Evaluating haptic technology in accessibility of digital audio workstations for visual impaired creatives.

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ABSTRACT

This research suggests new ways of making interaction with Digital Audio Workstations more accessible for musicians with visual impairments. Accessible tools such as screen readers are often unable to support users within the music production environment. Haptic technologies have been proposed as solutions but are often generic and do not address the individual's needs. A series of experiments is being suggested to examine the possibilities of mapping haptic feedback to audio effects parameters. Sequentially, machine learning is being proposed to enable automated mapping and expand access to the individual. The expected results will provide visually impaired musicians with a new way of producing music but also will provide academic research on material and technologies that can be used for future accessibility tools.

CCS CONCEPTS

• **Human-Computer Interaction** → **Haptic Technology**; • **Accessibility** → *Visual Impairement*; • **Music Technology** → Digital Audio Workstation.

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1 INTRODUCTION

Current music production tends to be a visually demanding medium. There is a shift towards a more skeuomorphic representation of hardware studio equipment on screen, making it harder for visually impaired (VI) users to interact. With the availability of software and online applications, bedroom music production has made a massive leap in recent years [1]. As a result, many Digital Audio Workstations (DAW) made redundant the use of bespoke studio hardware like pedals, effect racks, and mixers in their physical form. However, it is argued that such an approach also boosted a different type of creative practitioners in this field[22]. Many accessibility tools are now advanced enough and widely used, for example, the digitization of the braille system into displays and editors and the use of synthesized voices for reading text on a screen. These methods support the day-to-day lives of people with visual impairments. However, these are not practical and useful for other mediums such as video games, digital art, virtual and augmented reality and music production, which rely heavily on visual feedback.

Haptic technology, which is less invasive and discrete, has been proposed in human-computer interaction studies with a focus on accessibility and VI's with positive results. However, we do not know how specific haptic systems should be applied and tailored to the individual to enhance and provide the best possible experience. This research will explore and examine these methods that can potentially lower the barriers of VI musicians and the wider VI community by proposing embodied and immersive haptic-focused accessibility tools.

2 AIMS AND RESEARCH QUESTIONS

This research aims to identify the haptic feedback techniques that can best convey visually represented audio processing functions and, consequently, to suggest a machine learning algorithm that can enhance a long-term relationship between haptic feedback and VI users. As a result, the research questions are: How can we develop the best practice approach in DAW through haptic feedback for VI musicians, and how can machine learning adapt and adjust haptic feedback information based on users' needs?

3 RATIONALE

Human-Computer Interaction and the evolution of music technology form the basis of the argument about the dysfunctionality of contemporary design methods that often exclude people with disabilities.

Many elements of the Graphical User Interface (GUI), including DAWs, can be translated into text-based information for screen reader applications. However, when creating and performing music, there are still graphical elements and relationships that cannot be expressed through text. For example, how do we represent sound effects such as compressor, reverb and delay in a haptic format that can be better understood? Current tools such as screen readers disadvantage VI users through an overload of information and potentially discourage others from exploring music.

3.1 Human-Computer Interaction

The history of HCI reveals patterns that influence the design of accessible technological tools. Paul Dourish, reference in Tanaka[29] propose four stages of interaction evolution, *electrical*, *symbolic*, *textual* and *graphical*. The advancement of technology can be reflected,

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similarly, in these stages through the development from analogue computing to binary states and from coding interaction to visual representations. Through this process, the interaction with technology has become effortless and thus socially accessible. Music production can also be seen through the prism of the four stages of interaction. Tanaka[29] draws the parallels between the two by proposing that analogue synthesizers exist in the electrical stage, audio programming in the symbolic, live coding in the textual and finally, digital audio workstations in the graphical stage. However, such evolution excludes VI users.

Haenselmann et al. [12] suggest that electronic music developed in an uncomfortable way for people with visual impairments from analogue with direct tactile interactions, like holding and striking the strings of the guitar or playing the weighted keys of the piano, to digital devices with most of the feedback information shifted towards the screen or into other visual means of representation. Although current skeuomorphic representations might have made DAW accessible from the economic and social side of things, sadly, they demonstrate a dysfunctional design process where accessibility for VI users is denied. Frid[6] has identified trends in words "adaptive music", which suggests and proposes a new way of thinking design that is inclusive and allows technological tools to be adapted and become accessible to everyone.

