MAKING GRAPHICAL SCORES MORE ACCESSIBLE: A CASE STUDY

Christina Karpodini, Tychonas Michailidis
DMT Lab
School of Computing and Digital Technology
Birmingham City University
Birmingham, UK
{christina.karpodini, tychonas.michailidis}@bcu.ac.uk

ABSTRACT

This paper explores new ways of making graphical scores more accessible for visually impaired users. Existing assistive technologies demonstrate a gap in providing accessible tools for composing and performing contemporary music with non-traditional western notation. The two case studies presented, *Blocks Sound* and *Logothetis Sound* examine the interactive relationships and affordances through tactile interaction and how this interaction can influence their experience and understanding of both graphic scores and interactive composition of users. We present the process and limitations and propose the use of haptic technology and tangible experience for making contemporary graphic scores more accessible and inclusive.

1. INTRODUCTION

According to the World Health Organisation (WHO), more than two billion people around the world are suffering from a near or distance vision impairment [1] . Technological development facilitates more and more the needs of visual impairment in their place of work, how they communicate as well as around their creative aspirations. The digitisation of the braille system into displays and editors and the use of synthesised voices that can read digital text have been a massive step in the right direction. However, other types of recent media, such as gaming, digital art, virtual and augmented reality and music notation, that rely heavily on visual feedback, have been mostly inaccessible to these users. This paper explores the possibilities of making graphic scores, often a visual art piece that combines visual aesthetics with music representation, more accessible to people with visual impairment using contemporary means of technology. The case studies presented aim to bring closer the gap of accessibility in graphic scores by examining the work of composer Anestis Logothetis (1921-1994), a pioneer in graphical scoring and the use of interactive techniques and advanced computational methods.

[1] https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment

2. EXISTING TECHNOLOGY

Over the last 50 years, advances in technology have enabled new assistive technologies making digital information available to the visually impaired [1]. Text focus devices such as braille display printers, editors, and screen readers are now broadly available, and accessible to those in need [2]. However, looking at the artistic freedom of these devices, they have diminished capabilities due to interference with the required functionality for the visually impaired user. The focus is mainly on processing text or images by displaying them in a different format or through text-to-speech. There is limited opportunity to explore and experience graphic scores, something visually focused.

This paper focused on the visual aspect of the aforementioned graphic scores that bring together sound and visuals. Projects related to music and blindness focus on exploring traditional western musical semiography. Screen reader software like *Blindows* and *Jaws* braille display as well as printed sheet music in braille format, have been used extensively by those interested in learning and performing music [3]. However, despite development in technology, hardware and software, there is still a large part of compositions within 20$^{\text{th}}$ century that uses non-traditional methods and consequently make part of music history inaccessible. Contemporary composers describe their music in terms of sound quality at a microscopic level with tools no longer adequate by the traditional western music notation system.

Studies in Human-Computer Interaction (HCI) enable us to narrow down the problem of accessible tools for appreciating or making contemporary music. HCI studies related to music production help us to understand the relationships of the existing assisting technologies and the need for more innovative one. Haenselmann et. al [3] suggests that the evolution of 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 the majority of feedback information shifted towards the screen or into other visual means of representation.

Paul Dourish, referenced in Tanaka [4], comments on the same topic but from the prism of HCI evolution. Dourish suggests four ways of embodied–computer interaction: *electrical*, *symbolic*, *textual*, and *graphical*. In this context, the interaction shifts from being accessible to non-

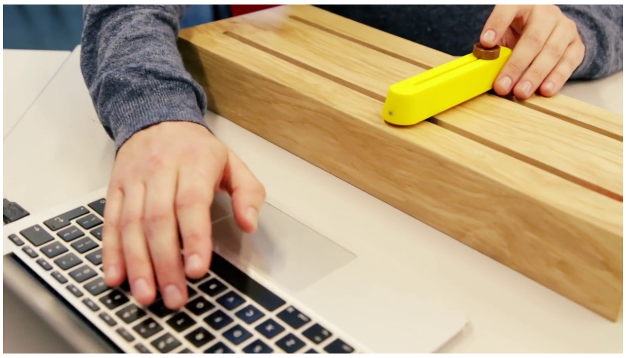

Figure 1. Haptic Wave.

