Designing a Spatial Vibrotactile Interface for Accessible Spatial Audio Mixing for Blind and Visually Impaired Music Producers

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Abstract

Spatial audio mixing is primarily achieved through a visually oriented interface in Digital Audio Workstations (DAWs). Accessibility tools, such as screen readers, have improved access to DAWs for blind and visually impaired (BVI) music producers; however, features such as spatial audio mixing remain difficult to use. Existing methods lead BVI users to adopt cognitively demanding workflows, often discouraging them from engaging with spatial mixing altogether. This study proposes using vibrotactile feedback via the bHaptics TactSuit (a wearable vest) to convey sound location and support intuitive interaction. Evaluation with 5 professional music producers (blind and sighted) provided initial feedback through semi-structured interviews on the tool's practicality and usability. The identified themes indicated that vibrotactile feedback enhances confidence and may improve the accuracy of sound localisation in space. Participants would use this tool in their workflow and suggested methods for improving the prototype, including greater precision and higher resolution. The overall feedback indicated the potential benefits of using spatial vibroatactile feedback for inclusive spatial audio mixing.

Keywords

Music Production, Spatial Audio, Accessibility, Haptic Feedback, Vibrotactile Feedback

1 Introduction

Blind and visually impaired (BVI) people face barriers to accessing Digital Audio Workstations (DAWs). The visually demanding interface, combined with the speech-based feedback of the screen reader assistive tool, makes workflows cognitively demanding [23]. The linear presentation of information through voice feedback is time-consuming and requires memorisation. Such tools often interfere with the audio being processed during music production [13], [23]. Existing literature provides insights from BVI music producers on novice accessibility tools and identifies areas within DAWs that could benefit from their application [13], [20]. Vibrotactile feedback was proposed as a potential accessibility method in DAWs, inspired by existing work such as wearable navigation tools [5] and obstacle-avoidance systems embedded in cane handles [8]. DAW features that could benefit from haptic feedback include Peak Meter, Waveform, Automation, Effects, Navigation, Spectral, MIDI, Spatial audio, and Metronome [20]. Spatial audio, specifically, is one of the most visually demanding plugins, and the available accessibility methods do not make the tool intrusive to use. 3D sound is increasingly used in production, especially in professional applications such as film and game soundtracks and sound design. Barriers to accessing this tool exclude BVI producers, making them less competitive than their sighted colleagues in the job market [20],[22]; they lag in practising contemporary techniques and therefore are less likely to be employed to produce such projects.

This paper proposes using a wearable vibrotactile feedback tool, the bHaptics TactSuit X40 vest [15], which provides 40 motors (20 on either side), as an alternative representation of sound location in the surround field. Vibrations are mapped to the sound location trajectory in the surround system, assuming the user is seated at the centre of the field. The aim is to make mixing multichannel spatial audio more accessible and less visually demanding. The prototype was developed and evaluated as proof of concept with 5 participants (BVI and sighted). They completed a series of exploratory tasks, provided qualitative feedback, and identified areas for improvement. This study questions (1) Can vibrotactile feedback enhance the audio-localisation process for BVI music producers? (2) What are the potentials of using vibrotactile feedback in DAW for spatial audio mixing?

