are available at no extra cost and allow users to make music straight out of the box. These plugins are also designed to be compatible with the VoiceOver, making them accessible for the visually impaired.

Apple actively engages in the visually impaired music producers community, addressing different issues and adding features in regular updates. As a result, the accessibility of Logic Pro is continuously improving. There are tutorials created by visually impaired music producers on YouTube and dedicated forums that can help other visually impaired people start using Logic Pro. Overall, Logic Pro can be considered one of the most accessible DAWs currently available.

2.3.3.3 Pro Tools

Pro Tools is one of the most popular DAWs for audio professionals, especially for recording bands. Avid, the Pro Tools manufacturer, has been working closely with the visually impaired community in recent years and has made significant progress in improving accessibility for visually impaired people. The current version of Pro Tools 12 is mostly accessible, and it offers some handy features for the visually impaired. For example, a feature called track preset is helpful in Cory Wilkins's workflow. It allows him to save chains for the most commonly used tracks such as kick, snare, or vocals, and then just use one key command on each track to insert all the saved plugins. [29] More advanced features such as volume automation are also accessible in Pro Tools.

Online videos and tutorials are available for music producers who want to get started with Pro Tools. There are tutorials on YouTube, and there is the "Pro Tools Accessibility" Google group. There is a strong community of visually impaired Pro Tools users supporting and advising each other. Unfortunately, these accessibility features only apply to macOS users because the Windows version of Pro Tools does not include screen reader support. It is therefore not accessible for the visually impaired.

Flo Tools is a series of UI scripts for the VoiceOver that aims to make using Pro Tools even more straightforward for visually impaired users and make their workflow more efficient.[30] For example, Flo Tools can read out how many tracks are present in the session, which helps the visually impaired users get a quick overview when they open a session. Other features include

29. Cory Wilkins, Email interview about DAWs conducted by Jakub Pesek. May 2020.
30. Flo Tools, *Enhanced Workflow for Pro Tools Users With Visual Impairments*, accessed November 14, 2020, http://flotools.org/Flo%20Tools/.

reading the loudness meters values when tracking or mixing audio. Music producer Julián Argoti Alejandro thinks that with Flo Tools, Pro Tools is an accessible DAW and has access to almost all the features that a sighted music producer can access.[31]

2.3.3.4 Nuendo and Cubase

Nuendo and Cubase, both developed by Steinberg, are currently not accessible by the screen reader. It is not possible for visually impaired music producers to use this DAW. It supports a zoom function which is helpful for producers with partial sight loss. The software offers good integration with Komplete Kontrol by Native Instruments, which might help use virtual instruments. However, other features for recording and mixing are not accessible.

2.3.3.5 Reaper

Reaper is accessible for visually impaired users on both Windows and macOS. An open-source extension OSARA is available, and it aims to make Reaper accessible for the VoiceOver or screen readers. OSARA makes it possible for the user to navigate smoothly through the session and allows the user to control most of the DAW features. OSARA can, for example, provide the user with information about track names or report adjustments to track mute, solo, input monitor, or volume.[32] However, the information displayed with graphics is still hardly accessible. There is also a well-documented accessibility Wiki page for Reaper. Tutorials included in the documentation can help visually impaired music producers to get started with using this software.

2.3.3.6 Sonar

Sonar by Cakewalk is a DAW mainly available on Windows. Sonar offers a special accessibility mode that allows the screen reader to access and read various information in the DAW.[33] Sonar was one of the first DAWs to be accessible for visually impaired music producers, starting with accessibility features around the year 2000. It allows visually impaired users to record and edit

31. Julián Argoti Alejandro, Email interview about DAWs conducted by Jakub Pesek. May 2020

32. James Teh, *OSARA: Open Source Accessibility for the REAPER Application*, 2020, accessed November 20, 2020, https://github.com/jcsteh/osara.

33. Cakewalk, *SONAR and Screen Readers for Vision Impaired Users*, 2016, accessed May 18, 2020, https://www.cakewalk.com/Support/Knowledge-Base/200709182/SONAR-and-Screen-Readers-for-Vision-Impaired-Users.

vocals.[34] Sonar was acquired by Gibson Brands in 2018 and is now distributed for free as a Cakewalk by BandLab DAW.

2.3.4 Music production plugins

In music production, recorded audio usually gets processed by post-production plugins such as equalizer, compression, or reverb. Because third-party developers often design these plugins, users need to rely not only on the accessibility of the DAWs but also on the accessibility of these plugins. Commonly, the developers design their graphical user interfaces to make them look modern and appealing, which is necessary for the product's success on the market. Unfortunately, accessibility is very rarely considered a relevant factor in the design process. As a result, the plugins often have an unsuitable design from an accessibility point of view.

Visually impaired music producers' experiences with plugins vary. Some find that they have the plugins they need for their workflow; some are struggling with accessibility. For example, even though Waves plugins are accessible by the VoiceOver, the resolution on the plugin knobs is very high. Cory Wilkins explains:

> Since I am doing everything with the keyboard, everything is being controlled with the arrow keys. If you open a plugin like the Waves CLA76, the release setting is at 4 by default. If I want the fastest release time, which is at 7, I have to right arrow through 4, 4.01, 4.02, 4.03 all the way to 7.[35]

These flaws in the plugin design cause ineffectiveness of the visually impaired music producers' workflow. A simple task that requires a sighted music producer to turn a knob with a mouse takes much more time to complete for a visually impaired music producer. On the other hand, native plugins in Pro Tools and Logic Pro are accessible. An extensive list of all accessible and inaccessible plugins available on the market does not exist. However, a sighted music producer unquestionably has a much larger number of plugins they can choose from.

34. YesAccessible!, "CakeTalking for SONAR," 2002, accessed November 29, 2020, http://www.yesaccessible.com/caketalking.html.
35. Cory Wilkins, Email interview about the DAWs conducted by Jakub Pesek. May 2020.

2.3.5 Education for visually impaired music producers

For a sighted person interested in music production, many schools, universities, online tuition and tutorials are available to help them learn how to use music production tools and become a music producer. For visually impaired music producers, the resources are much more limited. However, there is a robust online community of visually impaired music producers who create tutorials and podcasts to help each other learn. As mentioned above, Google groups and YouTube tutorials can help visually impaired producers learn about their options and opportunities in music production.

There are educational institutions that offer programs specifically made for the visually impaired. For example, a visually impaired music producer Jason Dasent created online courses to offer one-to-one tuition specifically for screen reader users. His courses cover using Pro Tools or Logic Pro and basic vocal production along with using virtual instruments. I See Music is an institute in the U.S. offering on-campus and virtual programs for low to no-vision people. Students can learn how to operate DAWs such as Pro Tools, Reaper or Logic Pro efficiently.[36] Berklee university also offers an Assistive Music Technology For Visually Impaired Musicians program. It is designed to "prepare visually impaired students to independently and effectively communicate with other sighted musicians using assistive music technology."[37]

2.4 Haptics

In the music production context, haptic interfaces could provide an alternative way of human-computer interaction to the screen reader. According to Atkinson (2002), vision is the main sensory system humans use for exploring the environment and interacting with objects.[38] However, the haptic sensory system provides a considerable amount of information to an individual in everyday interactions. In fact, when we touch an object, the haptics system informs us about a comprehensive set of information such as our arm's position and about the texture, material, weight, shape of the object. This set of information allows for appropriate interaction with the object. Human touch sensing capabilities can be divided into three categories: thermal (feeling

36. Music, I See, *I See Music - About us*, accessed May 18, 2020, https://iseemusic.org/about%7B%5C_%7Dus.php.
37. Berklee College of Music, *Assistive Music Technology For Visually Impaired Musicians*, accessed May 18, 2020, https://www.berklee.edu/assistive-music-technology.
38. Janette Atkinson, *The Developing Visual Brain* (Oxford University Press UK, 2002).

of warm, cold), hardness (pressure, density) and texture (friction).[39]

The human haptic system is a complex structure divided into three subsystems based on sensory, cognitive, and muscular capabilities. For example, a human hand contains various receptors connected to nerve endings in the skin, joints, and muscles. External stimuli, such as touching an object, activates appropriate receptors and trigger the transmission of electrical impulses through the afferent neurons into the central nervous system. These impulses get processed and analyzed in our brain, and then the signals are conveyed in the opposite direction through efferent neurons to the muscles to perform the desired task.[40]

Table 2.2 lists commonly used haptic terminology and its definition, proposed by Oakley, McGee, Brewster, Gray.[41]

Haptic	Related to the sense of touch
Kinesthetic	Meaning the feeling of motion. Relating to sensations originating in muscles, tendons and joints.
Cutaneous	Pertaining to the skin itself or the skin as a sense organ. Includes sensation of pressure, temperature, and pain.
Tactile	Pertaining to the cutaneous sense but more specifically the sensation of pressure rather than temperature or pain.
Force Feedback	Relating to the mechanical production of information sensed by the human kinesthetic system.

Table 2.2: Commonly used haptics terminology

The term haptics has been used since the beginning of the twentieth century in neurobiology and psychology, describing an active touch of objects by humans.[42] At the beginning of the 1990s, when robotics and novel computer machines research emerged, the term haptics started to be broadly used as both real and simulated touch interactions between robots and humans in real

39. M. Sreelakshmi and T.D. Subash, "Haptic Technology: A comprehensive review on its applications and future prospects," *Materials Today: Proceedings* 4, no. 2, Part B (August 2017): 4182–4187, https://doi.org/https://doi.org/10.1016/j.matpr.2017.02.120.

40. National Research Council, *Virtual Reality: Scientific and Technological Challenges*, ed. Nathaniel I. Durlach and Anne S. Mavor (Washington, DC: The National Academies Press, 1995), https://doi.org/10.17226/4761, https://www.nap.edu/catalog/4761/virtual-reality-scientific-and-technological-challenges.

41. Ian Oakley et al., "Putting the Feel in 'Look and Feel'," *Conference on Human Factors in Computing Systems*, April 2000, 415–422, https://doi.org/10.1145/332040.332467.

42. M. A. Srinivasan, "What is Haptics?," *Laboratory for Human and Machine Haptics: The Touch Lab*, 1995, http://medesign.seas.upenn.edu/uploads/Courses/Srinivasan.pdf.

or virtual environments.[43] Haptics has become a study of science and technology of transmitting and understanding information through touch. For this study's purpose, haptics is referred to as anything related to the sense of touch, considering the human haptic system's sensory, cognitive, and muscular capabilities.

2.4.1 Haptics and visually impaired

Visually impaired people have to rely on hearing, smell and touch in everyday tasks. If a visually impaired person wants to see a new piece of clothing, they will likely explore the material and texture by touching it. While a sense of touch is often seen as secondary to sighted people, visually impaired people need to make full use of it. For visually impaired people, interaction based on haptic feedback is a natural way of receiving information.

According to Goldreich (2010), visually impaired people are able to detect tactile information faster than sighted people.[44] In a study conducted with 150 volunteers, the participants were asked to discriminate between movements of a small probe that was tapped against the tips of their index finger. Participants who were blind since birth were performing significantly better than other visually impaired who obtained their condition later in life or than sighted users.

Assistive technology based on haptics has been important for the visually impaired for accessing print resources and allowing mobility in the environment. The most common way of tactile display of text is in the form of braille.[45] The letters and symbols, including musical notes, are coded in a six-point matrix embossed into the paper. Well-trained people can discriminate between the point patterns with their fingertips and can read the text this way. Another example of using haptics is the use of a white cane and guide dogs that are used to navigate in the environment and avoid obstacles. The white cane provides information about the obstacles and characteristics of the walking surface, which allows the visually impaired to be independent.[46]

43. Blake Hannaford and Allison M. Okamura, "Haptics," in *Springer Handbook of Robotics*, ed. Bruno Siciliano and Oussama Khatib (Springer Berlin Heidelberg, 2008), 719–739, https://doi.org/10.1007/978-3-540-30301-5_31.

44. Arindam Bhattacharjee et al., "Vibrotactile Masking Experiments Reveal Accelerated Somatosensory Processing in Congenitally Blind Braille Readers," *Journal of Neuroscience* 30, no. 43 (October 2010): 14288–14298, https://doi.org/10.1523/JNEUROSCI.1447-10.2010.

45. Gunnar Jansson, "Haptics as a Substitute for Vision," in *Assistive Technology for Visually Impaired and Blind People.* Ed. Hersh M. and Johnson M. (Springer London, 2008), 135–166, https://doi.org/10.1007/978-1-84628-867-8_4.

46. **ibid**.

Haptics is an essential part of visually impaired people's cognition of the world around them.

These low-tech aids are an example of very efficient and useful assistive tools visually impaired people use in daily tasks and interactions with physical objects in the real world. The advent of computers and increased use of information display in virtual environments through graphical user interfaces (GUI) made the human-computer interaction (HCI) for the visually impaired challenging.[47] The information on-screen is not accessible for the visually impaired because, by default, there is no auditory or haptic feedback provided. One of the first efforts of making GUIs accessible was the GUIB project in 1994.[48] It made the use of technology such as screen readers as well as novel pointing devices such as tactile computer mouse. Since then, many haptic interfaces were developed. Several haptic interfaces and their use by the visually impaired are presented in the following section to illustrate haptic interaction possibilities.

2.4.2 Haptics interfaces

Haptics interfaces aim to recreate the sense of touch by applying force, vibration, motion and textures. The information provided through these sensations enhances the users' interaction with virtual environments. Integrating haptic interfaces with sound and graphic components has created a new computer interaction experience. For example, users can get a sense of touch in virtual environments. When virtual objects are interacted with, they seem to be real and tangible. The created sensations help with operating virtual interfaces, and they augment the control properties of machines and devices.[49] Haptics interfaces are ranging from state-of-the-art devices to very simple ones. The best known haptic interface is probably an actuator inside a smartphone that vibrates when a user gets a notification.

At the time of writing, the haptic industry is developing rapidly, and new interfaces powered by novel technology are created at a high pace. As a result, the combination of haptic with

47. P. L. Emiliani, "Overview of the GUIB project," in *IEE Colloquium on Information Access for People with Disability* (1993), 11/1–11/3, https://ieeexplore.ieee.org/document/241321.

48. Gerhard Weber et al., "Training blind people in the use of graphical user interfaces," in *Computers for Handicapped Persons*, ed. Wolfgang L. Zagler, Geoffrey Busby, and Roland R. Wagner (Springer Berlin Heidelberg, 1994), 25–31.

49. Heather Culbertson, Samuel B. Schorr, and Allison M. Okamura, "Haptics: The Present and Future of Artificial Touch Sensation," *Annual Review of Control, Robotics, and Autonomous Systems* 1, no. 1 (May 2018): 385–409, https://doi.org/10.1146/annurev-control-060117-105043.

other senses in human-computer interaction is becoming more common.[50] Companies involved in the haptic industry are working on a broad range of applications for these interfaces, including automotive, entertainment, rehabilitation, and assistive technology.

The types of haptic interfaces can be sorted into three main categories based on their characteristics: graspable, wearable and touchable,[51] as displayed in Figure 2.3 (image by Culbertson et al.).[52] *Graspable* interfaces are typically fixed, and the user holds a tool that provides haptic feedback. *Wearable* interfaces are typically attached to the user's hand or body. Typical applications of such a tool are haptic gloves or exoskeleton. *Touchable* interfaces provide haptic feedback from a surface that user can touch with a finger without the requirement of holding it in hand.

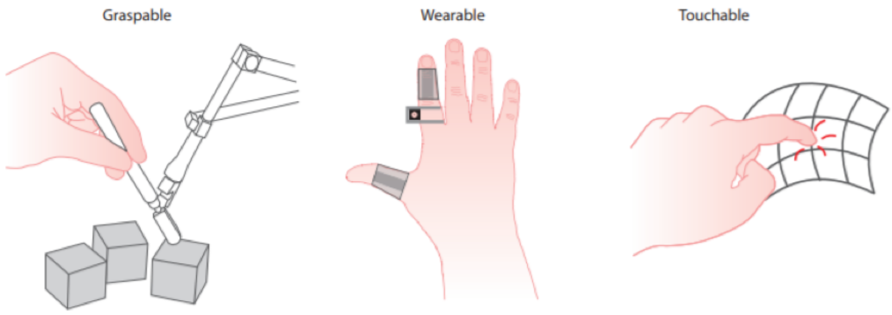

Figure 2.3: Graspable, wearable and touchable haptic interfaces

2.4.3 Examples of haptics interfaces

As mentioned above, there is a wide variety of haptic interfaces. Some of them are in development, and some are already implemented in the devices we use every day. This lists examples of mid-air and surface haptics interfaces. A thorough review of haptics interfaces was provided by Soni and Singh (2018).[53] This thesis focuses on mid-air and surface haptics interfaces for their versatility and particularly suitability for music production tasks.