accessible because of the focus on graphical/ skeuomorphic representation. Parallelisation of Dourish's four ways of interaction through the expansion of music technology are as follow:

- Electrical = Analog synthesizers
- Symbolic = Audio programming
- Textual = Live coding
- Graphical = Digital Audio Workstations

During the last 20 years, researchers have made great efforts to make contemporary and mostly digital music creation accessible. Such projects include, but not limited to, HapticWave [5] (see figure 1), ActivePaD [6], CuSE [3], Wedelmusic VIP Module [7], Soundsculpt [8] (see figure2). These academic projects often fade out rabidly without the support to become sustainable solutions. 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.

Fine arts institutions like galleries and museums, including artists have made a significant effort to make their visual art accessible. Although these efforts provide a unique experience of the art piece, there are limitations to what the attendee can perceive and understand by just touching the artwork. Very often, a multimodal approach is needed, with brail text or audio description to accompany the piece [9]. Therefore, the development of haptic feedback technology has become an essential feature in moving research forward and creating a more holistic experience for art pieces while providing tools for creation.

Unlike other visual art pieces, graphic scores cannot be accompanied by an audio description as they are sonic art pieces. Thus, the case studies presented here have focused on exploring ways of creating Logothetis's graphical score, accessible to visually impaired users, interpreted and analysed within the concept of interactive composition. The following case studies suggest how we utilise this idea. Graphic scores are an intriguing subject for multi-modal design research that combines accessibility, interactivity, tactility, and sound.

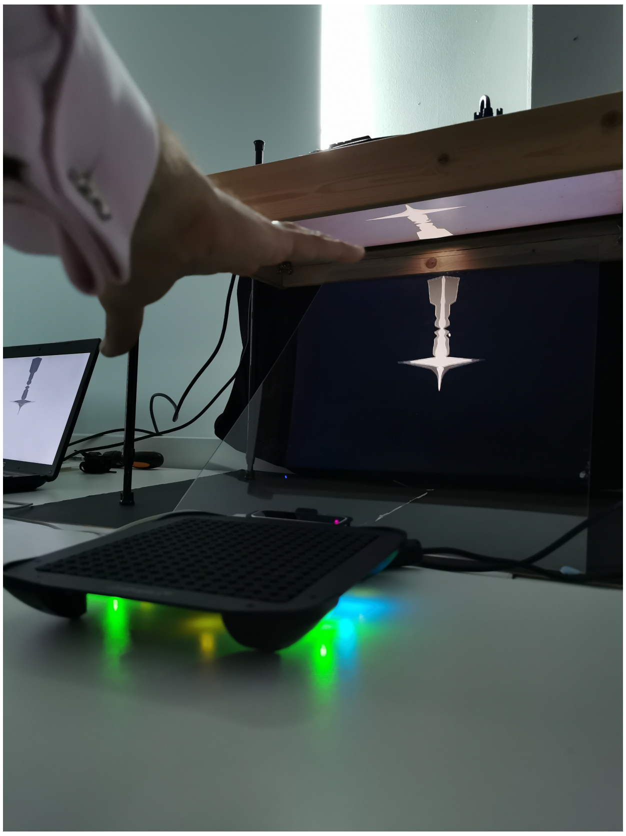

Figure 2. Soundsculpt.

3. THE SENSE OF TOUCH

Haptics has been extensively applied to systems for enhancing the experience of the user as well as to improve the music performance of particular tasks. The *Haptic Chair*, for example, by Nanayakkara et al. [10] provides a cross-modal audio-visual feedback system for making music accessible to people with hearing impairments. A study by Feierabend [11] suggests how visual experience influences the understanding of the spatial allocation of sounds in a multiple sources identification context, but not necessary with a single source. Similarly, we can understand the sounds by associating them with a shape, or graphical form such as letters and words [12]. Furthermore, the perception and understanding of music and sounds affect the different levels of visual disabilities [13, 14, 15]. The haptic feedback experience from a musical instrument is critical in understanding the musical quality of an instrument [16], and thus can be a crucial factor for developing accessible interfaces for musical expression for both visually [5] and hearing impaired [17].