2 Related Work

2.1 Accessibility of DAW for BVI people

BVI music producers access DAWs using screen-reader methods. A synthesised voice feedback system reads aloud the information available on the screen. Users navigate information presented in a linear format, such as menus, using the keyboard [23]. For example, accessing the *Solo* button for a track requires either a keystroke or a sequence of commands to navigate to the specific interface element. The level of accessibility of DAW through screen readers varies. Logic Pro and Ableton Live are functioning with Apple's VoiceOver, Windows Narrator, and NVDA. Pro Tools and Reaper, on the other hand, require installing external software, Flo Tools and OSARA, respectively, for full accessibility [20]. Although screen readers are vital for DAW accessibility, they present numerous barriers to BVI producers. The visual representations of audio-processing tools, such as buttons, waveforms, and audio meters, cannot be adequately conveyed via screen readers [11], and the software's complexity makes navigation laborious, time-consuming, and tedious [22]. Multimodal approaches suggest ways to mitigate these challenges and offer alternative methods for accessing music information, such as HapticWave [26], a table-based device with a handle that provides haptic feedback by moving along the x- and y-axes in response to the visual representation of the sound waveform, vibration patterns on an armband to encode EQ information [19] and a slider to facilitate parameter manipulation and provide vibration-texture feedback for changes in the sound (e.g., EQ, Meter) [14]. Haptic feedback provides non-intrusive, faster, less cognitively demanding access, making it suitable for accessibility in visually demanding music production tasks.

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2.2 Interaction with Spatial Audio Sound

Mixing for multichannel systems is common in music production, especially for commercial projects such as film music. There is significant investment in making sound more immersive for experiences like movies and XR [17]. This rapidly evolving technology overlooks the accessibility needs of blind music producers. The plug-ins used for surround sound mixing are often visually demanding, inaccessible to screen readers, or have a non-user-friendly interface; users need to interact based on audio feedback of the processed sound. According to Feierabend et al. [7] and Gori et al. [12], blind people are disadvantaged in accurate sound localisation due to a lack of visual calibration in the auditory space, indicating how alternative feedback (e.g., haptic) has the potential to enhance this task. For example, in Logic Pro, both features, angle in plane and plane size, are accessed through a slider (i.e., a 5 per cent increase at each keystroke) or a menu interface element (i.e., a degree or meter increase of 10 or 1). Interaction with the slider is via the left and right arrows, and with the menu via the up and down arrows (Figure 1). This example demonstrates that accessible interaction is not sufficient to match the intuitive interaction a sighted person would have with moving sound in the visual plane, using visual feedback and a mouse.

Tactile interaction with spatial audio exists in surface controllers, which assist with manipulation in 1D (stereo) and 2D (surround sound) using rotary knobs [10]. However, existing tools lack an intuitive, inclusive haptic method for 3D sound, including surround and proximity. Efforts have focused on using the Novint Falcon, a force-feedback device [10],[21], with participants reporting benefits for interaction and independence from visual feedback. Other methods include using Leap Motion, though participants preferred it less [10]. Von et al. [28] proposed a new musical interface in the form of a cylinder, which, among other performative controls, enables spatial manipulation using gyroscope technology (pitch, yaw, roll), mapped to azimuth, elevation, distance, and sound spread. Much of the tactile feedback research on 3D sound localisation has focused on assisting Deaf and hard-of-hearing (DHH) people; for example, Chelladurai et al. [4] suggested a head-mounted vibrotactile feedback device, and Jain et al. [16] proposed a chest or abdominal belt with 8 voice-coil motors to enhance sound localisation in VR. Based on previous work, this study suggests that the haptic vest, bHaptics TactSuit, has the potential to enable an intuitive interaction with spatial audio for BVI music producers.