50. Sreelakshmi and Subash, "Haptic Technology: A comprehensive review on its applications and future prospects."
51. Culbertson, Schorr, and Okamura, "Haptics: The Present and Future of Artificial Touch Sensation."
52. Heather Culbertson, Samuel Schorr, and Allison Okamura, *Examples of graspable, wearable, and touchable haptic systems. These three categories describe the breadth of interaction modalities for kinesthetic and cutaneous stimulation in interactive haptic devices.*, https://doi.org/10.1146/annurev-control-060117-105043.
53. Soni Saloni and Singh Ajmeet, "Haptic Technology," *Iconic Research And Engineering Journals* 1, no. 9 (March 2018): 333–338, https://irejournals.com/formatedpaper/1700502.pdf.

2.4.3.1 Mid-air haptics

Mid-air haptics interfaces do not require the user's hand to be in direct contact with actuators. Instead, interfaces create contactless haptic feedback in mid-air, usually between 15 to 30 cm above the interface.[54] A company named Ultraleap developed a mid-air haptics interface using an array of 256 ultrasonic transducers that project an ultrasonic sound wave with frequencies around 40 kHz. The user places their hand above the device, and they can feel haptic sensations on their palm. As the hand cannot perceive vibrations produced by the ultrasonic signal, the signal frequency gets modulated to around 200 Hz which creates vibrations detectable by the human hand. Sound waves are produced to create localized focal points on the user's hand. This is done by controlling the phase and intensity of each transducer.[55]

Mid-air haptics technology is available for purchase mainly for research and development purposes. Probably the most accessible mid-air haptics interface is a Stratos Explore by Ultraleap. It is combined with the Motion Leap hand tracker, which allows displaying haptic feedback very accurately on the user's hand and fingertips. Thanks to LeapMotion, the user can interact with the information by using hand gestures.[56]

One of the examples of mid-air haptics potential for accessibility is a study utilizing Ultraleap Stratos Explore to convey Braille symbols. The study showed promising results, and respondents reacted positively to the experiments. The average accuracy of 88% was achieved during the user study.[57] There are many possible applications of this technology, such as displaying information in elevators and public transport. Technology has great potential for improving the quality of everyday life for visually impaired people.

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54. I. Rakkolainen, A. Sand, and R. Raisamo, "A Survey of Mid-Air Ultrasonic Tactile Feedback," in *2019 IEEE International Symposium on Multimedia (ISM)* (December 2019), 94–944, https://doi.org/10.1109/ISM46123.2019.00022.
55. Ultraleap, *Turning ultrasound into virtual touch*, Online; accessed 20 November 2020, https://www.ultraleap.com/haptics/#how-it-works.
56. **ibid**.
57. Viktorija Paneva et al., "HaptiRead: Reading Braille as Mid-Air Haptic Information," in *Proceedings of the 2020 ACM Designing Interactive Systems Conference* (New York, NY, USA: Association for Computing Machinery, July 2020), 13–20, https://doi.org/10.1145/3357236.3395515.

2.4.3.2 Surface haptics

The surface haptic interfaces create programmable tactile feedback on different types of surfaces. One of the possible applications of a haptic interface is the implementation into touch screens. Conventional touch screens, tablets and smartphones can very accurately locate and measure human inputs. However, humans receive no haptic feedback in return, and the outputs of these devices are limited mainly to auditory and visual. Using surface haptic technology in touch screens enhances the user's experience.

The surface haptic interfaces produce variable forces on a user's fingertip as the user moves the finger across the surface. Different types of interfaces utilise different techniques to create haptic feedback, such as ultrasonic vibrations or electrostatic fields. Most of these devices are not available for purchase and are still being developed. Basdogan et al. (2020) gave a comprehensive overview of surface haptics technology.[58] These devices can find application in various industries such as automotive and aviation. Applications in these industries have the potential to work in combination with vision when the user is able to locate a button on the display with just a short glance, thanks to the haptic feedback. For the visually impaired, it is necessary to consider the usefulness of applying this technology for haptics alone, possibly enhanced with auditory information.[59]

Several companies are working on surface haptic interfaces. The company Tanvas developed the TanvasTouch, an interface that allows developers to use programmable textures and haptic effects that can be felt on touch screens and physical surfaces. TanvasTouch uses electroadhesion to modulate the friction between the finger and the surface.[60] Hap2U is a company developing a touch screen display with a cover glass with piezoelectric actuators. This 1 mm thick layer vibrates under the excitation of piezoelectric transducers.[61] Both of these interfaces can produce tactile sensations that create distinct levels of resistance on various surfaces.

Surface haptics has the potential to improve the accessibility of touch screen devices and enhance

58. Cagatay Basdogan et al., "A Review of Surface Haptics: Enabling Tactile Effects on Touch Surfaces," *IEEE Transactions on Haptics* PP (April 2020): 1–1, https://doi.org/10.1109/TOH.2020.2990712.

59. Jansson, "Haptics as a Substitute for Vision."

60. Craig Shultz, *Surface haptics technology enriches touchscreen interactions*, 2020, accessed November 11, 2020, https://uxplanet.org/surface-haptics-technology-enriches-touchscreen-interactions-6234db897321.

61. hap2U, *Surface Haptics: feedback technology for tactile screens*, accessed February 20, 2020, https://www.hap2u.net/haptic-technology/.

the way visually impaired people interact with these devices. For example, surface haptics could be used with a screen reader, making it possible to locate a number on a dial pad eyes-free.

TanvasTouch

The TanvasTouch Desktop Development Kit has been made available recently for research and development purposes, and it is not yet a commercially sold product. The state-of-the-art technology allows precise multi-touch tracking of the user's fingertips and produces real-time variable friction to each fingertip in contact with the touch screen surface.[62] Variable tactile sensations can be mapped onto graphical information. The haptic sensation, such as a surface texture, can be felt with a finger swipe. The Development Kit features a touch screen similar to a regular tablet.

In contrast to the actuators found in current smartphones, the TanvasTouch technology is solid-state, and there are no moving parts. Thanks to these characteristics, it can be implemented not only in glass touch screens but also in various other surfaces and curved displays.

62. Shultz, *Surface haptics technology enriches touchscreen interactions.*

Chapter 3

touchEQ: a surface haptic application

3.1 Introduction

Based on literature review findings and by conducting interviews with visually impaired music producers, the author identified an equalizer with the EQ curve's visual representation as a suitable audio effect to be used in the surface haptics application. The surface haptic interface provides the possibility to "view" a graphical EQ curve that is impossible to do with other currently available accessibility tools. In this study, this approach is applied to the audio equalizer. However, one can anticipate that a similar approach has the potential to be applied to a broader range of audio plugins and processing techniques.

In this chapter, the design and development choices for designing an accessible application for the surface haptic interface are unpacked. The application is called touchEQ, as a reference to an equalizer that can be controlled with touch. Haptic effects and sensations that have been created to explore the possibilities and limitations of TanvasTouch tactile feedback in music producers' workflow are presented.

Surface haptics has a broad potential for implementation in multiple fields of human-computer interaction and especially in improving accessibility for visually impaired users. One of the main objectives of this study is to develop a working application that the user will be able to operate eyes-free. This was done by creating haptic feedback for important user interface elements. The potential use in professional practice by sighted music producers was also considered. While non-visual interfaces are essential for visually impaired users, they also reduce the visual load for sighted users. Studies have shown that a high visual load can result in decreased critical listening[1] and negatively influence aural perception.[2]

The purpose of this study is not to test the TanvasTouch technology per se, but rather to use it to design an equalizer that will allow eyes-free operation and then test this application. Additionally, the intention of designing the touchEQ application is to enable a discussion about the possibilities and relevance of surface haptics in the context of music production for both visually impaired and sighted music producers and, thus, create opportunities for collaboration.

3.1.1 Equalizer

An equalizer (EQ) is a signal processing tool that features several different types of filters that increase or decrease the level of specified frequencies.[3] The effect of the equalizer can be displayed with an EQ curve representing the energy boost or cut.[4] An example of an EQ curve display in EQ is presented in Figure 3.1 (image by TAE Source[5]). The GUI of EQ audio plugins varies: some of the designs mimic hardware units and utilise rotary sliders, while others have a more innovative design, for example, with a visual representation of an EQ curve. As discussed in the literature review, operating the control elements displayed on the screen is challenging for the visually impaired users. The graphical display of an EQ curve is not accessible by screen readers, so visually impaired users miss out on an essential feature of the software.

1. Josh Mycroft, Joshua Reiss, and Tony Stockman, "The Influence of Graphical User Interface Design on Critical Listening Skills" (July 2013).
2. Michael Schutz and Scott Lipscomb, "Hearing gestures, seeing music: Vision influences perceived tone duration," *Perception* 36 (February 2007): 888–97, https://doi.org/10.1068/p5635.
3. Paul White and Matt Houghton, December 2008, accessed February 24, 2020, https://www.soundonsound.com/techniques/whats-frequency.
4. Andrew T. Sabin and Bryan Pardo, "2DEQ: An Intuitive Audio Equalizer," in *Proceedings of the Seventh ACM Conference on Creativity and Cognition* (Association for Computing Machinery, October 2009), 435–436, https://doi.org/10.1145/1640233.1640339.
5. TAE Source, *A visual parametric EQ implementation.*, accessed March 5, 2021, https://www.taesource.com/2020/07/impressions-of-tae-editor.html.

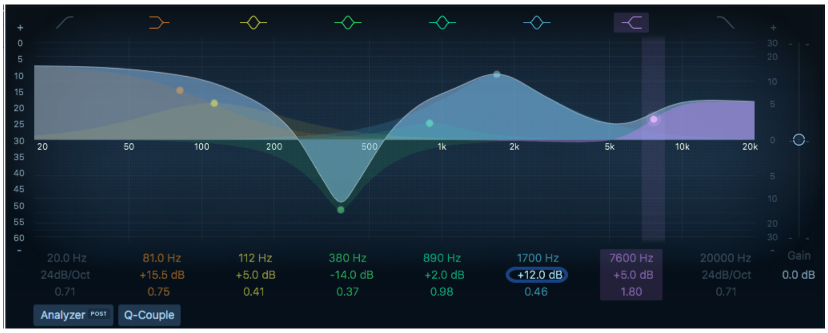


Figure 3.1: An equalizer with a visual display of an EQ curve

Generally, GUIs of parametric equalizers are complex even for sighted music producers. Sabin and Pardo argue that complexity can be a significant bottleneck in the creative process. Attention to the creative process can be disrupted by a large number of parameter settings and graphical elements.[6] Because these GUIs aim to display a lot of data at once, it can be challenging for the user to navigate in the application. The touchEQ application development goal was to build a parametric EQ with a simple user interface and with both a graphical and haptics representation of the EQ curve. The parameters of the touchEQ are controlled with faders and buttons. All these graphical elements have a haptics layer which enables completely non-visual interaction.

3.1.2 TanvasTouch

The application was developed using a state-of-the-art surface haptic interface TanvasTouch, a 10.1-inch touch screen with a 1280 x 800 px resolution. This innovative technology enables precise fingertip tracking and simultaneous haptic rendering. This way, the device can deliver the haptic feedback on the right spot of the screen. The haptics rendering requires both hardware and software to work simultaneously. The haptic sensations are software programmable by sending appropriate visual renders of haptic effects to the Tanvas Engine. The Tanvas Engine gets texture data from black and white image asset. White colour translates to 100% friction and full black to 0% of friction, which gives the developer 256 levels of haptic feedback strength to operate with. Different haptic sensations can be produced by creating textures and patterns made from

6. Sabin and Pardo, "2DEQ: An Intuitive Audio Equalizer."

elements with grayscale colours, as illustrated in the Figure 3.2 (image by Tanvas).[7]

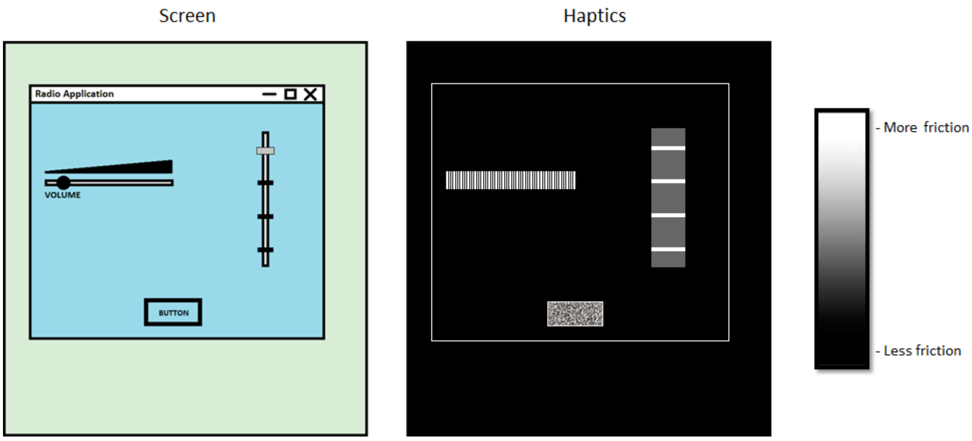


Figure 3.2: The first diagram shows the GUI. The second one illustrates the haptic values on the TanvasTouch device which correspond to the GUI.

The touch screen's haptic layer works on the electroadhesion principle, which is used to modulate the surface friction.[8] The voltage that is being applied to the indium tin oxide (ITO) matrix layer of the devices is changed by TanvasTouch Engine and API.[9] Thus, the adhesion of the user's finger to the touch screen surface can be manipulated. The normal friction between the finger and glass gets amplified and modulated, leading to an illusion of touching textures and surfaces.

At the time of writing, TanvasTouch Development Kit is only available as a resource for developers and academics and is not available as a commercial product for larger markets. Looking towards future deployment, the advantage of this technology is that only one extra ITO layer needs to be added in the manufacturing process of a regular touchscreen. The structure of TanvasTouch display can be seen in Figure 3.3 (image by Tanvas).[10] Therefore, there is a potential for a relatively straightforward implementation of this technology to conventionally used touch screens.

7. Tanvas, *Visual and haptic representation of a graphical user interface*, accessed March 5, 2021, https://tanvas.co/wp-content/uploads/2019/11/app.png.

8. Olivier Bau et al., "TeslaTouch: Electrovibration for Touch Surfaces," in *Proceedings of the 23nd Annual ACM Symposium on User Interface Software and Technology* (Association for Computing Machinery, October 2010), 283–292, https://doi.org/10.1145/1866029.1866074.

9. Shultz, *Surface haptics technology enriches touchscreen interactions*.

10. Tanvas, *Representative one-glass construction*, accessed March 5, 2021, https://miro.medium.com/max/1400/1*Sjmv5mbDD7Xa3uczkSshcA.jpeg.

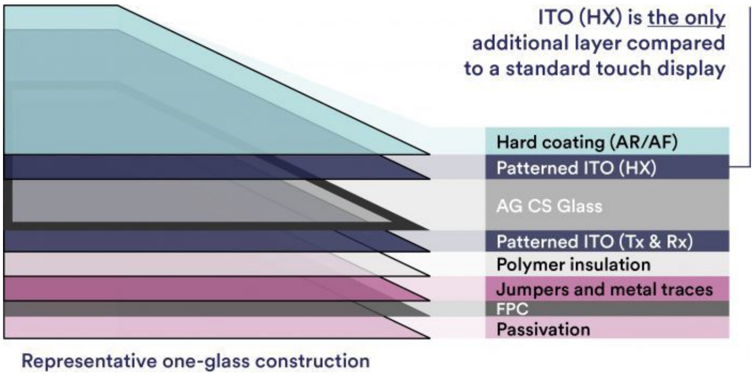


Figure 3.3: The implementation of electroadhesion-based surface haptics in a display assembly requires only the addition of a patterned ITO layer on the cover glass.