Alvarez [18] suggests that the exploration of art through touch has significant advantages regarding the overall understanding and perception of the art despite the visual inability. In addition, the sense of touch can challenge how we advocate other sensory input information provided by other senses. Lastly, Christidou and Pierroux [19] suggest that our understanding can be formed and changed through the comparison process of the actual touch experience, of an object, for example, and the anticipated visual information because of “texture, materiality, shape, temperature and size”.

4. ANESTIS LOGOTHETIS GRAPHIC SCORE

The evolution of music during the second half of the 20^{th} century led to the exploration of many new ways of producing sounds but also representing them. With graphic scoring being one of these innovative methods, pioneer composers like Anestis Logothetis explored how symbols and shapes can represent sound. His approach liberated him from the conservative way of notating music and let him add sonic features to his scores like timber, flexible form, time and speciality. Logothetis, quoted in [20], describe his process as follows: “When a piece of paper is used as a space for representing a sonic event, every point and line is brought into relationship with the entire surface [. . .]. The arbitrary correspondence between surface and symbols allows for the temporal associations of sonic events and the control of their duration; while out of the convention, the positioning of musical events high or low on the paper represents high and low pitches respectively”.

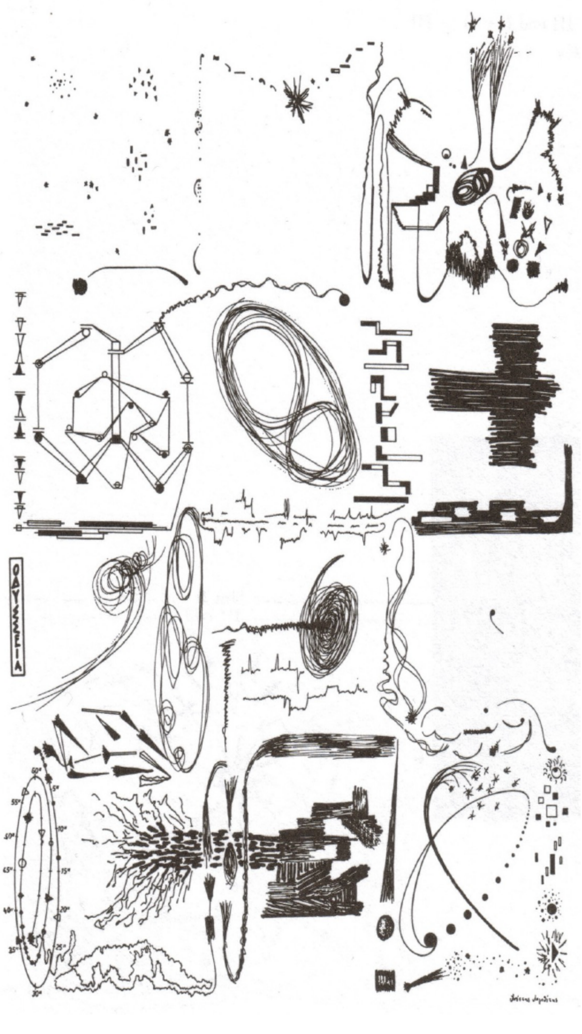

Figure 3. Graphic score *Odysee* (1963) by Logothetis.

Despite the freedom in the compositional process, his scores not only represent the musical information but also become a visual art piece that is aesthetically pleasing on its own, as seen in figure 3. Logothetis describes the physical *paper* as a space of interaction and music creation where the symbols become independent sonic entities ready to be performed. Moving forwards from this idea, we proposed that 3D tangible objects can be placed in space, ready to be manipulated and become interactive. Mongini [21] provides an overview of Logothetis aesthetic work, which provided the basis for conceptualising and designing these case studies. Furthermore, the analysis and taxonomy of symbols in Logothetis’s work *Odysee* (1963) by Baveli and Georgaki [20], enable a better understanding of the selection of the individual visual structures and symbols that installation uses.

5. CASE STUDIES

The two case studies presented here are influenced by the graphic scores and the design progress of the composer. *Blocks Sound*, offers a minimalist approach for using 3D objects in space where *Logothetis Sound* has a more direct relationship and inspiration from the piece *Odysee*. In addition, it contains micro-scaled visual structures that can be used individually.