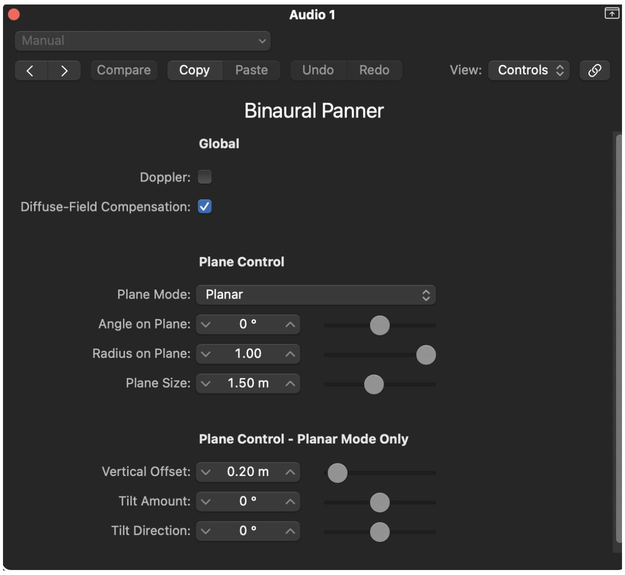

Figure 1: Logic Pro Binaural Panner plug-in, Controls View

3 Prototype Design

This study presented participants with two prototypes for spatial audio manipulation. First, the prototype is based solely on audio feedback; the second is based on audio and vibrations. Both prototypes are designed in Unity using Unity's built-in 3D spatial audio via the AudioSource and Spatializer SDK [27].

The interaction process is inspired by screen reader keyboard navigation, specifically the slider interaction in the controls view of Logic Pro (see 2.2). The movement of the sound and vibrations around the plane is made using the left and right arrows.

3.1 bHaptics TactSuit

The audio-haptic prototype utilises the TactSuit X40 vest by bHaptics [15], a commercial device used in VR, gaming and audio immersive. The choice of the torso as body location and the device was based on [1], [29], who suggest that the upper body is a highly suitable location for wearable technologies based on usability, psychological, and cognitive considerations. The torso's large skin surface supports the spatial distribution of vibrational stimuli, facilitating accurate recognition. The waist-based arrangement has been consistently used to provide directional cues in BVI navigation tasks, with positive results [5],[9]. Although the torso exhibits lower spatial acuity due to larger receptive fields, it is suitable for directional information, such as the auditory localisation task, which does not require fine-grained detail. The vest's egocentric reference enhances multisensory integration by enabling a direct mapping of auditory and tactile feedback. Finally, the device's resolution indicates opportunities for future development of the tool.

This device provides low-latency, wireless connectivity to PCs, VR systems, mobile devices, and consoles. It provides 40 points of vibration excitation, arranged in 2 grids (5-height x 4-width) of 20 motors, on the front and back of the torso (Figure 3).A prototype system was developed in Unity using C# and the bHaptics SDK [2]. The proposed system maps the audio's spatial location to a vibration cue utilising the vest's motor arrangement around the torso (i.e., 8 motors). Using interpolation from the bHaptics SDK PlayPath API, five surround-sound locations can be perceived in the vest at the exact sound trajectory (e.g., 45 degrees right front) (Figure 2). Bhaptics PlayPath enables fine-grained, real-time control of individual haptic motors without relying on predefined patterns. In this prototype, the x-axis represents the spatial information wrapped around the torso. When coordinates are between two motors, the SDK distributes the intensity across the neighbouring actuators using distance-weighted interpolation. This creates the perception of a continuous haptic point at the target location, a phenomenon also known as the phantom tactile illusion [24].

4 Methods

The prototype was evaluated by BVI and sighted music producers using a mixed-methods approach. A scenario-based approach was utilised to situate the task and enable natural engagement with the prototype [6]. During the mixing task, the music producer wants to manipulate the track's spatial location starting from

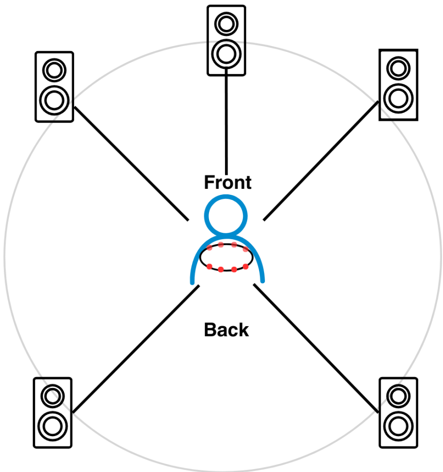

Figure 2: Mapping Surround Sound set up to 8 motors around the waist

the centre. This task was used to introduce the prototype to participants and to help them understand its use case in a mixing scenario.