Based on the author's observations and experiments, TanvasTouch surface haptics is suitable for identifying a 2D shape, differentiation between textures, and localization of 2D objects on the screen. The design of the haptic effects is discussed in detail in Section 3.2.

3.1.3 Related work

The most similar previous work is that of Karp and Pardo, who also designed an equalizer that is accessible for the visually impaired (HaptEQ). It is a "tactile interface that lets blind or visually impaired users create an EQ curve in an intuitive manner."[11] The interface uses image recognition to identify the shape of a chain placed on a board with a solid background. By dragging the chain up and down on the board, the user changes the shape of the EQ curve in the equalizer plugin that runs in a DAW. The HaptEQ presents a simple method to alter the audio with inexpensive equipment.

Another similar tool created is the HapticWave, designed to help visually impaired music producers with audio editing. The interface renders audio data as kinesthetic information that a user can feel with their finger.[12] The user can explore the audio waveform and change the time domain by pulling the slider in the horizontal direction. As the user drags the slider, the audio

11. Aaron Karp and Bryan Pardo, "HaptEQ: A Collaborative Tool For Visually Impaired Audio Producers," in *Proceedings of the 12th International Audio Mostly Conference on Augmented and Participatory Sound and Music Experiences* (Association for Computing Machinery, August 2017), https://doi.org/10.1145/3123514.3123531.
12. Adam Parkinson and Atau Tanaka, "The Haptic Wave: A Device for Feeling Sound," in *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (Association for Computing Machinery, May 2016), 3750–3753, https://doi.org/10.1145/2851581.2890249.

amplitude changes in value and electric motors push the slider up or down accordingly. The shortcoming of this device is that it does not offer the possibility to alter the audio. Further, it is a sophisticated mechanical interface that is difficult to manufacture on a large scale, and it serves only one purpose.

Both HaptEQ and HapticWave interfaces require a physical unit that is designed for one specific task. In this work, the author seeks to design an application for an already existing device rather than to design a whole new device. Novelty haptics interfaces such as TanvasTouch are designed to be deployed in a larger market application than just accessibility. It is targeted to be used in tablets, the automotive industry, for retail, and gaming. Therefore, it has the potential to be used by more people than just a relatively small group of visually impaired music producers. As opposed to many tools designed only for the visually impaired, when used by a larger market, the technology's price can be lowered, updates can be more frequent, and the visually impaired and sighted users can benefit from these advancements. There is currently no research done in the field of accessible music production software with the TanvasTouch or a similar surface haptic interface to the author's knowledge.

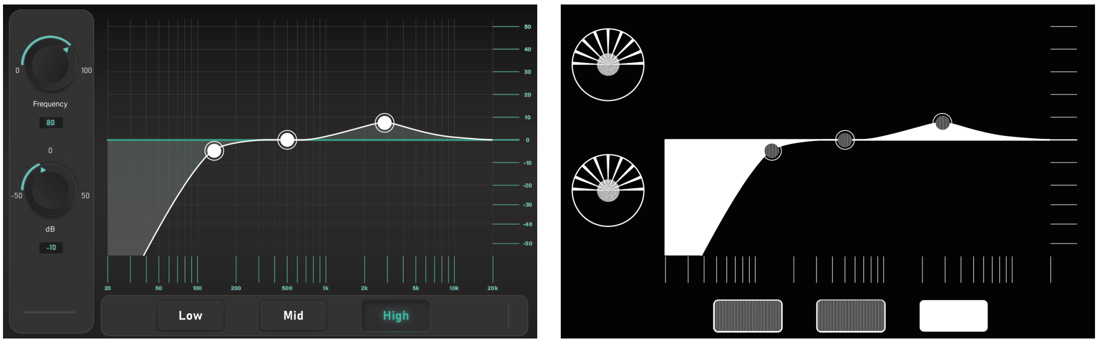
TanvasTouch also presents a compact device that could be easily implemented in a studio setup because of its convenient dimensions. Furthermore, it could be used for operating multiple audio plugins other than an equalizer. Various applications such as audio editing tool, compressor, audio source panner could be developed for TanvasTouch. For a studio owner, it represents a much more convenient setup than having multiple single-purpose devices.

3.2 Design

3.2.1 Introduction

The main goal was to design a 3-band parametric equalizer with a visualisation that can be controlled only with haptic feedback without any visual cues. This was achieved by designing a simple and effectively organized user interface combined with haptic feedback, which is discussed in this section. Specific haptic effects for each control element were designed for this purpose.

A graphical user interface for the touchEQ was also designed to allow sighted music producers' straightforward workflow. The aim was to develop an application that could be used by both visually impaired and sighted music producers to allow collaboration among them. The same application is accessible to visually impaired and sighted music producers. The visually impaired producers can control the EQ due to the haptic layer, while the sighted producers can take advantage of both visual and haptic layers. An initial design of these two layers is displayed in Figure 3.4.



(a) GUI design

(b) Haptic layer

Figure 3.4: Early design of the touchEQ. Control elements were later rearranged and knobs were replaced with faders.

3.2.2 Haptics design

As presented in the previous chapters, haptics is an important sense in everyday interactions such as identifying objects, materials, and textures especially for the visually impaired. Jansonn (2008) suggests that it is essential to keep the possibilities and limitations of haptics in mind when investigating the use of haptics in assistive technology.[13] He argues that if an interface fails to provide the information to the user, the fundamental reason might be a misjudgment of haptics' capabilities. Therefore, a realistic evaluation of haptics possibilities is needed throughout the design stage of an application. GUIs offer a possibility to present a large amount of information simultaneously, which is not possible to achieve with a non-visual interface.

One of the most significant advantages of vision over haptics is the ability to get an overview

13. Jansson, "Haptics as a Substitute for Vision."

of the whole user interface in a relatively short time. Getting an overview with touch is more time-consuming. However, Klatzky and Ledermann (1995) suggest that a haptic glance, a short contact with the object, can be used to get a quick overview of an object.[14] This applies especially if the observer "has hypotheses about what object to expect and the identification is based on local properties such as texture." Jansonn points out that when displaying graphs with haptics, one has to consider the difficulty of providing an overview. Some symbols that are easily recognized with vision are challenging to display with haptics.

As described in the literature review, music production plugins often rely on displaying information in a complex graphical form. This information display has to be designed differently for haptics. For example, grids in a graph that are helpful for sighted people are perceived as data lines when displayed with haptic feedback on TanvasTouch. These aspects were taken into consideration during the design process of the touchEQ application.

3.2.3 Control elements

The touchEQ is made out of several dynamic control elements discussed in detail in this subsection. These elements are represented by both graphic and haptic layers, and the elements are interactive so the user can change their value. The final version of the touchEQ layout is presented in Figure 3.5.

Fader

The fader is the central control element. There are three faders that control the values of the equalizer: gain, frequency, and Q (bandwidth). This is an element that users must locate to activate it and then drag it up and down to adjust the values.

Band buttons

Band buttons switch between three bands: low, mid, and high. The buttons are rectangular with a fixed position above the faders, making it easy to locate them. Haptic feedback indicates which button is currently selected.

14. Roberta Klatzky and Susan Lederman, "Identifying objects from a haptic glance," *Perception & Psychophysics* 57 (November 1995): 1111–1123, https://doi.org/10.3758/BF03208368.

Graph

The graph section of the interface displays EQ curves. A user can read the values that are set to the equalizer. X and Y axes of the graph are highlighted with haptic feedback.

Transport panel

The transport panel is used to load an audio file from the disk and for the audio playback. There is also a reset button that resets all the parameters to their initial value. These buttons do not provide haptic feedback as the panel will not be needed if the touchEQ runs inside a DAW.

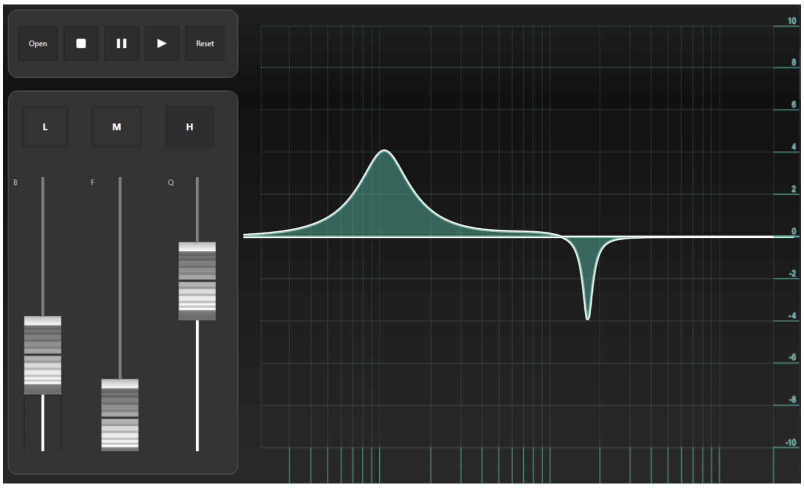


Figure 3.5: The final version of the touchEQ layout

3.2.4 Interaction design

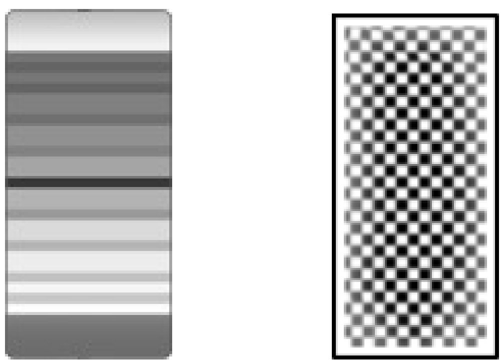
TanvasTouch interface can provide the user with various haptic sensations. For sighted users, haptic feedback is generally used to enhance the interaction with the touch screen. For the visually impaired, it is more than just an enhancement. The haptic feedback makes it possible to use and control software without auditory feedback, which, for the visually impaired, is an entirely new form of interaction with a touch screen. Interaction design for all the control elements was created and is discussed in the following subsection.

The TanvasTouch can produce 256 levels of intensity of friction at each pixel, as described in Section 3.1.2. The intensity gets manipulated by grayscale assets where black colour translates to 0 (minimum) friction and white colour to 255 (maximum) friction. Based on the resources provided in the TanvasTouch Development Kit and on the author's experiments, creating haptic effects from patterns such as stripes or grid chess pattern was identified as the best way to create haptic feedback on TanvasTouch. These patterns are usually formed from black (minimum friction) and white (maximum friction) colour elements but other shades of grey can be used if required.

3.2.4.1 Faders

There are three faders that are used to change the gain, frequency, and Q parameters of the equalizer. Each fader has a visual layer and a haptic layer, as presented in Figure 3.6. The faders' location in the GUI can be seen in Figure 3.5

Initially, rotary sliders were used as the means to control the values. However, based on feedback from a visually impaired person, rotary sliders were too difficult to interact with because they could not identify the controller's size. As a result, they could not tell the proportion of the rotating movement necessary to adjust the value, which was quite frustrating for them. Thus, a slider with a vertical orientation was identified as a more suitable control element. In the final version of the prototype application, vertical sliders that resemble faders that can be seen on a mixing desk were used.



(a) GUI visual layer (b) Haptic layer

Figure 3.6: Detail of the fader control element

Locating the fader

The user's first action when interacting with the touchEQ is to explore the interface and try to locate the fader. The fader's surface is highlighted with a haptic effect (inactive haptic effect) that is formed from a chess grid black and white pattern. This effect distinguishes the fader from the background and allows the user to precisely locate it. When the user slides their finger across the fader's surface, they can get a sense of its the size and location and at that point, they are ready to select it. This procedure broadly follows how a visually impaired audio engineer might be locating a physical fader on a mixing desk.

Selecting the fader

The selection of the fader happens when the user explicitly clicks on it to drag it. The user must additionally lift their finger and place it back down on the fader to start moving it. This prevents the fader's unintentional dragging during the locating of the fader or other interactions with the application.

Dragging the fader

When the user starts dragging the fader, the operating haptic effect gets enabled. When moving the fader in a vertical position up and down, the user receives tactile feedback. Therefore, the user can be sure that the fader's selection was successful and the values are being changed. The dragging of a fader ends when the user sets the desirable value.

Deselecting the fader

The interaction with the fader is finished by lifting a finger at the desired position. The operating haptics gets disabled, and the locating haptic effect is enabled again. This completes the fader interaction cycle and it is ready to be interacted with again.

Inactive haptic effect

The purpose of the fader's inactive haptic effect is to make it as easy as possible to locate the fader. When the user slides their finger across the fader, they feel a strong texture that stands out from the rest of the interface. To create this effect, a haptic image that consists of a black and white chess-patterned grid was created. This pattern is fading out into a white area which represents 100% friction. This provides a contrasting edge with the black background (0% friction). As a result, the fader has easily detectable region-based haptic feedback.

Operating haptic effect

The intent of the haptic effect that is active during the fader's dragging is to emphasize motion and transition. Horizontal lines of white colour (100% friction) and medium width (4 px) mark the fader's tick points. Combining full black (0% friction) background with lines that have the maximum friction leads to a strong haptic perception. This means that if the user feels a tactile tick, they are instantly aware that they are moving the fader.

The 0 value of the fader is highlighted with condensed white lines. This is to ensure that the 0 value stands out and the user can locate it. Due to this haptic effect, the user can instantly tell when they are dragging the fader across the 0 value. It increases the user's orientation and helps to set the values accurately. Figure 3.7 shows the haptic effect that gets activated when the user starts dragging the fader. Three fader tracks are next to each other, one for each fader, following the control element layout displayed in Figure 3.5.

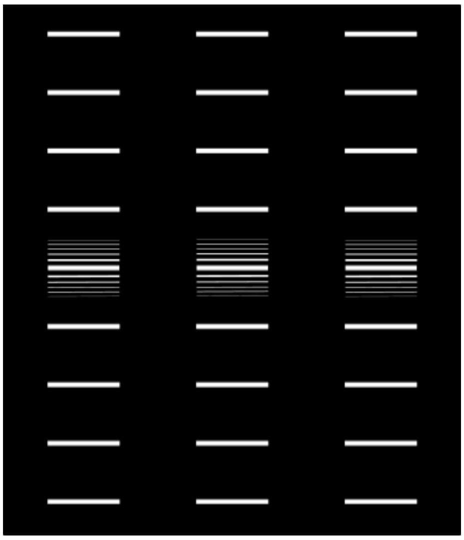


Figure 3.7: Haptic effect displayed when the fader is being dragged

Size of faders

The size of a fader was chosen based on the proportion to the screen size. The fader has to be large enough to be easy to locate. However, there has to be enough space between the faders. Otherwise, there would be too many haptics objects in a small space, making it confusing for the user. In the end, the size of 60 x 126 px (15,5 mm x 33,2 mm) was chosen as a compromise between these two factors.

3.2.4.2 Buttons

The buttons have the purpose of switching between three EQ bands: low, mid, and high frequencies. The low band is selected as a default when the touchEQ is loaded. All of the buttons have haptic feedback. Two haptic effects are used to differentiate between selected and unselected buttons.

Locating the button

Each button has a different haptic effect as seen in Figure 3.8. The buttons are located in a fixed position on the screen, making it easy to find. The selected button has a black and white high noise grain background. This leads to a strong texture that stands out. The unselected buttons have a striped black and white pattern. This pattern is still also easily noticeable but it is different from the grain pattern. As a result, the user can tell which band is currently selected.

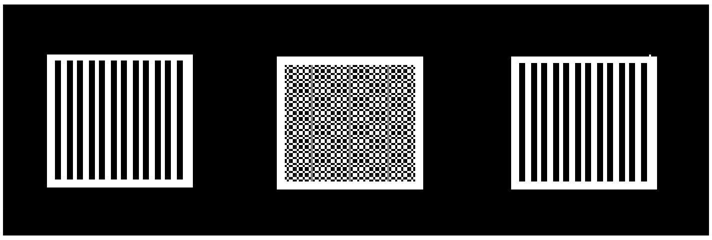


Figure 3.8: Button haptic effects. The middle button is selected.

Clicking the button

The user can switch between the bands by clicking an unselected button. A successful click triggers a band change followed by a short click sound which informs the user that the band selection has changed. Previous studies by McGee et al.[15] and Kasamatsu et al.[16] explored combining haptic and auditory feedback and showed promising results and suggested that using auditory and haptic feedback increases the positive experience of the user. In a music production

15. Marilyn McGee, Philip Gray, and Stephen Brewster, "The Effective Combination of Haptic and Auditory Textural Information," vol. 2058 (January 2000), 118–126, https://doi.org/10.1007/3-540-44589-7_13.