The following case studies reflect how such a graphical score can become the medium for interactive compositions for visually impaired users.

5.1 Blocks Sound

5.1.1 Introduction

Block Sound (see figure 4) installation examining how the audience responds and perceives sounds in an interactive composition. It requires participants to compose their music by positioning little LEGO-like blocks on the specified white area. The installation aims to transform the traditional musical notation into a playful tactile experience by moving and rearranging the different size blocks. Participants can interact with the block as if they are notes by simply dragging them across the board and altering the synthesis of the score. In addition, it introduces participants to musical concepts like pitch location (high and low). It makes interactive music-making tangible and accessible to people with lower or restricted vision [2] .

5.1.2 Process

The installation consisted of a lighted board, a PS3eye camera, audio speakers and LEGO-like blocks. The lighted board is placed within on a wooden box specially designed and laser cut to hide the laptop and any exposed cables. The installation is 37cm(W) x 40cm(H) x 24cm(D) excluding the speakers whose size might vary depending on the exhibitions circumstances. Blocks Sound has been developed in OpenFrameworks and Max [3] programming environments and uses a blob detection algorithm based on the

[2] *Blocks Sound*. It has been presented as an installation in various festivals such as Peckham Digital, Goldsmiths Pop-Up, Hack and Scratch (Trajectory Theatre), where participants have been asked to give feedback on their experience. https://vimeo.com/337125549

[3] www.cycling74.com

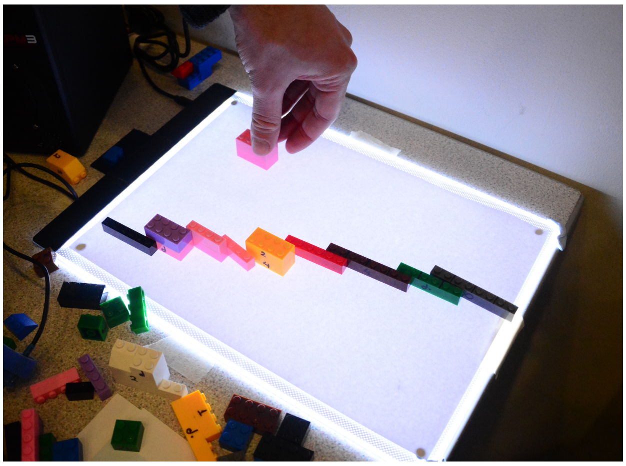

Figure 4. Blocks Sound.

ofxOpenCV [4] framework that can identify the location of the blocks within the frame of the board and translate these coordinates into individual moments of sonic events.

The camera, placed above the whiteboard, uses the algorithm, converts the incoming image into greyscale, and memorises the first frame as the default background colour. The lighted board emits white colour as the background so users can quickly identify blocks placed on top. From that point, any new object placed in the frame of this background (lighted board) is being identified as different, and its centred coordinates and contour coordinates are being saved in an array of new objects. A virtual cursor/ line moving from left to right, the same way we would read western music notation, scans the screen's pixels to find the top left corner coordinate of the identified contours.

To create a polyphonic system, the screen's height has been split into eight equal parts where only one block can be identified at the time. These eight lines are a decision taken considering the distance between the board and the camera and the number of blocks that can fit in the total height of the board. For example, if blocks are positioned on top of each other across the height of the board, they will not be able to fit more than eight blocks.

Moreover, when the cursor meets the identified object within the specified height region, it triggers a sonic event. In this way, we can have up to eight sonic events triggered simultaneously. When the virtual cursor reaches the end of the camera's window width, which is also the physical length of the whiteboard, it will loop the sequence from the start.

Following this process, the coordinates are sent to Max software programming environment via Open Sound Control (OSC) communication protocol, where they are creatively sonified.