4.1 Participants

Five participants (all male, 4 BVI and 1 sighted), aged 25 to 42 (M: 32.6, SD: 7.8), were recruited for this study. Participants were recruited from a pool of prior participants and through snowball sampling. A consent form and information sheet were provided in an accessible format via email. All participants are experienced in music production. Table 1 shows participants' preferred DAW and accessibility tool.

4.2 Apparatus

The test was conducted using the university's laptop and headphones. Vibrotactile feedback was transmitted through the bHaptics Tact Suit X40 (Figure 3). Audio was played through the AKG K77 Perception headphones, and participants' feedback was recorded using a Zoom H4N audio recorder.

5 Procedure

Participants were invited to come to the university where the test apparatus is located. Upon their arrival, participants were introduced to the TactSuit. They wore the vest, and the researcher adjusted the size to ensure a proper fit. Then, participants were asked to sit at a desk-like setup, with a laptop in front of them and a pair of headphones.

The evaluation comprises a familiarisation, free exploration, a short instructed activity, and an interview. In the first part, participants were given the opportunity to experiment freely to familirise them selves with the system. Then, participants were asked to manipulate the sound by positioning it at five locations (Figure 2), first using only audio, then with audio and vibration feedback from the vest. Participants used a keyboard-based interaction system based on the existing SR interaction method. Specifically, the right and left arrows move the sound source to the corresponding directions. The study lasted approximately 40 min.

Figure 3: bHaptics TactSuit X40

After completing the tasks, participants were invited to take part in a semi-structured interview and provide feedback. The questions of the interview were the following:

- Can you describe the strategy you used to locate the movement of the sound in space with and without the vibrations?
- Which method did you find easier with or without the vibrations?
- Did your strategy change when you did the task with the vibrations?
- In the vibration task, did you rely on sound/ vibration or both?
- How quickly did you familiarise yourself with the vibration and the system?
- Did the task become easier over time?
- How intuitive was your interaction using the vibrations?
- How mentally demanding did you find the task with audio only, compared to audio plus vibrations?
- Any suggestions for different patterns or mappings (intensity, location, vibrations)?
- What do you think of the prototype and its future integration in DAW?
- How can we improve the interaction and the experience with the vest?

Additionally, participants were asked to evaluate the prototype using the AttrakDiff semantic differential scale [25]. The questionnaire consists of bipolar adjectives which aim to evaluate the hedonic and pragmatic qualities of the suggested system.

5.1 Analysis

The qualitative interview data have been analysed using thematic analysis, which allows for flexible interpretation [3]. The process included generating codes associated with participants' quotes, followed by grouping them into themes. The results of

Participant	Visual Condition	Age	DAW	Accessibility Method
P1	Blind	28	Logic Pro	VoiceOver
P2	Blind	40	Reaper, Ableton	NVDA
P3	Low Vision	31	Logic Pro X, Pro Tools	Magnifying tool
P4	Low Vision	25	Cubase	Magnifying tool
P5	Sighted	42	Pro Tools, Logic Pro	None

Table 1: Participant demographics and accessibility methods

the AttrakDiff questionnaire were presented by the mean values of all participants of the semantic differential for four dimensions: (1) pragmatic quality, (2) hedonic quality/identity, (3) hedonic quality/ stimulation and (4)attractiveness [25].