3.2 Screen Readers and users' feedback

VI users rely on other senses to access information in the physical and digital worlds, mainly through hearing and touch.[25] Advances in technology over the last 50 years pushed the barriers of accessibility, making more and more digital information available to users[16]. Devices such as braille display printers, editors, and screen readers are now widely available and accessible to those in need[13]. They focus on interpreting text and images using different presentation formats or text-to-speech approaches.

Screen Readers were found to be the primary tool that VI users can access DAWs[21]. Whilst screen readers are very good at reading text, they have diminished capabilities in conveying visual information, especially in an audio processing environment. Often the information is not translated successfully, or the screen reader overlaps with other information causing "cognitive overload" to the users[21].

Nick et al. [21] interviewed 4 VI individuals regarding their experience with the existing assistive technology and how this affects their workflow in a DAW. Among other information, his observations include: several actions and time needed to complete a task, the navigation with the help of the screen reader slowed down particular tasks, some graphical features could not be translated to the other senses, and spatial sound manipulation was inaccessible. Similarly, Payne et al.[24] interviewed 11 individuals with VI, and they noted the following challenges. First, users could not do many things simultaneously; they needed to invent their own methods to facilitate their workflow where technology is inaccessible with frequent unsuccessful results. Screen readers do not always follow the updates of the program. Lastly, some users asked for help from facilitators to check on their work, particularly when a musical score was used.

Efforts have been made to produce accessible musical instruments; however, according to Frid's review, only 3.6% is focused on assisting people with VI[6]. Such projects include, but not limited to, HapticWave[30] , ActivePaD [20], CuSE[12], Wedelmusic VIP Module [9], Soundsculpt[5] . These academic projects often fade out rapidly without the support of becoming sustainable solutions[6]. The variety of approaches in these projects, including tools for audio editing, processing and recording to a haptic musical database, is evidence of the complexity of sound as raw material and the challenges faced in transforming it into other non-visual forms.

3.3 Haptic Technology

Srinivasan et a.[28] propose "computer haptics" as the new discipline that started to appear more in the literature towards the end of the 20th century. It was rapidly adopted and got incorporated into modern technological tools such as mobile phones and entertainment applications as well as advancing accessibility Goggin[11]. The advantages of haptic feedback are, according to Van Der Linden, the ability to reduce the cognitive overload of a musician significantly [17] and, according to Charoenchaimonkon et al.[2] to reduce the time of completion of a task, especially in comparison to auditory or visual feedback alone. A wide range of applications and case studies demonstrate the positive contribution of vibrotactile feedback, from tools for rehabilitation procedures to day-to-day assistive technology. Besides the applied research, there is significant literature that examines the possibilities of haptic feedback at a microscopic level focusing on the use of different types of haptic feedback. For example, where on the body is best to perceive a vibrotactile feedback [23] [4] and ways we can use vibration motors, and which one offers the most effective results [26]. Furthermore, Marshall et al.[18] suggest the importance of including haptics in the new digital musical instruments design. Van Der Linden[17] propose the *musicjacket*, which assists new violin students in improving their posture through haptics.

There is a wide range of projects about vibrotactile feedback in music technology as an assistive tool for VI users. Researchers are focusing on one aspect of the problem at the time such as interviewing VI users[21][24], examining the existing technology[6][19], focusing on developing a prototype [7][3][27]. However, there is a lack of a holistic consideration in order to understand better the long terms needs to propose better solution for the user.

4 METHODOLOGY

The suggested solution for lowering the barrier of accessibility of music creation within the DAWs for visually impaired users includes two stages. The first stage will examine the relationship between the perception of sound and vibrotactile feedback. Semi-open interviews will identify VI users' current barriers while using specific software applications and functions. The primary interviews will form the basis of a series of user experience testing with both participants with VI and non-VI users. These experiments are designed to examine the relationship between the perception of sound, visual interaction on the screen and vibrotactile feedback, how the users are experiencing haptics and the degree to which it can be used as a solution to the discussed problems.