16. Keiko Kasamatsu et al., "Effective Combination of Haptic, Auditory and Visual Information Feedback in Operation Feeling," in *Human-Computer Interaction. Novel Interaction Methods and Techniques*, ed. Julie A. Jacko (Springer Berlin Heidelberg, 2009), 58–65.

context, auditory feedback should be used with consideration as overuse of audio stimuli could result in conflict with the audio playback.

3.2.4.3 Graph

The purpose of the graph is to provide the user with information about the EQ curve. The curve gets dynamically updated when the user changes the gain, frequency, or Q value. In combination with the auditory feedback, the user can get a precise idea of what parameters are currently set to the equalizer. The graph is not an interactive element, meaning that the user can only read the values and not alter them. Dragging of the EQ curve is used in several commercially available equalizers such as Fabfilter Pro-Q 3, which is popular for its fast workflow. Having a possibility to drag the EQ curve directly in the graph and change the values is one of the possible future developments of the touchEQ.

Reading values from the graph

Haptic exploration allows the user to discover the EQ curve shape. EQ curves are displayed in the form of a striped pattern with black and white lines of 3 px width, as displayed in Figure 3.9. This was identified as the most suitable haptic effect in the exploratory usability test (Section 4.2). Two haptic effects were tested during the initial usability study. EQ curves vary in size and shape and can be very narrow but also very wide, which had to be considered in choosing the haptic effect. All six participants preferred the striped pattern as it made it easier for them to locate the exact position of the EQ curve.

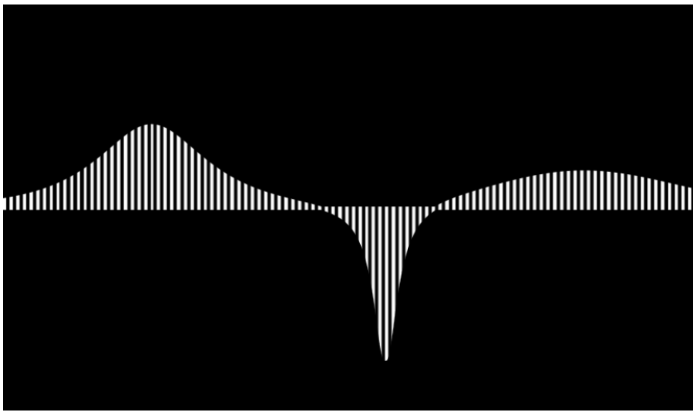


Figure 3.9: Haptic effect for displaying EQ curves

As mentioned above, Jansonn's[17] argues that a visual display can not be directly transformed into a haptic display but rethinking the design is necessary. Thus, some information usually found in visual graphs was omitted from the haptic design. The frequency and decibels grid, which is often found in the industry-standard equalizers, had to be removed from the haptic layer because it made it impossible to read the data areas correctly. The graph design was also tested in the exploratory usability study. The 0 line is displayed with a haptic effect as it highlights the middle of the graph and improves the user's orientation in the graph.

3.2.5 User interface layout

The initial user interface layout can be seen in Figure 3.4. Several versions of the user interface layouts were considered and tested during the design process. The final design, presented in Figure 3.5, consists of two main parts. On the left side of the screen, there is a control area with buttons and faders, which covers 30% of the screen size. The rest of the screen is used to display the EQ curve in the graph. The reasoning for this layout is to provide a big enough graph so the user can comfortably read the data but at the same time provide enough space for faders and buttons so they can be controlled without visual feedback. TouchEQ running on TanvasTouch is presented in Figure 3.10.

Figure 3.10: The final version of the touchEQ prototype running on the TanvasTouch interface

17. Jansson, "Haptics as a Substitute for Vision."

3.3 Software technical details

In order to make a working application for the TanvasTouch interface, the appropriate programming language had to be chosen. Nowadays, most of the audio programming for virtual instruments and audio effects is usually done in C or C++ programming languages because of their favourable performance and relevant features when compared to other languages. Audio frameworks such as JUCE provide a good starting point for developers and make DSP processing manageable. These options were considered and could be a suitable choice for common audio plugin development.

The TanvasTouch API is written primarily in C# .NET and at the time of writing, the C++ API version is highly unstable. To prevent cross-language programming issues, the touchEQ was developed as a Windows Presentation Foundation C# .NET application. The high-level C# API is used for adding surface haptic interactions to the .NET application.

The touchEQ application consists of three main components. The first component is the NAudio framework which is used for audio playback and for adjusting the frequency balance. Secondly, it uses the OxyPlot .NET library that is used for displaying the EQ curves. The graph reads the values that are being set to the NAudio framework and creates the EQ curve. Finally, it uses TanvasTouch API to create haptic feedback. XAML (Extensible Application Markup Language) is used for describing the GUI of the application.

3.3.1 Equalizer

The touchEQ is a 3-band equalizer constructed using digital biquad filters. The filter design is based on the peaking EQ formula and coefficients specified by Robert Bristow-Johnson.[18] The filters are used to affect frequencies of audio that is in the playback. As such, it applies peak (bell) shaped gains or cuts. Other types of curves, such as shelves or high pass or low pass filters, can be implemented in future versions.

18. Robert Bristow-Johnson, *Cookbook formulae for audio EQ biquad filter coefficients*, accessed March 1, 2021, https://webaudio.github.io/Audio-EQ-Cookbook/Audio-EQ-Cookbook.txt.

3.3.2 Platform support

The touchEQ is a standalone application that runs on Windows 10 and higher. In future development, it is possible to wrap the application in a VST host to make it work inside a DAW. The future support for macOS and other platforms is a possibility. It would be desirable from the user's point of view because, in the audio industry, macOS is often used in a professional recording situation. The main restraint in this regard is that the TanvasTouch Engine currently runs only on Windows 10 and higher, making it impossible to offer support for more platforms.

Chapter 4

Methodology

In the literature review, this thesis makes use of a discourse analysis research methodology. Robson defines content analysis as a codified common sense, a refinement of ways that might be used by laypersons to describe and explain aspects of the world around them.[1] By reading and analysing relevant literature, an overview of the accessibility of music production software was provided. Primary data was collected by conducting fully structured email interviews with visually impaired music producers. These interviews brought an insight into the visually impair music producers' workflow. Further, it helped identify potential shortcomings of the technology currently used and highlighted the areas where haptic feedback could be used as an alternative form of interaction.

In the methodology part, this thesis adopts human-computer interaction (HCI) as the main field of investigation. This thesis aims to propose a surface haptic audio application and test if it is possible to control it eyes-free, direct feedback from interested individuals is fundamental for this type of research.[2] The study uses commonly used methodology in HCI such as usability testing and interviews to gather feedback from individuals who are presented with a piece of new technology. Both qualitative and quantitative data can be collected during the usability tests.

1. Colin Robson and Kieran McCartan, *Real World Research, Fourth Edition*, Fourth Edition (December 2017).
2. Jonathan Lazar, Jinjuan Heidi Feng, and Harry Hochheiser, "Usability testing," in *Research Methods in Human Computer Interaction*, Second Edition (Morgan Kaufmann, 2017), 263–298, https://doi.org/10.1016/B978-0-12-805390-4.00010-8.

This research was affected by the COVID-19 pandemic and the methodology had to be adjusted over the course of the study to make sure that the planned procedures were in line with the current government measures. The way the research was affected is discussed in the last section of this chapter.

4.1 Usability testing

Usability testing is a research method used to evaluate the software by testing it on real users. Generally, it is used to ensure that the final version of an application is intuitive and easy to use for the target audience by finding weak areas that need improvement in early versions of an application.[3] According to Lewis, usability testing involves representative users attempting representative tasks in representative environments, on early prototypes or working versions of computer interfaces.[4] Commonly, a usability test study includes the following five stages: obtain suitable participants, design test scripts, conduct usability sessions, interpret test outcomes, and produce recommendations.[5]

In this study, exploratory and summative user-based tests were conducted to evaluate the proposed touchEQ application's usability. In both of these tests, users performed a set of realistic tasks and their performance and subjective feedback were recorded. During the tests, participants were encouraged to narrate their thoughts while interacting with the application. For example, a concurrent think-aloud protocol (CTA) where the verbalisation happens simultaneously with participants' interactions with the interface[6] was applied. This method gives the moderator of the test an insight into the participants' immediate thoughts.

3. Spencer W. Black, "Current Practices for Product Usability Testing in Web and Mobile Applications" (PhD diss., 2015), https://scholars.unh.edu/honors/226/.
4. James Lewis, "Usability Testing," in *Handbook of Human Factors and Ergonomics: Fourth Edition* (March 2012), 1267–1312, https://doi.org/10.1002/9781118131350.ch46.
5. Black, "Current Practices for Product Usability Testing in Web and Mobile Applications."
6. Obead Alhadreti and Pam Mayhew, "Are Two Pairs of Eyes Better Than One? A Comparison of Concurrent Think-Aloud and Co-Participation Methods in Usability Testing," *Journal of Usability Studies* 13, no. 4 (August 2018): 177–195, https://uxpajournal.org/wp-content/uploads/sites/8/pdf/JUS_Alhadreti_August2018.pdf.

4.1.1 Group size

Group size between four and six participants was chosen as appropriate for this study. There is an ongoing discussion in the HCI community about the ideal group size for a usability test. According to Virzi (1992), a usability test with a group of five participants will identify approximately 80% of design flaws and problems.[7] Nielsen and Landauer (1993) argue that 7 participants is an optimal number for a small study and 15 for a medium to large scale study.[8] Later, Nielson (2000) suggested that a group of 5 participants uncovers most of the flaws in the software design and that an appropriate strategy is to conduct multiple smaller usability tests during different stages of the development, rather than one larger study.[9]

4.2 Exploratory usability test

An exploratory test, sometimes known as a formative usability test, takes place in the preliminary stages of development to evaluate early design ideas.[10] The focus is rather on the user's perception of an interface and testing effectiveness of design concepts than on how well they complete a certain task.[11] Rubin and Shisnell argue that it is essential for a successful design to collect this data early on when critical design decisions that form the whole design approach are being made.

4.2.1 Background summary

Early touchEQ experimentation showed that more data is needed about the users' perception of various haptic sensations produced by the TanvasTouch interface. Because of the novelty of the interface, a few studies have been conducted to evaluate the effectiveness of different types of textures to display graphical information, so primary data had to be collected. Thus, the exploratory usability test was organized to test and evaluate surface haptic effects and their

7. Robert A. Virzi, "Refining the Test Phase of Usability Evaluation: How Many Subjects Is Enough?," *Human Factors* 34, no. 4 (August 1992): 457–468, https://doi.org/10.1177/001872089203400407.
8. Jakob Nielsen and Thomas K. Landauer, "A Mathematical Model of the Finding of Usability Problems," in *Proceedings of the INTERACT '93 and CHI '93 Conference on Human Factors in Computing Systems* (Association for Computing Machinery, May 1993), 206–213, https://doi.org/10.1145/169059.169166.
9. Jakob Nielsen, *Why You Only Need to Test with 5 Users*, March 2000, accessed December 5, 2021, https://www.nngroup.com/articles/why-you-only-need-to-test-with-5-users/.
10. Lewis, "Usability Testing."
11. Jeffrey Rubin and Dana Chisnell, *Handbook of usability testing: how to plan, design, and conduct effective tests* (Wiley, May 2008).

use in the music production context. The main goal was to determine if the haptic sensations produced by the electroadhesive layer of TanvasTouch are suitable for displaying EQ curves and audio waveforms. Additionally, this study compared the effectiveness of two different haptic sensations presented to the participants and examined the users' interaction with the interface.

The participants were asked to give their opinions on the haptic effects according to the CTA protocol, and their thoughts and answers were recorded. The nature of the exploratory test was informal, as suggested by Rubin and Shisnell. There was a lot of interaction between the moderator and the participants, which allowed to explore the users' thought processes. A total of six individuals took part and all of them were students or lecturers at the Art of Sound department at The Royal Conservatoire The Hague.

First, the participants were presented with a set of eight EQ curves and were asked to read their values from the graph and identify what EQ curve is being displayed (e.g. high pass filter at 180 Hz). Secondly, they were presented with four audio waveforms. The task was to identify inactive places in the audio waveform. During both sets of tasks, the assets were displayed only with haptic feedback provided by the TanvasTouch interface without any visual cues.

The participants' behaviour while performing the tasks was observed. One of the purposes of this type of test is to understand why the user performs as they do by collecting qualitative data. Rubin and Shisnell suggest asking participants how to improve confusing areas.[12] Hence, participants were asked to give opinions about the haptics interface, which was encouraged by asking open-ended questions throughout the experiment. Additionally, quantitative data to evaluate the graph design's effectiveness was collected by recording the users' performance and the accuracy of data reading on video. The collected data was used to inform design decisions in the latter part of the touchEQ development.

4.2.2 Objectives and questions

The objectives of this exploratory usability test were:

1. To explore the suitability of the haptic sensations created by TanvasTouch haptics interface

12. Rubin and Chisnell, *Handbook of usability testing: how to plan, design, and conduct effective tests.*

for a haptic display of EQ curves and audio waveforms.

2. To compare the effectiveness of two proposed haptic effects - solid white background and striped black and white pattern.

3. To find out if the EQ graph design is suitable for reading values by haptic feedback.

These research questions were formulated to explore the objectives of the test:

1. Is the TanvasTouch interface suitable for displaying EQ curves and audio waveforms?

2. Which of the two haptic effects used is the most effective?

3. How accurately can users read data in the graph? Are X and Y axes chosen appropriately?

4.2.3 Participants

Five audio engineering students from the Art of Sound department and one Art of Sound lecturer participated in the experiment. All participants are experienced audio engineers with good critical listening skills, and they commonly use graphical parametric equalizers in their audio engineering practice. All six participants had no prior experience using a surface haptic interface before this test. All of them use devices with touch screens daily.

4.2.4 Test session procedure

The test sessions took place on the 30th of November 2020 on a Monday afternoon on the Royal Conservatoire The Hague campus. There were six test sessions, and each participant had an allocated slot of 30 minutes. The moderator welcomed the participants, and the procedure of the test was explained. A consent form, presented in Appendix A.1, with information about the usability test and data ethics was handed out to each participant, and an appropriate time to read the form was provided.

After signing the consent form, the participants were invited to explore the TanvasTouch interface, and two introductory demo applications made by Tanvas were shown to the participants. This allowed them to explore several haptic sensations and provided a basic understanding of the possibilities the TanvasTouch technology provides. They were also encouraged to try to feel the haptic sensations with both hands and different fingers.

The participants were asked three pre-test questions:

1. Do you have any experience with working with a haptic interface such as this one?
2. Do you prefer using a graphical equalizer that can show EQ curves or a simpler equalizer with fewer graphic elements?
3. When editing audio, do you concentrate on the graphical representation of the EQ curve?

After that, the participants were presented with a set of eight EQ curves, followed by a set of four audio waveforms.

4.2.5 Haptic effects

Two different haptic effects were designed to display the EQ curves and audio waveforms by creating two different textures that were sent to the TanvasTouch API. The users had the opportunity to interact with both haptic effects. Their preference was recorded in order to determine which effect is more suitable for the information display.

1. The first effect is formed by a solid white background which represents a 100% friction that TanvasTouch is able to display, as shown in Figure 4.1. This effect creates a smooth surface with a high resistance on the fingertips. It creates a clear contrast between the black (0 friction) background and the highlighted area.

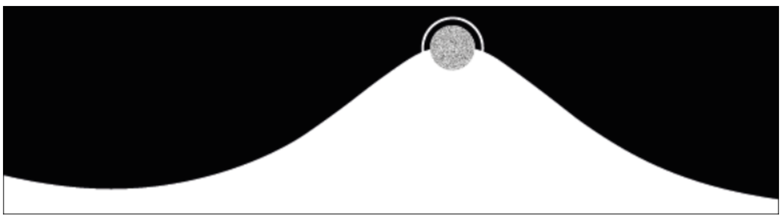


Figure 4.1: An example of a solid white background haptic asset.

2. The second effect is created by black (0 friction) and white (maximum friction) lines with width of 2 px that form a striped pattern, as shown in Figure 4.2. This effect creates a rough texture that is clearly noticeable when sliding a finger across the highlighted area.