6 Results

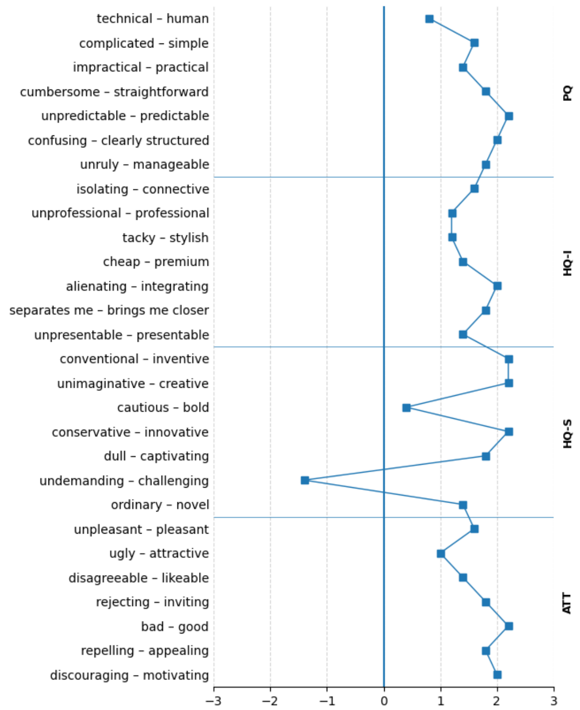

Figure 4: AttrakDif (Means)

Participants provided feedback through semi-structured interviews, and their insights indicated four themes. Participants' quotes are publicly available on GitHub [18].

6.1 Theme 1: Benefits of Vibrotactile feedback in accuracy of sound localisation and lowering cognitive load

All participants preferred the audio-with-vibration method over audio alone for positioning sound in one of the 5 surround-sound locations. Some of their quotes included: *"it gave me a clear imaging"* (P1), *"I'm hearing the sounds better now in relation to audio alone"* (P3).

More specifically, participants noted the benefits of a second modality for task execution. The benefits focus on task engagement and reassurance of accuracy. P4 mentioned *"And having another sense to assist that makes me feel a bit more comfortable with the sides (of the vest), or like with imagining the sound in the space.[...] once you have another sense to support your experience, at least I find it a bit more reassuring".*

These benefits build on the reduction in cognitive demand. When comparing doing the task with audio alone versus audio-with-vibration, P4 commented *"It was very difficult with the audio, but with the vibrations, it felt like I could rely on another sense to give some more reassurance. So I felt like with the vest, it wasn't as mentally demanding as if I just had audio to focus on."* Some participants compared the cognitive load of completing the task with the screen reader. P2 mentioned *"I don't think it's (cognitive) demanding in the slightest because it's using a different thing. You're feeling the music, you're hearing the music. Music is vibrations anyway. I think you made the experience a lot more enjoyable than it would have been, just hearing this screen reader. Often, I'll just turn the screen reader down so I can kind of hear what's going on, but it's not getting in the way of the music. But with this, you don't need to do that."* P1 mentioned that SR feedback doesn't offer adequate support for him, contrary to this suggested system *"I did have the screen reader on. Whatever angle it was announcing, I didn't understand anything of that."*

Two of the participants use magnifying tools as accessibility aids, and another participant is sighted. They all agreed that the system design resembled how sighted people perceive this information through visual feedback and could potentially replace it. P1, although blind, feels like he can do this task with the same confidence a sighted person would do, relying only on the visual feedback *"I think it just took the load off me. Sometimes when I'm working on my projects, I just feel too tired wearing the headphones and especially mixing because you just, start noticing differences or you fail to come to a decision when you're mixing. So, with this vest, I can just put my headphones aside. I'm giving a break to one sensory approach, but the other is filling in, and my workflow doesn't stop, so maybe we'll lead to a faster workflow."*

6.2 Theme 2: Easy familiarisation with the system and initial usability impressions

All participants agreed that the familiarisation with the system was very easy and quick. They specifically commented on the intuitiveness of the interaction and how much faster it was to complete the task with vibrations versus audio alone. Additionally, P3 supported the intuitiveness through the felt embodiment of the sound.

Focusing more on the system's practical usability, participants noted that although the system is already intuitive, better vest-to-body calibration or additional training would improve usability.