In the second stage of the methodology, we will propose a machine learning algorithm that automatically adjusts the haptic feedback to the audio effect. We will use the data from the analysis of the above-proposed experiments and map them with data that characterise the functionality of different audio effects. This process aims to expand the accessibility of the audio manipulation and provide an enhanced experience where it is needed, together with the screen readers and other tools users already have at their disposal. This approach also aims to make third-party audio plugins more accessible.

4.1 Proposed Experiment 1

For the first experiment, we will use a location that can also be accessible without causing discomfort to the user [23][4]. Furthermore, consideration has been given to the choice of embodied (wearable) technology[8]. Embodied systems make the perception of the haptic feedback effortless and reduce even more cognitive overload. Therefore, the experiment's designed apparatus will be an adjustable wristband that can be worn anywhere between the wristband and the elbow.

Vibration motors can be used in various ways according to their mechanical properties. The vibration consisted of frequency, amplitude and duration. Giordano et al.[10] elaborate on how the sense of touch can convey a message in pitch, rhythm, roughness and timbre. Those ways are a combination of the mechanical properties of a vibration motor, and they support the design decisions of this experiment. The chosen methods are the use of amplitude which can be interpreted as roughness, how strong the vibration can get, the use of different rhythmic patterns, and the experiment with distributing the signal in more than one vibrator.

The elements that are inaccessible according to the existing literature are those that are based on visual representation and are accessible to interact with through that representation (see figure 1). Some examples of those are the Equalizer, Filters, Automation, and Panning. These examples can be translated into text (see figure 2). However, the access to these numbers and what they represent and the manipulation with a screen reader demands much action, high cognitive overload and delays the creative process[21]. In the proposed experiments of this research, we aim to use haptic feedback as an alternative representation of these numbers and examine if that method is effective with possibilities to be applied by the music technology industry.

The System Usability Scale (SUS) will be used to identify the level at which users found the proposed system acceptable and usable during the music production scenario. Thus, a semi-structured interview will take place after each test to further analyse and capture the user's perspective on the system. In addition, data will be collected from each user during the tasks regarding the completion speed, errors, and accuracy. First, the recruited visually impaired and non-visually impaired users will undertake a simple test consisting of four tasks with the haptic system. Following, they will undertake four identical tasks without the haptic system but with the preferred set-up, which might or not involve audio assistive technology from the screen reader. The setting of the computer will be as close as possible to the one they are familiar with. Tasks are simple, asking users to control only one parameter at a time of the audio effect that is being tested each time. Participants will have a maximum of 1 hour to complete the test.

Figure 1: EQ effect in graphic representation

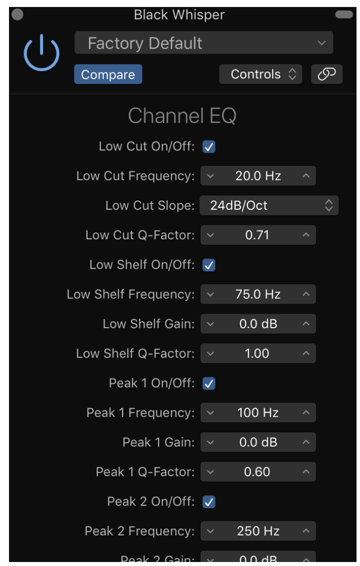

Figure 2: EQ effect in text base representation

The tests will be formed as follows:

- EQ effect: Bring EQ level to 0%, 50% 100% and the preferred amplitude
- Panning: pan it to centre, left, right and preferred position.
- Automation: identify the pick moments and bottom moments on the arrangement.
- 2D test: identify the highest, middle and lowest frequency band and put it down to 0.

4.2 Mapping

In the context of this research, mapping, according to Hunt et al.[14] is the assignment of elements of one set of data to another. The initial mapping will be the amplitude of the vibration on a fixed frequency to the number related to the cut frequency amplitude that will be manipulated in an EQ effect. That is the process of adjusting the volume of different frequency bands within an audio signal. Then, the same vibration mode will be mapped to the amplitude of

Vibration Motor	Audio Effect
Amplitude	EQ – frequency- amplitude
Amplitude	Automation amplitude line
Pattern (in a form of density)	EQ – frequency- amplitude
Pattern (in a form of density)	Panning left right
3 vibrators	Panning left right
Amplitude and pattern	Amplitude and frequency of EQ

Table 1: Mapping: Audio effects to Vibration feedback

the automation, a way to control changes in parameters over time in an arrangement.