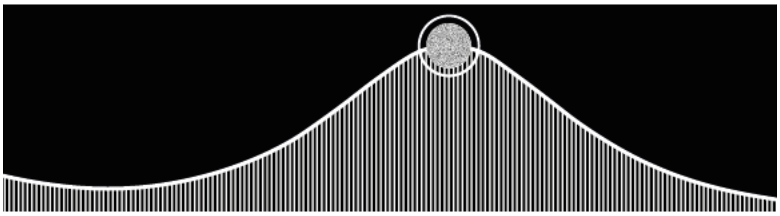
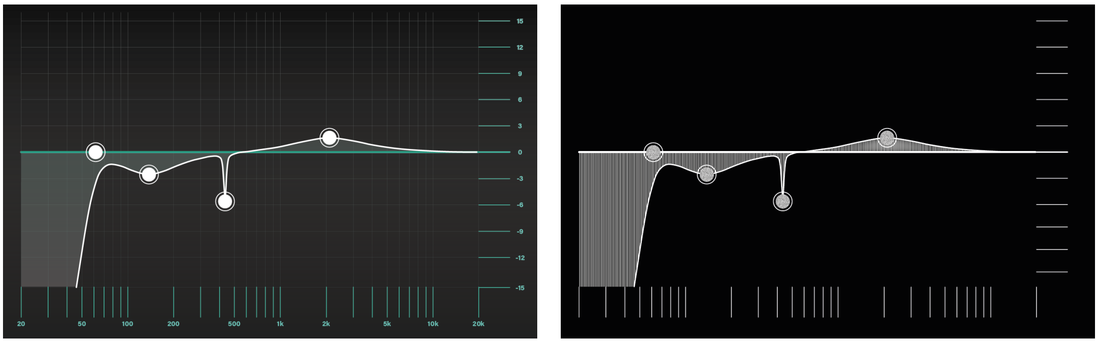


Figure 4.2: An example of a striped pattern haptic asset.

These two haptic effects highlight the frequency areas affected by equalizer settings. These two haptic effects were also tested for the display of the audio waveforms.

4.2.5.1 Graph design

As Jansonn (2008) suggests, displaying complex graphs including grids and X and Y axes with haptics is challenging and can result in an unreadable and cluttered information display. Therefore, a simplified graph layout was designed. This design aims to make it possible for the user to read the graph values by displaying X and Y axes with haptic feedback and highlighting EQ curve areas, also with haptic feedback. Figure 4.3 shows the proposed layout for the user interface used in this test.



(a) Visual layer

(b) Haptic layer

Figure 4.3: Proposed design of haptic display of graph with an EQ curve

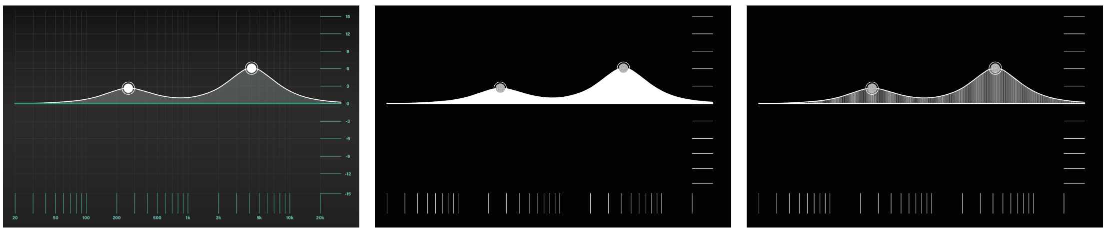
The frequency parameter is measured on the horizontal X-axis representing logarithmic values divided into three bands: low 20-100 Hz, mid 200 Hz to 1 kHz and high 2 kHz to 20 kHz. The gain value is measured on the vertical Y-axis in decibels, and each step represents a change of

3 dB. Values on both axes are displayed with white lines 3 px wide. When a user slides across the axes, they can feel slight bumps, and they can orientate themselves in the graph. This test examined the suitability of this design.

4.2.5.2 EQ curve recognition

The users were presented with a set of EQ curves that were displayed in the graph. Because all of the test participants were sighted, the GUI was showed on the screen at first to provide an opportunity to get an overview of the user interface layout. After that, the GUI was hidden, and the participant could see only a black screen. This was done to test if the data can be read in a non-visual way, only with haptic feedback without any visual cues.

EQ curves can form various shapes and sizes. The tasks were designed to test which haptic effects are most suitable for what shapes. Thus, different types of filters (e.g. peaking, high shelf) and gain settings were tested to find out what values can users comfortably read from the graph. A set of all tasks that participants performed is listed in the appendix. An example of an EQ curve used in the test is presented in Figure 4.4.



(a) Visual layer (b) Haptic layer - solid white (c) Haptic layer - striped pattern

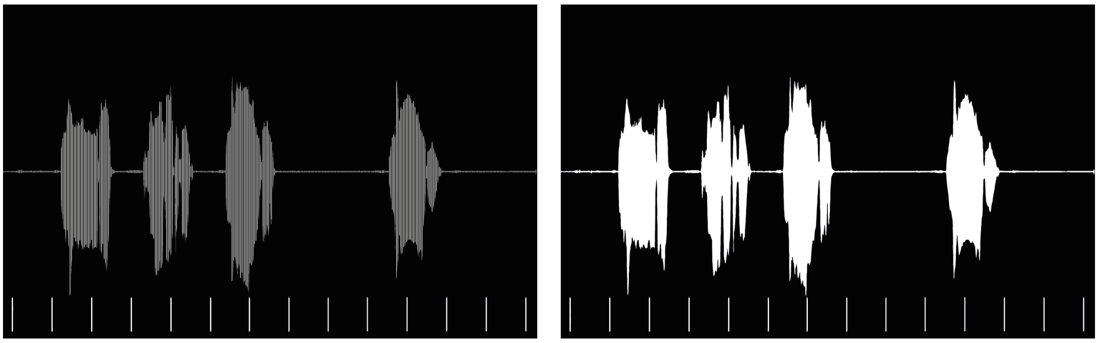
Figure 4.4: An example of a presented EQ curve - a boost with wide Q at 250 Hz and 4 kHz

A set of eight different EQ curves was presented to the test subjects. These curves differed in their complexity, starting with a low cut covering a large area and progressing into a combination of multiple curves such as high shelf and bell peaks with different Q settings. The aim was to explore individuals' ability to recognize different EQ curves and find out how accurately they can read the values.

At this point in the test, the users could see only a black screen, but they could feel the haptic effects. For each EQ curve, the participants were shown a solid white haptic effect followed by a striped pattern haptic effect and they were asked which one they prefer more. After sufficient time spent exploring the haptic display, and once they were confident about their response, the visual layer was shown to determine if their answer was correct.

4.2.5.3 Audio waveform recognition

The participants' task was to explore the audio waveform by sliding the fingers across the screen and identify inactive places in the audio. In these places, a cut might be suitable to clean up the audio from unnecessary noise. This is a task that is performed often for, for example, producing vocals. The waveforms were displayed by two haptic effects described in Section 4.2.5. The same vocal recording was used as a source for the waveform for all four tasks. For each task, the zoom level was different to explore on what scale it is possible to recognize inactive audio areas. Figure 4.5 shows an audio waveform displayed by two different haptic effects that were compared in this test.



(a) Haptic layer - striped pattern (b) Haptic layer - solid white

Figure 4.5: Audio waveform of a vocal recording

As mentioned above, the exploratory test took place in the early stages of the touchEQ development. It was not yet decided if the TanvasTouch development would focus on an equalizer or creating an audio editing tool. Thus, both EQ curves and audio waveforms were explored in this test. Later it was decided that an equalizer would be more suitable for this study. However, the collected data regarding audio waveforms is valuable to anyone considering using TanvasTouch for creating an audio editing or a similar tool.

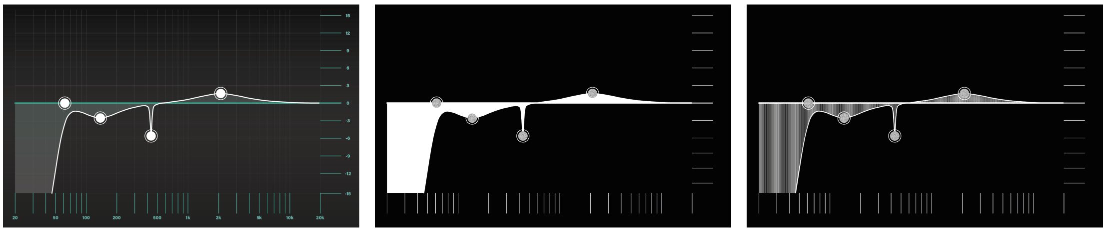
4.2.6 Evaluation

The feedback collected from the participants and qualitative data from the exploratory usability test indicated that it is possible to effectively use surface haptics to display EQ curves and audio waveforms. Participants were able to recognize and read EQ curves. However, in some tasks, the data recognition accuracy was an issue. Research questions underpinning the exploratory test research questions are answered below:

Is the TanvasTouch interface suitable for displaying EQ curves and audio waveforms?
According to the data collected in this study, it is possible to display and read the EQ curves and audio waveforms with haptic feedback produced by the TanvasTouch interface. Stimuli that the interface can provide are suitable for differentiating between the highlighted and non-highlighted areas.

Which of the two haptic effects used is the most effective?
All six participants preferred the stripes haptic effect to the solid white haptic effect. Both of the haptic effects were working well to create highlighted and non-highlighted areas. However, the striped effect provided stimuli that were more easily recognizable with different shapes and sizes of EQ curves. Users reported that when viewing the solid white effect, they were sometimes not sure if they are sliding their finger in a highlighted area or not.

How accurately can users read data in the graph? Are the X and Y axes chosen appropriately?
The users could comfortably identify larger highlighted areas. However, when the area was too small, e.g. when the gain value was 2 dB or less, participants were starting to get confused and were doubting if there was a change in the EQ curve or not. In several situations, participants failed to recognize this kind of curve (example in Figure 4.6). Because a haptic effect highlights the 0 line, a small EQ boost was sometimes mistaken for this effect. Support of zooming in and out on the EQ curve could help to solve this issue.



(a) Visual layer (b) Haptic layer - solid white (c) Haptic layer - striped pattern

Figure 4.6: EQ curve #9 - only 1 participant was able to recognize a boost of 1,5 dB with wide Q at 2 kHz

4.2.6.1 Findings and limitations

It is essential to consider that because all the participants were sighted, their haptic perception might differ from those who are visually impaired. Several occurring patterns were identified which were used in the design of the touchEQ application.

- All six participants preferred the stripes haptic display in all EQ curves they were presented with
- Five out of six participants were not able to differentiate a change of 1 dB
- The EQ curve with a very narrow Q and a boost of 4 dB was recognized by four out of six participants
- Filters that highlight larger areas such as low and high pass filters were recognized by all six participants

The findings from this experiment informed the design decisions used in touchEQ. A striped haptic effect was used in the display of the graph. Even though an option of changing zoom settings is not provided in the prototype, the graph was re-designed by changing the step value on the Y-axis from 3 dB to 2 dB. The audio waveform recognition data was not used in the latter part of the study. However, it showed that TanvasTouch haptic feedback has the potential to be used in audio editing.

4.3 Summative usability test

After conducting the exploratory test and implementing the findings in the touchEQ application, a summative test of a working prototype was conducted. Unlike an exploratory test, a summative usability test takes place after high-level design choices have been established. The test is designed to explore how well the user can perform a set of realistic tasks.[13] Both qualitative and quantitative data can be collected in this type of test. In comparison with an exploratory test, a summative test is more formal, and the moderator's interaction with participants is reduced. Even though participants are encouraged to think aloud, the actions and performance play a more important role.[14]

4.3.1 Background summary

To evaluate the possibility for eyes-free control of the touchEQ application, the summative usability test was carried out in the later stage of the development once a formal prototype was developed. High-level design choices have already been made, and the participants were presented with a functional prototype of the touchEQ application running on the TanvasTouch. The purpose of this usability test was to evaluate the effectiveness of the application design. The main focus was on completing realistic tasks only with haptic feedback, such as changing parameter values. The users' performance and subjective opinions were recorded on video. Therefore, a combination of quantitative and qualitative data was collected in this test. The data identified weak points in the functionality and uncovered possibilities for further improvements of the design.

As mentioned above, this study aims to evaluate the possibility of eyes-free control of the touchEQ, where the GUI is not visible. Further, it was planned to test this application with the visually impaired music producers to determine if the proposed design is valid. Because to COVID-19 pandemics and travel limitations, it was impossible to organize a usability test with visually impaired musicians or music producers. Therefore, all volunteers in this usability study were sighted. During the task performance, the GUI was hidden. Only haptic feedback

13. Rubin and Chisnell, *Handbook of usability testing: how to plan, design, and conduct effective tests*.
14. Lewis, "Usability Testing."

was used to control the application to simulate a situation similar to what a blind user could experience when using the touchEQ. Furthermore, inviting sighted music producers provided an opportunity to explore their view on using a surface haptic interface in their workflow.

4.3.1.1 Data collection

Both quantitative and qualitative data were collected. Participants were asked to brainstorm and give opinions, but the emphasis was on the participants' performance.

These performance measures were collected:

- success rate
- task accuracy
- error rate
- subjective evaluation

A set of six tasks was developed. In each task, the participant had to set three parameters (gain, frequency and Q) to a specified value. The task was considered directly successful if the user set the parameters within 20% of the gain or frequency values, as specified in Tables 4.1 and 4.2. If the user struggled to complete the task, the touchEQ could be reset, and another try to perform the task was allowed. An error was recorded when the participant set two or more parameters outside of the accepted value range.

Parameter	Success	Failure
Gain	value set inside 20% range	value set outside 20% range
Frequency	value set inside 20% range	value set outside 20% range
Q	correct value	wrong value

Table 4.1: Parameters success and failure matrix

Direct Success	All 3 values set successfully
Partial success	2 values set successfully, one failure
Fail	2 or more failures

Table 4.2: Success and failure decoding

4.3.2 Objectives and questions

The objectives of the summative usability tests were:

1. To determine whether is it possible to control the touchEQ application by using only haptic feedback without any visual cues.
2. To find out how accurately can the user set the equalizer parameters by using only haptic feedback and auditory feedback.
3. To identify any design or development flaws that could be improved.
4. To explore the use of surface haptics in a workflow of sighted music producers.

To meet these objectives, these research questions were formulated:

1. How well organized is the layout of the application? Are all controls easy to find?
2. How does the set parameter value compare to the assigned value?
3. What is the overall experience of using the touchEQ? Does it feel like the user has control over the equalizer even without visual cues?
4. What obstacles and issues do participants encounter when using the touchEQ?
5. Can surface haptics provide benefits to sighted music producers?

4.3.3 Participants

The usability study took place on the Royal Conservatoire The Hague campus, and four individuals took part. Two of the participants are lecturers at the Art of Sound department and have their professional practice. The other two participants are students at the Art of Sound department. All participants are sighted audio engineers experienced in using music production software and have good critical listening skills. All of them use an equalizer with a visual representation of an EQ curve regularly in their audio engineering practice. For all participants, it was the first time using a software application controlled only by haptic feedback. Three participants already took part in the exploratory usability test, so they were already familiar with the TanvasTouch interface.

4.3.4 Test session procedure

The summative usability test took place on the 15th of February 2021 during afternoon hours in a recording studio located in the Conservatoire campus. In total, there were four sessions, and each participant had an allocated slot of 30 minutes.

After welcoming participants into the test room, they were provided with the usability test explanation and consent form, presented in Appendix A.2, informing them about the usability test procedure and how their data will be used in this research. It was pointed out that the purpose of this usability test is to investigate the touchEQ application and not to test the participants and their skills per se. Throughout the test, participants were encouraged to brainstorm and think out loud.

Following the usability test introduction, each participant had the opportunity to explore the touchEQ with GUI and enabled haptic effects for about five to ten minutes to get familiar with the application. Participants could play piano and guitar audio loops through high-end studio speakers. As they changed the parameters on the touchEQ, the audio coming from the speakers was affected. Thus, their decisions were informed by haptic and auditory senses.