Two participants (both SR users) commented on the keyboard interaction within the system, noting that the left and right arrow keys improve the user experience. P1 described how he used the keys too for doing the task: *"Making sure that the short press is consistent, I'm just trying to count approximately how many clicks it takes to complete the circle."*

Finally, P4 highlighted that the system helped them anchor to points in the surround system via vibrations, making sound manipulation in the field easier.

6.3 Theme 3: Ways of improving the system

Participants described their experience with the vest and the mapping of sound to vibration location. They reported a misalignment between sound and vibration, where the two were not on the same trajectory at all times. Some specify the problem in vibration interpolation due to the low resolution of the vest circumference (8 motors around the waist) or in mapping 5 points of the surround system to 8 motors (odd-numbered to even-numbered). Participants also had different waist circumferences, which influenced the perceived distance between the two side motors and the transition from the front to the back.

P1 described *"And then as you keep going around it, this becomes softer, and this becomes confusing. So I was just hoping that two vibrations can just be one."* P5 added *"I was consciously aware of one point that the sound wasn't aligned with what I know. I think it felt off by a degree."*

Focused on their experience, the participants suggested improvements to the system based on the vest (e.g., vibration arrangement and resolution) and the vibration design (e.g., patterns, frequency, intensity). Precise alignment of the vibrations with the audio source was a fundamental requirement for improvement. The lack of direct representation of the centre front and the sides of the vest, where there are no vibration motors, was also requested as an area for development.

P2 suggested *"the thing is with the centre, once you get used to where it is, it's ok, it's because there's no vibration in the zip. If there was some way of having a vibration, if there was some way of having a vibration strip on the thing (vest), on the zip, you'd know that centre."*

Different motor arrangements and resolutions would also provide higher audio resolution and greater precision, rather than relying on the 5-speaker metaphor.

Participants proposed vibration design techniques to enhance the prototype, such as increasing vibration at the key anchors (e.g., more intense vibration every 25 degrees (P3)).

Finally, participants requested the freedom to customise the vibrations. P1 suggested *"I think it's very good, but I would just like the customisations to be at my fingertips. Some days I want to feel like a softer vibration, some days I want it to be a little more intense, depending on how I'm feeling, also like it doesn't vibrate until you press the arrow key, maybe at times I want that to change, and I want that to keep vibrating."*

6.4 Theme 4: Integration to DAW

Participants were asked about other areas of DAW where this prototype could be used. The key functionalities that emerged were the use of a metronome, the simultaneous display of multiple instruments' spatial locations, and the visualisation of FX parameter intensity.

P1 suggested *"The haptic metronome is now becoming a thing. I saw a couple of apps, metronome apps for the Apple Watch and it's not really accurate at the moment. The watch haptic is very soft. A drummer would prefer that (the vest). The drummer is already involved in an intense activity when he's drumming. So he's not going to feel the wrist vibration. It has to be really intense. Something like a vest will give you that intensity."*

P4 described *"I think there might be ways of experiencing different plugins within the vast. Let's say a parametric EQ?"*

"[...] I think one of the things that personally I would be more keen on, I mean, I would like to try, is this in a stereo scenario instead of surround. I wonder where, like, the vest could be used in conjunction with a reverb plugin to sort of simulate the space a bit more."

7 Discussion

Five participants tested a new prototype that maps surround-sound locations to vibratactile feedback around the waist via the bHaptics Tactsuit X40. AttractDiff showed positive scores across all four dimensions (PQ, HQ-I, HQ-S, ATT). Thematic analysis revealed four main themes: perceived benefits of vibrotactile feedback for sound localisation accuracy and reduced cognitive load; ease of familiarisation with the system; initial usability impressions; and suggestions for future system improvements and integration with music production ideas.