Second mapping will use a rhythmic pattern that will express the density of vibration from very dense (frequent) to more sparse (less frequent). First, that will be mapped to the amplitude of the frequency band manipulated in an EQ effect. Secondly, it will be tested and mapped with a panning effect where dense vibrations will express the sound being in the centre and sparse being left or right.

Third mapping will include multiple vibrators aligned around the wristband. The test will map three vibrators to the panning of the track, left centre right equivalently[15] [2].

In addition, the test will combine two of the vibration methods to examine a 2D represented effect. EQ is one of the effects that is being used by producers mainly through its visual representation. On the other hand, non-visually impaired users will manipulate the frequency and its amplitude at the same time via visual feedback. This test examines the possibility of perceiving this 2D information with vibration feedback. Thus, the amplitude of the vibration will be mapped to the amplitude of the frequency band, and the vibration's density will express the frequency range. Table 1 shows the proposed mapping for the experiment.

4.3 Analysis and Results for Experiment 1

The results will be analysed in three different ways. First, the SUS will be analysed and completed according to the standard process derived from the literature review. The focus of the SUS will be on the haptic system. Second, the interviews will be transcribed and analysed using thematic wording from the users. This analysis will help us to establish a more expansive view of the hypothesis and whether further studies are needed on this subject. The interviews will also provide an overview of the aims and objectives of this study and validate data from the tasks as well as from the SUS. Third, the data captured during the test will be compared with each user using the haptic and separately the screen reader. This data set will be further analysed to argue whether haptics is effective for the visually impaired and other users. Finally, the R programming language will be used to analyse and produce statistical results and identify patterns in the performance data.

4.4 Machine Learning Approach

Machine-learning algorithms will be developed as part of the second stage of this research. Data analysis of audio-haptic and audio-visual relationships will be analysed and form the basis of this application. As a result, the proposed approach described here is rather theoretical and subject to change. The aim is to facilitate the mapping of the haptic feedback to audio effects and procedures based on the user's objective. The system will be able to propose the proper use of the haptic feedback among the examined (amplitude, pattern, panning) for the requested parameter of the audio effect. For example, suppose the user has only one vibrotactile feedback method at their disposal. In that case, the system can adjust the haptic signal's representation to address the user's best possible experience.

5 STATUS OF THE RESEARCH

My PhD studies started in May 2022 with a full scholarship from Birmingham City University, School of Digital Media Technology, Digital Media Technology Lab (DMT Lab). At the time of writing, I have completed the first two months of my studies. I am exploring the existing literature in this field and further examining research approaches to support my methodology's design. The immediate goals for the next couple of months are synthesising a systematic literature review which explores the publications related to assistive technology for VI music users and the use of haptic feedback, including commercial devices from haptic and music technology companies. An emphasis is given to the haptic hardware needed for undertaking these experiments and if the development of a bespoke device is necessary.

In parallel, I am completing the ethical approval form necessary for performing experiments with human subjects, especially with vulnerable adults. I am in contact with organisations and VI individuals that can be part of this study to help me develop a better narrative and provide feedback during an iterative process. Several positive communications have taken place so far.

6 THE ENVISIONED CONTRIBUTIONS TO THE ACCESSIBILITY FIELD

This research aims to provide a new perspective on using haptic feedback as a tool that supports VI users. This study will focus on music production, aiming to remove or significantly reduce the barriers for VI users working in music production. Contribution to knowledge and the accessibility field would be towards a modular approach that can provide adaptable solutions to users through haptic feedback. With machine learning, the system can provide the best possible haptic experience to the user based on specific tasks and applications. This will be based on the user's experience with haptics and available hardware that the music technology industry can use to broaden the accessibility tools or make their existing technology accessible by incorporating haptic feedback. More specifically, this research will also contribute to the development of general use of machine learning for accessibility tools design and will be a platform for future research development.

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