The moderator's role was less hands-on than in the exploratory test, so there was less interaction with the participants. He asked the participants to perform the tasks, observed the interaction with the touchEQ, recorded users' performance, answered questions, and guided users if required. Because it would not be possible for one person to perform all these tasks during the test, sessions were video-recorded, which allowed for in-depth analysis of the data. Verbal feedback and the participants' finger movements on the screen are included in the video.

Using touchEQ with the GUI

At this stage of the test, participants could see the GUI. First, participants were asked to play an audio file through the touchEQ, investigate the application, and alter the sound by changing the EQ settings. After that, they were asked to set a specified gain, frequency and Q parameters. This task provided data about the usability of the application when the GUI is displayed.

Using touchEQ without the GUI

To evaluate whether is it possible to control the application only with haptics, the GUI was covered with a black non-transparent background during this stage of the test. This way, participants could not see the GUI (only the transport panel was visible to allow audio playback and the reset of the touchEQ), but they could feel the haptic effects. Participants were asked to perform a set of six tasks that varied in complexity.

Table 4.3 lists the tasks the participants were asked to perform.

With GUI	
Task 1	Set cut of 8 dB, 250 Hz, narrow Q
Without GUI	
Task 2	Set cut of 3 dB, 80 Hz, narrow Q
Task 3	Set boost of 8 dB, 400 Hz, wide Q
Task 4	Set boost of 6 dB, 4 kHz, narrow Q
Task 5	Set cut of 10 dB, 50 Hz, wide Q
Task 6	Set boost of 8 dB 5 kHz wide Q

Table 4.3: The set of tasks performed by all participants

In Task 1, participants were able to see the GUI. Starting from Task 2, the GUI was hidden, and the user could see just a black screen except for the transport panel, which was visible. The users were required to switch between low, mid and high bands and set different gain, frequency and Q settings in the tasks.

Finally, post-survey questions were asked to find out participants' thoughts after using the application. The following questions were asked:

1. How difficult were these test assignments using the touchEQ? (1=very easy, 5=very difficult)

2. How would you describe your overall experience with the touchEQ?

3. If you could change one thing in the application, what would it be and why?

4. How do you expect that this kind of haptic equalizer could look like in the future?

Figure 4.7: A participant interacting with the touchEQ during a usability test

4.3.5 Evaluation

The video recordings and participant feedback from the summative usability test were analysed to determine if some general problems occurred for multiple users and if users were able to find solutions to their problems. Four participants performed a set of six tasks. In each task, the participant was asked to set three values to the equalizer: gain, frequency, and Q. The participants' results were categorised into three categories based on a method described in Section 4.3.1.1: success, partial success and failure. Tasks 5 and 6 were completed only by three participants because of time constraints. Table 4.4 lists participants' performance data, the list of participants' performance accuracy is presented in Figure A.1.

	Success	Partial success	Failure
Task 1	100%	0%	0%
Task 2	0%	100%	0%
Task 3	25%	75%	0%
Task 4	0%	50%	50%
Task 5	67%	33%	0%
Task 6	33%	67%	0%

Table 4.4: Success and failure rate of tasks completion

Observed problems

Two critical problems were uncovered during the test.

1. Users have problems identifying and locating faders. It is also difficult to differentiate between these three faders, and sometimes, the users are not sure which one they are dragging.

   Four out of four participants experienced issues operating the faders.

2. Buttons are sometimes accidentally clicked in an attempt to drag a fader. As a result, the wrong band is selected and the user gets confused.

   Three out of four participants accidentally clicked buttons.

3. The TanvasTouch malfunctioning occurred for two participants. The touch input was triggered continuously in the upper right corner of the touch screen, so the device became unusable. For one participant, it occurred multiple times and negatively affected the experiment results. For the other participant, it was solved by restarting the device and the application.

   Two out of four participants had this issue.

4.3.5.1 Limitations

The summative study had several limitations. Arguably, more time is needed to get familiar with using the TanvasTouch haptic interface. The interface is a novel device, and the users need substantial time to get used to using a touch screen with haptic feedback. Ideally, the user should spend a couple of hours getting familiar with the device. Participants may have had some difficulty using the interface because of their lack of experience with the haptic feedback.

These findings are the results of usability tests with sighted music producers. Even though they operated the equalizer only with haptic feedback to simulate a non-visual interaction, the interface should be tested by visually impaired people to confirm this study's results. Multiple experiments with participants from different backgrounds and with different visual impairments would provide more comprehensive validation of the application.

4.3.5.2 Findings and recommendations

The usability test findings indicate that it is possible to control a parametric equalizer with a visual representation of EQ curves using haptic feedback with no visual cues. The proposed application is an early prototype, so some design changes are needed to improve usability. One of the most common problems for participants was locating the faders because they were confusing them with buttons or they were unsure which fader they were dragging. This is a design flaw that could be solved by reducing the area taken up by the EQ curves, which currently take about 70% of the screen space. That would provide space to create a more suitable layout for the control elements. It could then be tested if a dedicated haptic effect for each fader would help to differentiate between faders.

During the test, the participants were listening to three different audio loops. In some of the tasks, they were asked to alter the frequency spectrum that was not present in the audio example (e.g. 80 Hz cut on a piano loop). In these cases, they had to rely only on the haptic sense to check the settings by "viewing" the graph's EQ curve. Participants showed more accurate results when working with the frequencies that could be heard in the audio examples (e.g. 400 Hz boost on a piano loop). This suggests that one can use the touchEQ application in a non-visual way when combining haptics and auditory feedback. Furthermore, one of the participants said that not seeing the GUI made him focus more on the aural feedback. A non-visual interface can help users pay more attention to what they can hear rather than what they see on the screen.

While visually impaired music producers have not yet tested the final version of the touchEQ, the author assumes that according to the sighted participants' performance data, the visually impaired will be able to operate the application. The author hopes that it will be possible to organize a future study that would validate this assumption.

4.4 Research during the COVID-19 pandemic

The COVID-19 pandemic created challenges for this study, and the methodology had to be altered to make sure that all the activities were in line with the current measures. It was also essential to ensure that the study followed health and safety protocols so the research participants were not being put in any danger. Because of the travel regulations and urgent advice to limit social contacts, it was impossible to test the proposed application with larger groups of people or to come and visit individuals in their own studios nor to visit other universities' campuses. Because the TanvasTouch interface is a haptic interface, one has to be able to physically feel it in order to be able to evaluate it. Therefore, online evaluation was not an option. The following paragraphs present a short overview of the initial methodology plan before it had to be changed.

4.4.1 Focus groups

The initial methodology plan was to form two focus groups with sighted music producers, organize usability tests with visually impaired music producers and conduct semi-structured interviews with them. According to Kreuger (1994), the focus group of five to seven participants is an optimal number of people for an in-depth conversation.[15] It was not possible to organize focus groups of this size. According to Lazar, Feng and Hochheiser, interviews and focus groups "help build an understanding of the needs, practices, concerns, preferences, and attitudes of the people who might interact with a system."[16]

The focus groups would provide an opportunity to collect users' reactions to using surface haptics for controlling music production software and for finding the potential benefits of the haptic feedback in a sighted music producers' workflow with the possibility to start a more general

15. R.A. Krueger and R.A. Krueger, *Focus Groups: A Practical Guide for Applied Research* (SAGE Publications, 1994).

16. Jonathan Lazar, Jinjuan Heidi Feng, and Harry Hochheiser, "Interviews and focus groups," in *Research Methods in Human Computer Interaction*, Second Edition (Morgan Kaufmann, 2017), 187–228, https://doi.org/https://doi.org/10.1016/B978-0-12-805390-4.00008-X.

discussion about the relevance of this technology in music production. It would also provide an opportunity to start a discussion about the issue of the inaccessibility of music production software. The focus groups were planned to be formed by higher education students between 20 to 26 years of age, representing a segment of young people studying audio engineering and interested in music technology. One of the focus groups was planned to be formed by students of Royal Conservatoire The Hague, while the second focus group was planned to be formed by the students of Amsterdam University of Arts.

4.4.2 Usability tests with visually impaired

Besides focus groups formed by sighted music producers, individual usability tests were planned to take place with visually impaired musicians or music producers. It was also planned to conduct semi-structured interviews with the participants after the usability test was finished. The interviews would allow more in-depth discussion about accessibility issues, and user testing would clarify the surface haptics' potential to improve the visually impaired music production workflow. Combining focus groups with usability tests and semi-structured interviews could form a comprehensive evaluation of the application prototype by visually impaired and sighted users.

To ensure that the research methodology followed the government measures, one-to-one usability tests with sighted music producers were chosen as a suitable method to evaluate the proposed application. The tests presented a relatively low risk for transmission, especially when following measures such as face coverings and social distancing. These tests took place with students and lecturers from the Royal Conservatoire The Hague, so no travelling between cities, which the government did not advise, was needed.

Chapter 5

Discussion

The following chapter presents the literature review findings, interprets the usability tests results, and addresses the two main research questions.

5.1 Accessibility of music production software

Q1: What are the current ways the visually impaired interact with music production software, and how accessible is this software?

The following section discusses the literature review findings in order to answer the first research question. An analysis of the most popular DAWs accessibility features was done to evaluate the accessibility of each DAW. The challenges and barriers that visually impaired people face were unpacked by conducting online interviews with visually impaired music producers. Four of these interviews were in the form of an online meeting, four of them were structured email interviews and can be found in the Appendix.

5.1.1 Assistive tools

A screen reader is currently the primary tool that visually impaired people use to access the DAWs and audio plugins. The use of screen reader in music production has shortcomings, as described in Section 2.3.2.1. Some visually impaired music producers use physical MIDI controllers to map software controls to physical control elements. This method is usually combined with the use of a screen reader that has the function of navigating the software, while the physical controller enables to precisely manipulate audio plugin settings.

5.1.2 Accessibility of DAWs

As described in Section 2.3.3, the issue of inaccessibility of DAWs is still existent and a relevant topic to be discussed. Even though we have seen a tremendous effort from both developers and visually impaired music producers' community in recent years, some functionalities of DAWs are still not accessible by the screen readers. Some DAWs, such as Ableton Live, are not accessible at all. Even though some DAWs such as Pro Tools and Logic are mostly accessible, workflow efficiency is lower compared to sighted producers. Table 5.1 presents DAWs' accessibility based on a screen reader support.

DAW	Accessibility
Ableton Live	No
Logic Pro	Yes
Pro Tools	Yes
Nuendo, Cubase	No
Reaper	Yes
Sonar	Partly

Table 5.1: DAW accessibility by screen reader

In the past 20 years, the DAWs have become the central component for music production and music recording. Nowadays, we hardly see a music producer or an audio engineer working exclusively with analogue hardware and excluding a DAW from their workflow entirely. Therefore, the DAWs' inaccessibility is a significant disadvantage for visually impaired music producers and audio engineers.

5.1.3 Accessibility of third-party plugins

Additional problems arise when the visually impaired music producer decides to use third-party plugins. Even some of the larger developers still do not offer screen reader support, making their products inaccessible for visually impaired users. Based on the experience of visually impaired music producers who took part in this research, third-party plugins are often unreliable for their accessibility features. Music producer Zachary Taibi-Bennoui says that:

> I do not use a lot of third-party plugins outside of the Logic stock plugins because most of them are not accessible. I would say that is my biggest frustration with audio production at the moment.[1]

Furthermore, it is difficult to access information about which plugins are and which are not accessible. The visually impaired producer does not know straight away if a particular plugin is accessible. Even prominent plugin developers such as Slate Digital, Eventide or Waves do not provide any accessibility-related information on their websites. Simply put, accessibility is not an exciting area for developers because the visually impaired music producers market is small. Unfortunately, this creates a significant drawback for the visually impaired.

5.1.4 Findings

In a professional situation, DAWs or third-party plugins' inaccessibility puts visually impaired music producers at a disadvantage compared to sighted music producers. Arguably, this creates an entry barrier for visually impaired music producers in becoming professionals in this field. There are examples of successful visually impaired audio professionals, but that might be only a small fragment of the number of visually impaired who might be making music if the software was more accessible.

The opportunities for visually impaired music producers are not equal. For example, when a visually impaired music producer wants to work with a specific plugin because of creative reasons and this plugin is inaccessible, their only option is to ask a sighted music producer for assistance, or to use a different plugin. While the visually impaired can record and produce

1. Zachary Taibi-Bennoui, Email interview about DAWs conducted by Jakub Pesek. June 2020.

music with the existing software, they do not have access to the same tools and do not have the same opportunities as sighted music producers. Despite these issues, there is a tremendous commitment and effort from the visually impaired music producers' community to "make things work" and learn how to create workarounds and new opportunities. Producers form online groups and forums to advise each other and share tips on using music production software.

To sum up, the most accessible DAW for visually impaired music producers on the Windows operating system is Reaper, while Pro Tools and Logic Pro are the most accessible DAWs on macOS. We have to consider that even though some DAWs are mostly accessible, users can run into problems with third-party developers' plugins. An extensive debate about accessibility in music production software needs to occur before we will be able to see equal opportunities for the visually impaired. The promotion of accessibility by recording industry professional organizations such as the Audio Engineering Society could help raise awareness about these issues.

5.2 Accessible surface haptic audio equalizer

Q2: Can a surface haptic interface serve as an eyes-free controller for music production software?

The second research question's objective was to investigate the possibility of using a surface haptic interface in the music production context, more specifically use it for operating an audio equalizer eyes-free. A working prototype of such an application called touchEQ was developed for the TanvasTouch interface, and two usability tests have been conducted to evaluate the application's effectiveness.

Based on the results of the tests, the author concludes that the touchEQ application can be operated eyes-free using TanvasTouch. However, the efficiency of the proposed method could be improved. The data in the Table 4.4 suggest that participants were struggling to set all three parameters (gain, frequency, Q) correctly, and in most of the tasks, they failed to set at least one parameter within the allowed range. Improving the user interface by re-designing the layout of the controls could help to improve users' performance further.

The data also suggest that the touchEQ works better if auditory and haptic feedback are combined. During the test, users were asked to set a cut at 80 Hz, which is the frequency that was not present in the audio excerpts. In these cases, the performance diminished when compared to tasks when the user could check the EQ settings with auditory feedback.

Overall, participants' feedback about the touchEQ application was positive. All the participants showed interest in haptic technology and saw its innovative potential. Some think that sensory enrichment might bring advantages to their professional practices. Two participants said they would find it helpful to use a touch screen with haptic feedback when working in a live sound scenario. In this situation, a sound engineer often works with touchscreens on mixing consoles and with haptic feedback, it would be easier to operate the user interface. A sound engineer could look at the musicians on stage while operating the buttons and as a result, the communication with musicians could be improved.

Furthermore, it is interesting to consider that after turning off the GUI with the EQ curve, participants started to pay more attention to what they could hear rather than what they could see on the display. Previous studies[2,3] also showed that the quality of critical listening decreases with a need to concentrate and interact with a GUI. Further experiments with the touchEQ could be conducted to determine the effect of removing the visual layer on the listening performance. In the touchEQ workflow, the participants can still "view" the EQ curve with haptic feedback, however, their auditory perception is not influenced by immediate visual feedback.

Finally, the exploratory test results suggested that the surface haptics could be used in multiple music production applications other than an equalizer. Assets of a similar nature to the EQ curve, such as frequency response or an input-output graph for a dynamic range compressor, could also be viewed using the TanvasTouch interface. Additionally, the study provided an insight into the possibility of using TanvasTouch for making graphs accessible for the visually impaired. The experiment was conducted only with an EQ curve, however, the findings indicate that the technology could make other types of graphs accessible for the visually impaired.

2. Mycroft, Reiss, and Stockman, "The Influence of Graphical User Interface Design on Critical Listening Skills."

3. Schutz and Lipscomb, "Hearing gestures, seeing music: Vision influences perceived tone duration."

5.3 Study limitations

There are several limitations to this study. Due to time constraints, it was decided not to organize more experiments and it was not possible to develop the application's prototype version further. The preliminary findings of this research provide an opportunity for future research. Secondly, while the visually impaired person tested the touchEQ application in the initial stages, the final version was not yet tested by visually impaired music producers as initially planned. It was impossible to organize the usability tests because of the difficulty of travelling and meeting people during the COVID-19 pandemic. The author hopes that it will be possible to organize these experiments in the near future in research building on this master thesis.