7.1 Enabling accessible spatial audio mixing for BVI music producers

Participants' feedback indicated confidence in manipulating a sound in space using the presented prototype. Adding a second modality to interaction makes the task less cognitively demanding. Studies have provided evidence that this is a required function in accessible music production setups [13],[20], and it is perceived positively by users when evaluated in equivalent prototypes [19]. The combined results of AttrakDif's Practical Qualities scores and participants' insights indicate that this prototype offers a more inclusive approach to spatial audio mixing. The system was perceived as better than the screen reader method and as resembling visual interface elements (by the low-visual and sighted participants). Additionally, it provided reassurance about the accuracy of task completion through the feeling of sound embodiment. On a practical level, the vest was comfortable to wear and easy to familiarise with. These results answer the research question and suggest that vibrotactile feedback can enhance the audio-localisation process for BVI music producers.

7.2 Potential use of vest-based vibrotactile feedback in DAW

Participants provided ideas on integrating the system into music production workflows. Previous work on the use of vibrotactile feedback in music production with an armband device identified DAW functionalities such as peak meters, FX, and codified information [19]. In this case, using a vest revealed opportunities for metronome, FX intensity, and spatial information across multiple instruments/tracks. The higher resolution enables more complex information; at the same time, its proximity to the body offers distinct possibilities and benefits [29]. Participants compared using the metronome on a smartwatch versus the vest, which is more immersive.

Participants support their positive approach to this system with positive scores on hedonistic qualities - identity, supporting their willingness to use it in their workflows. A slightly lower score but still positive in Hedonistic qualities - Stimulating indicated that the system is easy to use and straightforward without providing any surprises. Participants provide real evidence of the potential of vibrotactile feedback in DAW, both for spatial audio manipulation and other applications, thereby addressing the second research question.

8 Future Work

This study examines a prototype and provides initial insights into the perceived potential of using vibrotactile feedback from the bHaptics TackSuit for spatial audio mixing. Participants' insights indicated areas for improvement, particularly better alignment of sound location and vibration. Additional feedback suggested using specific vibration parameters, such as frequency or intensity, to mark positions in the surround field, providing anchors for the user. Future work includes improving the prototype's precise evaluation, including both sound localisation and manipulation tasks, to provide concrete quantitative data supporting the argument that vibrotactile feedback can assist with spatial audio mixing and make the task more inclusive and accessible for BVI music producers. Future evaluations will also include a greater number of participants with diverse demographics (e.g., gender, age, and music production experience). Finally, this prototype explored only the movement in a surround field but not other spatial audio elements such as azimuth, elevation, and distance. Future prototype aims to incorporate more features using up and down arrow interaction to advance the prototype features.

9 Limitation

The study design required participants to attend university facilities, which limited the participant pool and, consequently, the sample size. The diversity of participants' visual conditions and assistive tool use may influence perceptions of the prototype, although the data are largely homogeneous. Additionally, participants' diverse body shapes and the vest's fit influence the distance between the motors on the left and right sides of the body, which alters the perception of the prototype. Finally, using headphones instead of a speaker setup reduces the quality of the surround-sound experience.

10 Conclusion

The results of this study indicated that the proposed prototype, which maps sound location to vibration feedback around the waist using the bHaptics TactSuit, has the potential to improve the accessibility of sound localisation and manipulation for BVI music producers and can be useful in the music production workflow, especially for spatial audio mixing. Participant requested to manipulate sound and position it in specific locations in the surround field with audio only and with audio with vibration from the vest using keyboard interaction (left and right arrows). Participants indicated that the vibration-enabled system gave them confidence in the accuracy of task completion. The system offered the benefits of the second modality, reducing cognitive load and providing a sense of sound embodiment. Screen reader users found the system a better alternative, and they all agreed on its ease of familiarity. Although further improvements and adjustments are needed to enhance confidence and accuracy in use, the system demonstrated potential for spatial audio mixing and related tasks, such as metronome and FX parameter control.

11 Ethical Approval

Ethical approval for this study was granted by the Birmingham City University Ethics Committee. An ethics consideration statement has been provided as supplementary material.

12 Acknowledgements

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