5.1.3 Users' feedback

Seven members of the public attending the Peckham Digital [5] art exhibition were asked to provide feedback related to their experience, the interaction and the design of this installation. The range of participants was between 26 to 35 years, with an average age of 29.5. Out of the seven, the three were professional musicians, and the remaining four had no musical background. Regardless of their musical background and experience, all participants understood the interactions with the blocks, how they are used and what they represent. All participants answer positively to a question regarding the functionality of x and y axes and the blocks. When participants were asked how the tactile feedback experience helped them understand musical notation, six out of seven responded "Yes, significant" and the other participant replied, "Not so". Asking "how easy was it to create new musical patterns by changing the position of the bricks?", five answered "very easy" and two responded with "neither easy nor hard". Overall the feedback was positive, and the system was able to engage haptically and musically. One participant said: "really nice. It was fun creating music that way", and participant two commented, "great idea, creative and entertaining way to learn for someone!".

Although we were hoping to test the system with visually impaired attendees during the installation, we had no participants who volunteer. Future iterations of this research will include invited participants in a supervised and controlled environment. Whilst none of the participants was visually impaired, the feedback provided positively contributes to a proof of concept for tangible 3D objects applied in interactive graphic scores.

Computer vision	OpenFrameworks C++
Recognition of blocks	ofxOpenCV
Sending x,y location to sound program	OSC
Sonification of coordinates	Max

Table 1. Applications used for *Blocks Sound*.

5.2 Case Study Two: Transforming Logothetis Sound

This case study builds upon the knowledge and feedback gained from case study one, *Blocks Sound*. When we observe the limitations of interaction and audio, the approach taken here was to develop more complex interactive objects with enhanced audio-tactile relationships. The case study uses composition *Odysee* (See figure 3) as the backbone of the system. *Odysee* consists of small sections bringing out freedom and flexibility in the interaction and form. The aim was to shape the 2D symbols from the score and transform them into 3D objects to create a more engaging tangible experience. The new objects need to be self-exploratory and understandable via the sense of touch aimed toward users with visual impairment.

In the first approach, we used graphic design software to extract the features of specific symbols from the 2D images and laser cut and engraved the symbols in wood (see figure 5). This process gave the signs individual tangible entities. Five moderately small blocks of wood, average 10cm(W) x 10cm(H) and wood thickness 4mm, represent five different parts of Logothetis composition. However, the results

[4] https://openframeworks.cc/documentation/ofxOpenCv/
[5] https://www.peckhamdigital.org/

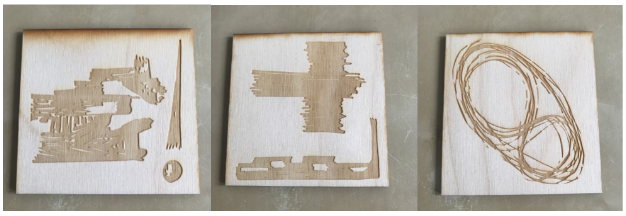

Figure 5. First attempt, wood engraving.

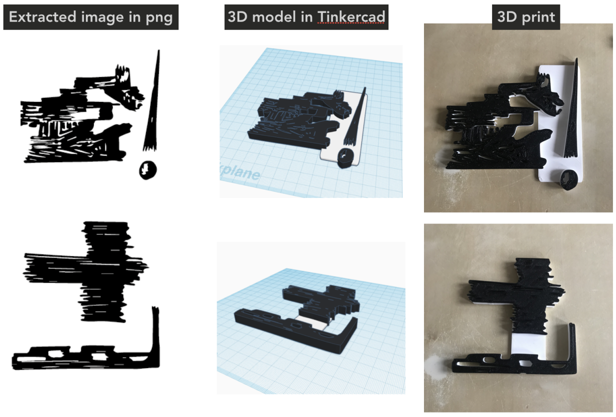

Figure 6. 3D objects.

of the wood engraving were not satisfactory in terms of the tangible feel and haptic feedback experience since the depth of the image was not deep enough >0.01mm, to provide a mental representation of the symbol.

The second step was to 3D print these specific symbols to enhance the features. Three of the graphic score symbols that were used for the laser cutting approach were imported into Tinkercad [6] software and have been extracted into 3D objects (see 6. The size of the final PLA 3D prints that have been used for this project is 110mm(W) x 100mm(H) x 8mm(D).