Despite the limitations, this study's strength is that the touchEQ application was tested on music producers who are students or work professionally in the music industry. Therefore, the experiment was close to a realistic situation where the producer would be using the touchEQ in serious audio production.

Chapter 6

Conclusion

This work proposed an equalizer that utilises a novel surface haptic interface TanvasTouch. Although the work achieved in this research is only a small step towards accessible music production tools and towards building an audio industry where visually impaired music producers have equal opportunities, it introduced a new way of interaction with music production software for the visually impaired. Furthermore, this thesis has provided a thorough overview of the accessibility of digital audio workstations, listed current haptics technology and provided an insight into accessibility issues by conducting online interviews with visually impaired music producers.

This study's primary aim was to investigate the use of surface haptics for the eyes-free interaction with music production software. A working prototype of an audio equalizer called touchEQ was designed and developed. The evaluation was performed by organizing two usability tests with music producers. Participants were asked to perform a set of realistic tasks with the application while controlling it only with haptic feedback. Further, the tests explored the potential for the use of this technology in sighted music producers' workflow. Participants subjective opinions and performance was recorded and analysed to determine if the touchEQ is usable.

The usability tests findings showed that the TanvasTouch device could be used to operate an equalizer eyes-free. Further, it demonstrated that users could read EQ curve values from a graph without any visual feedback. At this stage of understanding, the author believes that there is considerable potential in using surface haptic interfaces for improving accessibility. Further, subjects indicated that this technology could be to benefit sighted music producers, e.g. in live sound.

This research provided insights for using surface haptics in the context of music production. To the author's knowledge, this work is one of the first of its kind, exploring the accessibility of music production software and surface haptics in particular.

Original contributions of this research:

1. An overview of the currently used accessibility features in the most commonly used digital audio workstations was provided.

2. Online interviews with visually impaired musicians were conducted to find out how they work and their struggles with music production software. This has brought light to the limitations of currently used assistive technology such as screen reader.

3. The accessible parametric equalizer application touchEQ that runs on the TanvasTouch interface was developed and evaluated in two usability tests.

One of the other aims of this work was to highlight the lack of accessibility of music production software. Still, visually impaired music producers do not have equal opportunities, making it challenging for them to start with music production and work in the industry. The inaccessibility of DAWs and third-party plugins creates a barrier for visually impaired music producers.

This research sets the groundwork for upcoming research using haptic interfaces in the music production context. This thesis makes an initial and original contribution to the problematic of accessibility of music production tools but also to accessibility in human-computer interaction in general. In the author's hope, this work will also serve as a stimulus for starting a discussion about accessibility between individuals involved in the audio industry and their representative bodies.

6.1 Recommendations for future work

This research is one of the first works dedicated to the problem of accessibility of music production software. It has pointed towards several opportunities for future research, some of which were already indicated throughout the thesis.

As a continuation of this research, multiple usability studies with a more refined application version with visually impaired individuals can be conducted. Other applications for surface haptics in music production could also be investigated. As explored in the exploratory usability test, audio waveform recognition showed promising results, suggesting an audio editing tool could also be designed. Further, other haptic devices such as mid-air haptics or wearable interfaces seem to have the potential in the music production context, and their use should be investigated.

For future research, accessibility guidelines for music production software developers could be created, similarly to web accessibility standards. These guidelines could involve a series of recommendations and explanations about how the developers can create accessible content and optimize it for screen readers. Furthermore, a method for identifying accessibility issues could be designed to determine problems and shortcomings in accessibility features.

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Appendix A

Usability testing

A.1 Consent form - exploratory usability test

Participation in a research project

A study of using a surface haptic interface in the context of music production

Background and Subject

The objective of this research is to investigate the accessibility of music production tools for the visually impaired, determine limitations of the currently used accessibility tools and propose a haptic interface that could overcome these limits. A comprehensive overview of tools typically used by visually impaired musicians and music producers to interact with audio is presented. The aim is to develop a working application prototype for haptic interface in order to introduce a method for better human-computer interaction.

What does it entail to participate in this research?

The participants will be presented with a set of 8 different EQ curves and 4 different audio waveforms, displayed on TanvasTouch surface haptic device. The first task will be to recognize and identify different types of EQ curves and read what frequencies are affected by the equalizer settings. The second task will be to explore audio waveform and identify spots suitable for making a cut to the waveform. In both tasks, participants will be presented only with haptic feedback and no visual representation of the information.

The experiment will take place in Studio B at The Royal Conservatoire building on 30th November 2020. The participants need to have a good understanding of equalizers and graphical representation of EQ curves. They also need to be experienced in audio editing.

What happens to the information about you?

All of the information will be treated confidentially. Personal information will not be necessary in this research, only information about age group and the performance of the test. All information generated from the user test will only be available to signatory. The data will be stored on an external hard drive that requires password. The data will be anonymised right after the observation.

Participation is voluntary

It is voluntary to participate in the research, and you can at any given time pull your consent without giving an explanation. If you decide that you do not want to participate after all, all of the data about you will be removed. If you want to participate in the study, or have any questions, please contact:
Jakub Pesek

A.1.1 Consent to take part in the research

I have received the information about the research and am willing to participate:

. . . .

(Signed by the participant, date)

I hereby consent to the following method for data collection being utilized:

Type	Yes	No
Observation		
Video recording		
Record of the performance		

A.2 Consent form - summative usability test

Participation in a research project

A study of using a surface haptic interface in the context of music production

Background and Subject

The objective of this research is to investigate the accessibility of music production tools for the visually impaired, determine limitations of the currently used accessibility tools and propose a haptic interface that could overcome these limits. A comprehensive overview of tools typically used by visually impaired musicians and music producers to interact with audio is presented. The aim is to develop a working application prototype for haptic interface in order to introduce a method for better human-computer interaction.

What does it entail to participate in this research?

The participants will be presented with a set of 6 different tasks in which they will be setting parameters to the EQ that will be displayed on TanvasTouch surface haptic device. The experiments consists of two phases; learning and the actual usability test. This is to ensure that the participants can get familiar with the design of the EQ and the TanvasTouch technology before the usability test. The participants will be presented only with haptic feedback and no visual representation of the information.

The experiment will take place in Studio B at The Royal Conservatoire building on 15th February 2021. The participants need to have a good understanding of equalizers and graphical representation of EQ curves. They also need to be experienced in audio editing.

What happens to the information about you?

All of the information will be treated confidentially. Personal information will not be necessary in this research, only information about age group and the performance of the test. All information generated from the user test will only be available to signatory. The data will be stored on an external hard drive that requires password. The data will be anonymized right after the observation.

Participation is voluntary

It is voluntary to participate in the research, and you can at any given time pull your consent without giving an explanation. If you decide that you do not want to participate after all, all of the data about you will be removed. If you want to participate in the study, or have any questions, please contact:
Jakub Pesek

A.2.1 Consent to take part in the research

I have received the information about the research and am willing to participate:

....

(Signed by the participant, date)

I hereby consent to the following method for data collection being utilized:

Type	Yes	No
Observation		
Video recording		
Record of the performance		

A.3 Participants' performance

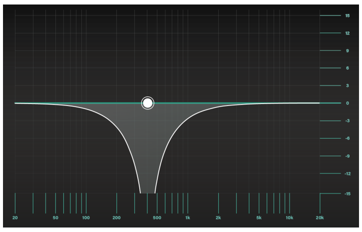
A.3.1 Summative usability test results

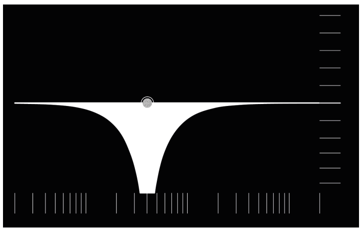
Task	Gain	Frequency	Q	Completion
Participant 1				
T0				Direct success
T1	plus 2db	plus 70 Hz	OK - narrow	Indirect success
T2	accurate	minus 70 Hz	OK - wide	Indirect success
T3	plus 4db	minus 2 kHz	OK - wide	Fail
T4	accurate	minus 10	OK - wide	Direct success
T5	plus 2db	plus 5	OK - wide	Indirect success
Participant 2				
T0				Direct success
T1	minus 2db	plus 70 Hz	OK - narrow	Indirect success
T2	plus 1db	minus 150 Hz	OK - wide	indirect success
T3	minus 2db	plus 6k	OK - very wide	indirect success
T4	accurate	minus 30 Hz	OK - wide	indirect success
T5	plus 2db	plus 10k	Ok - wide	indirect success
Participant 3				
T0				Direct success
T1	minus 1db	plus 40 Hz	OK - narrow	Indirect success
T2	plus 2db	plus 400 Hz	OK - wide	indirect success
T3	plus 4db	plus 5k	OK - very wide	Fail
T4				Not given to the participant
T5				Not given to the participant
Participant 4				
T0				Direct success
T1	minus 2db	plus 60 Hz	OK - narrow	Indirect success
T2	plus 1db	plus 50 Hz	OK - wide	Direct success
T3	plus 2db	10k	OK - very wide	indirect success
T4	accurate	plus 20hz	OK - wide	Direct success
T5	plus 2db	plus 200Hz	OK - wide	Direct success

Figure A.1: Accuracy of participants' performance

A.4 Graphical assets for exploratory usability test

A.4.1 EQ curves recognition


(a) Visual layer


(b) Haptic layer - solid white

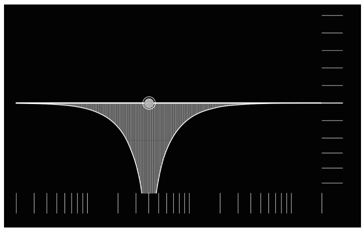
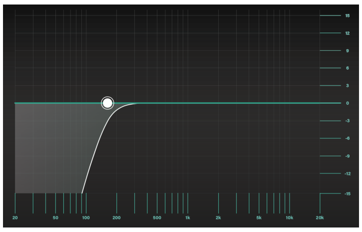
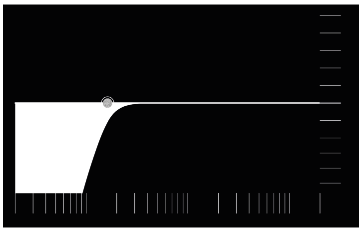

(c) Haptic layer - striped pattern

Figure A.2: EQ curve #1 - notch at 400 Hz


(a) Visual layer


(b) Haptic layer - solid white

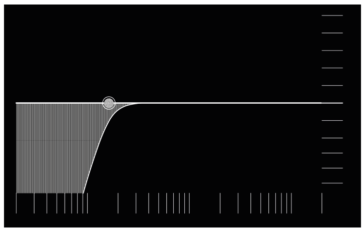
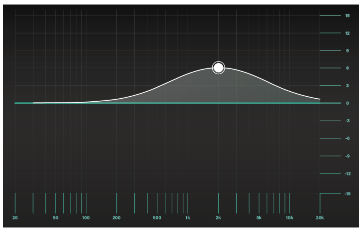
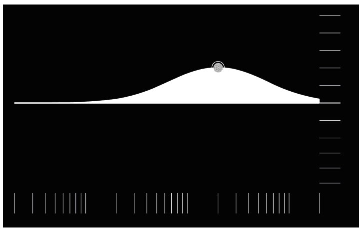

(c) Haptic layer - striped pattern

Figure A.3: EQ curve #2 - high pass filter at 180 Hz


(a) Visual layer


(b) Haptic layer - solid white

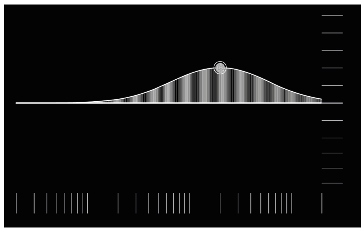
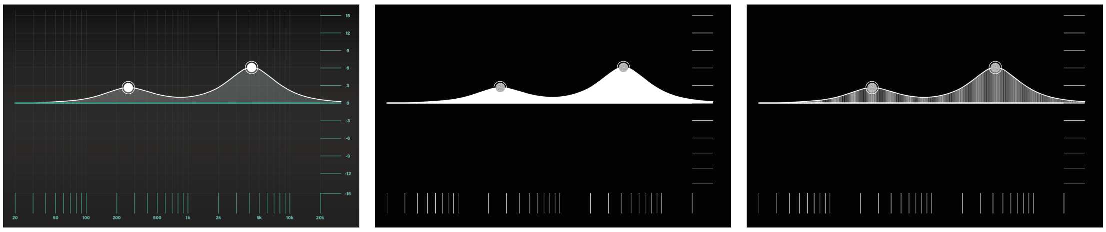
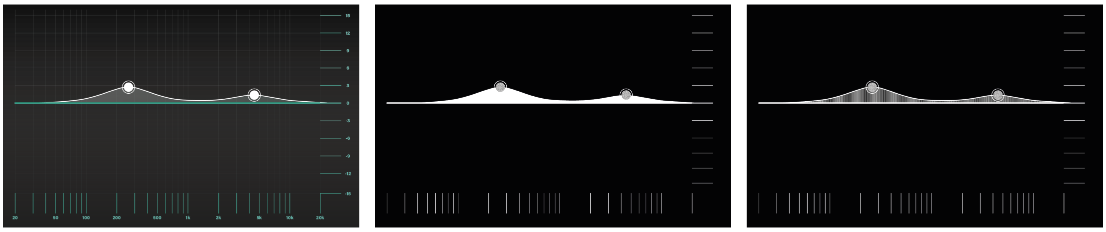

(c) Haptic layer - striped pattern

Figure A.4: EQ curve #3 - boost of 6 dB at 2 kHz wide Q



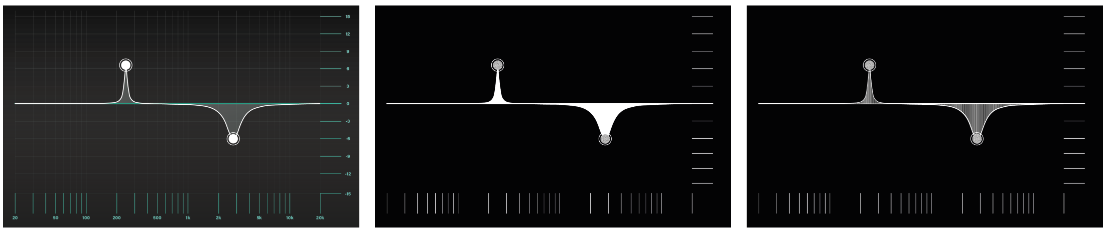
(a) Visual layer (b) Haptic layer - solid white (c) Haptic layer - striped pattern

Figure A.5: EQ curve #4 - boost of 3 dB at 250 Hz wide Q, boost of 6 dB at 4,5 kHz wide Q



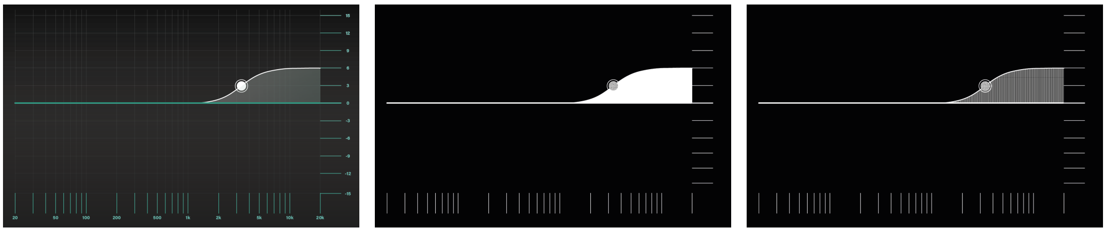
(a) Visual layer (b) Haptic layer - solid white (c) Haptic layer - striped pattern

Figure A.6: EQ curve #5 - boost of 3 dB at 250 Hz narrow Q, boost of 1,5 dB at 2,8 kHz, medium Q



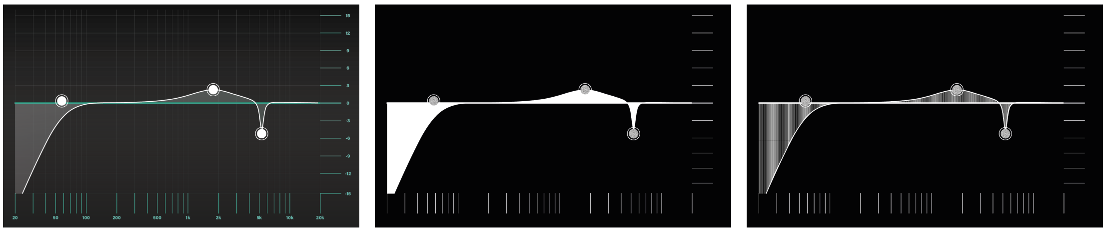
(a) Visual layer (b) Haptic layer - solid white (c) Haptic layer - striped pattern