This approach gave more satisfactory results, and it has been used for the final version of this project. The next step of this project was to test the 3D printed symbols with computer vision algorithms. The complexity and refined detail shapes of the 3D printed symbols exclude the use of blob detection and contour detection. The approach here was to sonify all details available from the 3D object and not just the general position of the x and y-axis. Therefore the first test has been made with the darkest pixel detection algorithm where the black 3D objects have been identified instead of scanning the difference in the white background they are placed on. This algorithm, unlike the blob detection algorithm of the first case study, creates a rich set of data of recognised pixels.

Following the same technique as with *Blocks Sound*, the cursor line that moves across the window sends the coordinates of the identified pixels to a polyphonic synthesiser in Max via OSC. As a result, the synthesised sound is rich in dissonant frequencies reflecting the outlines, shapes and densities of the drawings of the composer.

Similar wooden box and electronic components found in *Blocks Sound* are also used for this case study. While the overall system of the installation remains the same, the individual 3D objects that are sonified are unique. Users can experience the tactile feedback, using their fingertips, from the 3D object and listen to the sounds generated from that object. They can also rearrange and perform with the 3D objects by placing them in a different order and angles to change light and thus the sound.

[6] https://www.tinkercad.com/

5.3 Case studies sonification process

These case studies aimed to create simple and understandable audio-haptic feedback relationships through interaction. *Blocks Sounds* has been through many sonic interactions due to the simplicity of information that the interactive blocks send to generate the music. As a result, single events in time generate endless sound synthesis ideas. The only limitation is that the pitch controls the number of blocks available on the Y-axis.

Unlike *Blocks Sound*, which has a simple and relatively linear interaction between the movement of the block and the sounds they produce, *Logothetis Sound* demands a different approach to reflect the aesthetics of the composer best. Therefore, the two sound approaches are blended and interconnected. The proposed sonification method here is similar to the *Blocks Sounds* on how the Y-axis controls the pitch of the sound and the X-axis the time. It applies physical modelling techniques to recreate orchestral sound styles similar to those available at the time of composing *Odysee* (1963) and still retain a level of interaction and engagement with the performance of the score. For a more organic approach, there is the option to use an existing recording of known performances as the source material. In addition, the system uses machine learning vision algorithms to recognise the symbols and generate the sound.

6. DISCUSSION AND CONCLUSION

The two projects *Blocks Sound* and *Logothetis Sound* support the idea of making alternative and contemporary music notation systems like graphic scores more accessible to visually impaired people. The acknowledgement of existing assistive technology, relevant projects, and the study of them through the prism of Human-Computer Interaction facilitates this research and design process. Feedback from the users of the first case study created a variety of questions regarding the affordance of this interaction and the possibilities of an extended application. The case studies can be helpful from an educational viewpoint for understanding music and sound notation and representation. In addition, the case studies are also a step forward toward understanding and creating graphic scores for visually impaired musicians. These new complex objects question the available technology and open the possibility of experimenting with different technologies. For example, machine learning, symbol identification and psychical computing can replace the current computer vision algorithm and provide more tailored audio-haptic feedback. Future iterations of these projects will concentrate on haptic interaction design and how it can become more effective and accessible but also creative.

Acknowledgments

Thanks to Prof. Atau Tanaka for his support and guidance on the case studies and Robert Hall from Goldsmiths University of London for his help with laser cutting and the 3D printing process.

7. REFERENCES

[1] L. Kugler, "Technologies for the visually impaired," *Commun. ACM*, vol. 63, no. 12, p. 15–17, nov 2020. [Online]. Available: https://doi.org/10.1145/3427936

[2] W. Homenda, "Intelligent computing technologies in music processing for blind people," *Proceedings of the 2010 10th International Conference on Intelligent Systems Design and Applications, ISDA'10*, pp. 1400–1405, 2010.

[3] T. Haenselmann, H. Lemelson, and W. Effelsberg, "A zero-vision music recording paradigm for visually impaired people," *Multimedia Tools and Applications*, vol. 60, pp. 589–607, 10 2012.

[4] A. Tanaka, *Embodied Musical Interaction: Body Physiology, Cross Modality, and Sonic Experience*. Springer Science and Business Media Deutschland GmbH, 2019.

[5] A. Tanaka and A. Parkinson, "Haptic wave: A cross-modal interface for visually impaired audio producers," in *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. New York, NY, USA: Association for Computing Machinery, 2016, p. 2150–2161.

[6] J. Mullenbach, D. Johnson, J. Colgate, and M. Peshkin, "Activepad surface haptic device," *Haptics Symposium 2012, HAPTICS 2012 - Proceedings, Vancouver, Canada*, 03 2012.

[7] A. Georgaki, S. Raptis, and S. Bakamidis, "A music interface for visually impaired people in the WEDELMUSIC environment. design and architecture," in *Proceedings of the 1st International Symposium on Music Information Retrieval (ISMIR 2000)*, Plymouth, United States, 2000. [Online]. Available: https://doi.org/10.5281/zenodo.1417291

[8] B. Di Donato, C. Dewey, and T. Michailidis, "Human-sound interaction towards human-centred cross-modal interaction with sound," in *Proceedings of the 7th International Conference on Movement and Computing*, ser. MOCO '20. New York, NY, USA: Association for Computing Machinery, 2020.

[9] L. C. Quero, J. I. Bartolomé, and J. Cho, "Accessible visual artworks for blind and visually impaired people: Comparing a multimodal approach with tactile graphics," *Electronics (Switzerland)*, vol. 10, pp. 1–19, 2 2021.

[10] S. Nanayakkara, E. Taylor, L. Wyse, and S. H. Ong, "An enhanced musical experience for the deaf: Design and evaluation of a music display and a haptic chair," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ser. CHI '09. New York, NY, USA: Association for Computing Machinery, 2009, p. 337–346. [Online]. Available: https://doi.org/10.1145/1518701.1518756

[11] M. Feierabend, H. O. Karnath, and J. Lewald, "Auditory space perception in the blind: Horizontal sound localization in acoustically simple and complex situations," *Perception*, vol. 48, pp. 1039–1057, 11 2019.

[12] R. Bottini, M. Barilari, and O. Collignon, "Sound symbolism in sighted and blind. the role of vision and orthography in sound-shape correspondences," *Cognition*, vol. 185, pp. 62–70, 4 2019.

[13] A.-A. Darrow and J. Novak, "The Effect of Vision and Hearing Loss on Listeners' Perception of Referential Meaning in Music," *Journal of Music Therapy*, vol. 44, no. 1, pp. 57–73, 03 2007.

[14] L. Pring, K. Woolf, and V. Tadic, "Melody and pitch processing in five musical savants with congenital blindness," *Perception*, vol. 37, no. 2, pp. 290–307, 2008.

[15] B. Jones, "Spatial perception in the blind," *British Journal of Psychology*, vol. 66, pp. 461–472, 1975.

[16] C. Saitis, H. Järveläinen, and C. Fritz, *The Role of Haptic Cues in Musical Instrument Quality Perception*. Cham: Springer International Publishing, 2018, pp. 73–93. [Online]. Available: https://doi.org/10.1007/978-3-319-58316-7_5

[17] S. C. Sanayakkara, L. Wyse, S. H. Ong, and E. A. Taylor, "Enhancing musical experience for the hearing-impaired using visual and haptic displays," *Human–Computer Interaction*, vol. 28, no. 2, pp. 115–160, 2013.

[18] A. Alvarez, "Please touch: The use of tactile learning in art exhibits." From Content to Play: Family-Oriented Interactive Spaces in Art and History Museums Symposium, Paul Getty Museum, June, 2005, pp. 4–5.

[19] D. Christidou and P. Pierroux, "Art, touch and meaning making: an analysis of multisensory interpretation in the museum," *Museum Management and Curatorship*, vol. 34, pp. 96–115, 1 2019.

[20] M.-D. Baveli and A. Georgaki, "Towards a decodification of the graphical scores of Anestis Logothetis (1921-1994). The graphical space of odysee(1963)." SMC-5th Sound and Music Computing Conference, Berlin, Germany, 2008.

[21] C. Mongini, "Sign and information: On anestis logothetis' graphical notations," *Deleuzeand Contemporary Art*, p. 227, 2010.