Figure A.7: EQ curve #6 - boost of 6 dB at 250 Hz narrow Q, cut of 6 dB at 2,8 kHz, medium Q



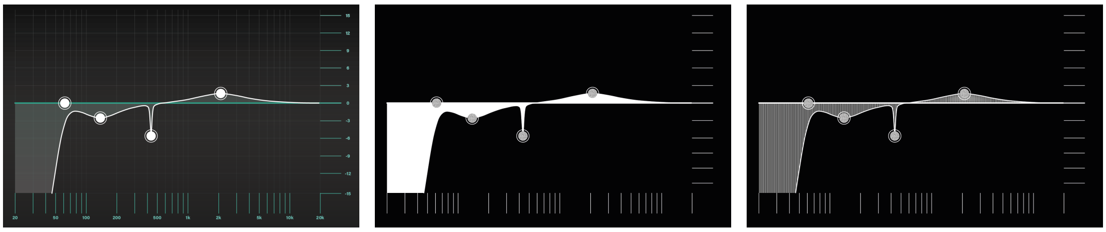
(a) Visual layer (b) Haptic layer - solid white (c) Haptic layer - striped pattern

Figure A.8: EQ curve #7 - high shelf of 6 dB 3,5 kHz



(a) Visual layer (b) Haptic layer - solid white (c) Haptic layer - striped pattern

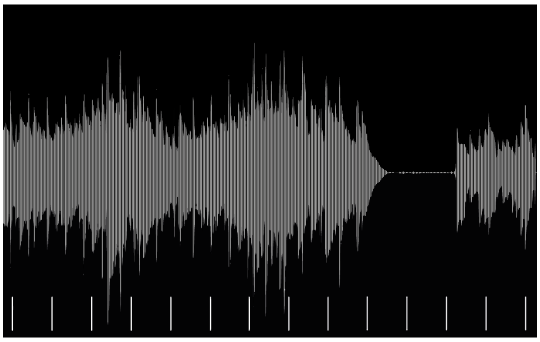
Figure A.9: EQ curve #8 - high pass at 60 Hz, boost of 3 dB at 1,8 kHz, cut of 5 dB at 5 kHz narrow Q



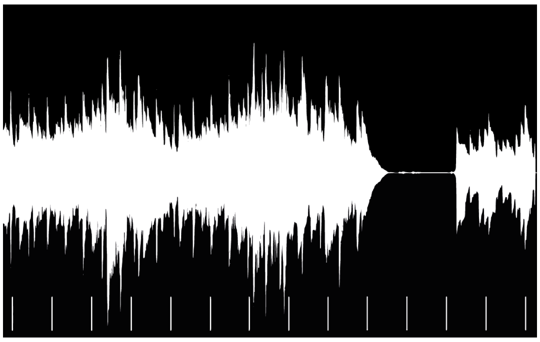
(a) Visual layer (b) Haptic layer - solid white (c) Haptic layer - striped pattern

Figure A.10: EQ curve #9 - brick wall at 60 Hz, cut of 3 dB at 150 Hz wide, cut of 6 dB at 420 Hz narrow Q, boost of 1,5 dB at 2 kHz wide Q

A.4.2 Audio waveforms recognition

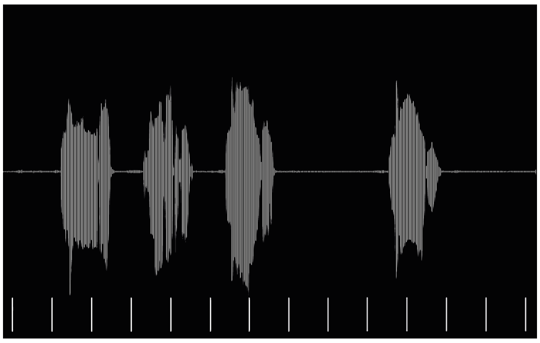


(a) Haptic layer - striped pattern

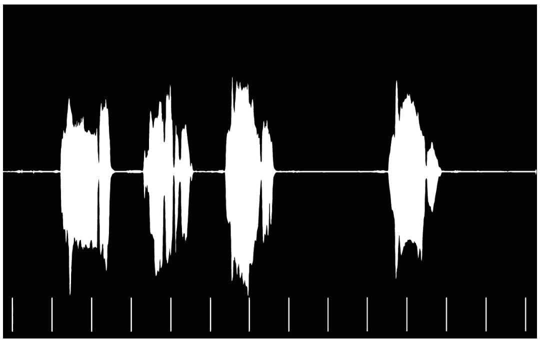


(b) Haptic layer - solid white

Figure A.11: Asset #1 - audio waveform

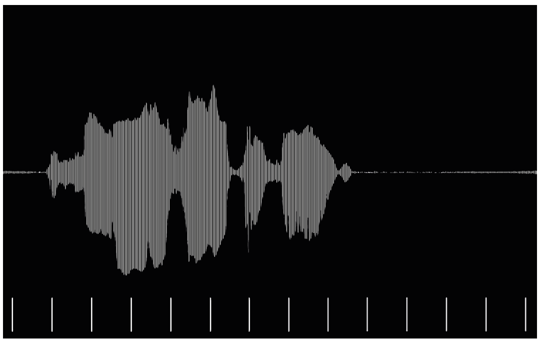


(a) Haptic layer - striped pattern

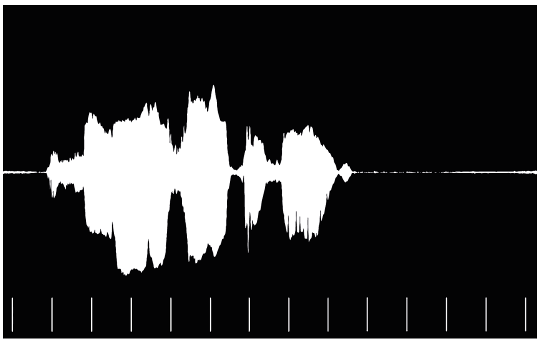


(b) Haptic layer - solid white

Figure A.12: Asset #2 - audio waveform

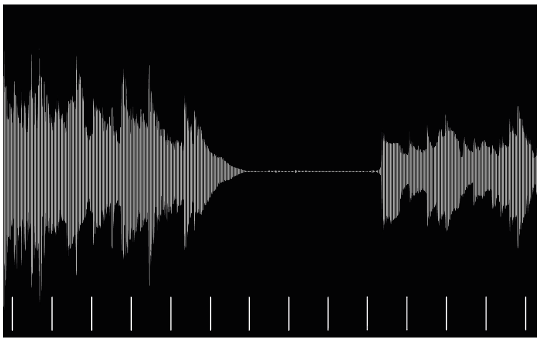


(a) Haptic layer - striped pattern

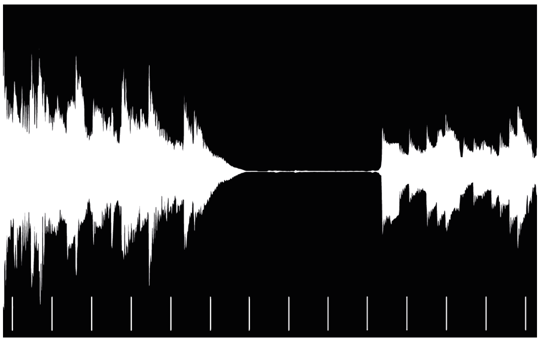


(b) Haptic layer - solid white

Figure A.13: Asset #3 - audio waveform

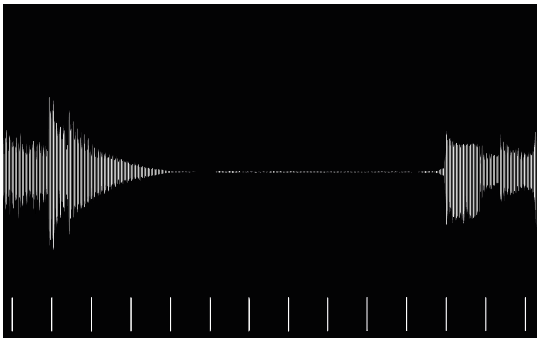


(a) Haptic layer - striped pattern

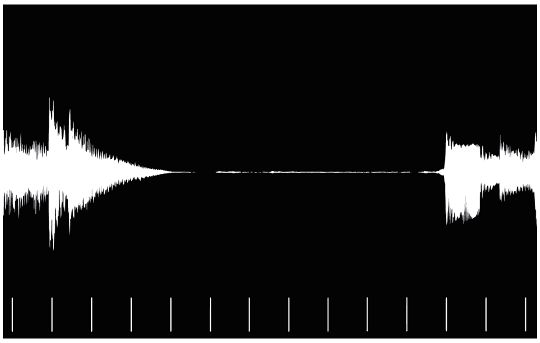


(b) Haptic layer - solid white

Figure A.14: Asset #4 - audio waveform



(a) Haptic layer - striped pattern



(b) Haptic layer - solid white

Figure A.15: Asset #5- audio waveform

Appendix B

Email interviews with visually impaired music producers

B.1 Questions

1. What is your DAW of choice and what was the process of choosing it? Did you experiment with more DAW? What are the features you do not have access to in your DAW?
2. How do you find the accessibility of plugins such as EQ, reverbs, virtual instruments? Do you try out new plugins often?
3. What are the things you struggle most in your workflow?
4. Does the audio from VoiceOver get in the way when you are mixing for example?
5. There is also this new thing called immersive or 3D audio. It is a higher format then stereo and 5.1, one of the most popular formats for immersive audio is Dolby Atmos - 7.1.4 format. Do you have any experience with mixing for this kind of format?

B.2 Interview 1 answers

What is your DAW of choice and what was the process of choosing it? Did you experiment with more DAW? What are the features you do not have access to in your DAW?

My choice of recording software is Pro Tools.

How do you find the accessibility of plugins such as EQ, reverbs, virtual instruments? Do you try out new plugins often?

I find that this recording software is easier to learn than other software it talks a big percentage of the surroundings in it. I think it is a great idea to work on the hardware unit for plug-ins specially when a lot of the hardware units do not react to the actual plug-ins. I think hardware is a vital foundation for a blind person in the recording studio for a more efficient workflow.

What are the things you struggle most in your workflow?

I had this idea for a couple of years of a hardware unit that can be also a rack mount pretending to be a compressor, limiter, equalizer, reverb, delays and many other. Where you can reach to the rack without having to touch the mouse to make any changes. Not taking away that also a mixing surface is as good also. I truly want to help you do this be part of it because I am in doors with a couple of big name brands in the Recording industry. That could be a way to cut a deal for a product distribution.

Does the audio from VoiceOver get in the way when you are mixing for example?

I use the voice over on my computer through the computer monitor not the recording or mixing monitors. I choose to do that because it does not get in the way of the main monitors when I am mixing I can separately turn down the volume on the computer if I want without affecting what I am mixing in the moment.

There is a new audio format called immersive or 3D audio. It is a higher format then stereo and 5.1, one of the most popular formats for immersive audio is Dolby Atmos - 7.1.4 format. Do you have any experience with mixing for this kind of

format?

I have not worked on a surround Mix yet. Every audio or visual production I have worked on has been just a stereo mix.

B.3 Interview 2 answers

What is your DAW of choice and what was the process of choosing it? Did you experiment with more DAW? What are the features you do not have access to in your DAW?

My DAW of choice is Pro Tools. I did some searching on line for Pro Tools with voiceover and I found Pro Tools with Speech which demonstrated how PT could work with voiceover. I also discovered another program called Flo Tools which provides a much larger number of keyboard commands to speed up the process. Everything from metering to plugin insertion. I spent a short amount of time trying to get Samplitude working with JAWS without much luck.

How do you find the accessibility of plugins such as EQ, reverbs, virtual instruments? Do you try out new plugins often?

I have found some plugins that are not accessible, most of the TDR stuff for example. Waves plugins are accessible, but the resolution on the controls is very high. Since I am doing everything with the keyboard, everything is being controled with the arrow keys. If you open a plugin like the CLA76, the release setting is at 4 by default. If I want the fastest release time, which is at 7, I have to right arrow through 4, 4.01, 4.02, 4.03 all the way to 7. It takes maybe 10 seconds to adjust a setting in a plugin that would take less than half a second on my hardware 1176. I am also a huge fan of console1 by softube. I use this on every track of every mix as if I were mixing through a desk.

What are the things you struggle most in your workflow?

My biggest challenge in the studio is workflow. This really ties in to your 4th question about having voiceover be too present when I mix. This is a huge problem for me and I am seriously considering giving up most of my metering to mix almost completely out of the box with a console and outboard. Every time I have to dim a mix to listen to feedback from voiceover, I lose focus on my mix, and that can make me a little angry if I am really in the zone. One thing that PT offers that is beneficial with my workflow is the track preset feature. I have saved chains for all of my most common tracks, aggressive vocals, smooth vocals, kick, snare, electric, acoustic, bass, piano etc and just use one command on each track to insert all of the plugins I want in that chain. Again, just how you would do it on a console, you would have the channle that your lead vocal always goes in with your most common prefered vocal chain already wired up in the patchbay.

Does the audio from VoiceOver get in the way when you are mixing for example?

There is also this new thing called immersive or 3D audio. It is a higher format then stereo and 5.1, one of the most popular formats for immersive audio is Dolby Atmos - 7.1.4 format. Do you have any experience with mixing for this kind of format?

B.4 Interview 3 answers

What is your DAW of choice and what was the process of choosing it? Did you experiment with more DAW? What are the features you do not have access to in your DAW?

I studied music production about 6 years ago, in that time I worked with Sonar producer 8.5. This software is for windows only. It is great but at this time it is very old and the scripts for jaws do not working. Now I do not working with production because I would like to change to mac system. Actually the most powerful and accessible daw for blind people is pro tools. In mac with voiceOver it is complitly accessible. There are some macros to improve the accessibility, it is called Flotools. You can see more in www.flotools.org In sonar I could recorded and mixing, but actually with Pro tools is better because there are many features that in Sonar are not accessible such as: For edition, there are more features in pro tools, there are many ways to edit an audio, you can select for clips and you can move to left and right and you can extend the selection as you want. Another feature is automation, there are many automation modes in pro tools, but in Sonar is not possible do that.

How do you find the accessibility of plugins such as EQ, reverbs, virtual instruments? Do you try out new plugins often?

In sonar, some plugins are accessible for example you can use de EQ and compressors that Sonar bring and you can also other plugins like Waves, but at this time I do not know if they are stil working. In Pro Tools all native plugins are accessible, and you can use other plugins such as Waves, iZotope, and you can also use virtual instruments like, Komplete Kontrol, from Native Instruments, etc..

What are the things you struggle most in your workflow?

I think maybe the edition. In sonar you cannot edit clips, and you cannot do plugins automations.

Does the audio from VoiceOver get in the way when you are mixing for example?

No if you can, you are able to listen to VoiceOver from other devise.

There is also this new thing called immersive or 3D audio. It is a higher format then stereo and 5.1, one of the most popular formats for immersive audio is Dolby Atmos - 7.1.4 format. Do you have any experience with mixing for this kind of format?

I have never mixed this type of productions. I do not know about it.

B.5 Interview 4 answers

What is your DAW of choice and what was the process of choosing it? Did you experiment with more DAW? What are the features you do not have access to in your DAW?

I use Logic as my main DAW, though I have tried Protools and Reason in the past.

How do you find the accessibility of plugins such as EQ, reverbs, virtual instruments? Do you try out new plugins often?

I do not use a lot of third-party plug-ins outside of the logic stock plug-ins because most of them are not. Accessible. I would say that is my biggest frustration With audio production at the moment.

What are the things you struggle most in your workflow?

Does the audio from VoiceOver get in the way when you are mixing for example?

There is also this new thing called immersive or 3D audio. It is a higher format then stereo and 5.1, one of the most popular formats for immersive audio is Dolby Atmos - 7.1.4 format. Do you have any experience with mixing for this kind of format?
Unfortunately, I do not have any experience mixing in surround sound, though I would love to get into it.