Accessibility of Graphic Scores: Design and Evaluation of Tactile Supports for Blind People

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ABSTRACT

In this paper, we present the outcome of a musical workshop on accessibility of graphic scores for blind people, held in Brescia, Italy with the support of *Unione Italiana dei Ciechi e degli Ipovedenti ETS - APS*[1] (UIC). Through a series of meetings and side-by-side study sessions, four blind musicians were involved in a collective musical experiment, culminating in a final concert based on three pieces from the historical repertoire. During these meetings, a series of semi-structured interviews with the participants allowed us to collect a series of guidelines and suggestions regarding the design and creation of tactile scores and to discuss performance strategies, in order to facilitate accessibility of this peculiar repertoire to visually impaired people.

Author Keywords

Accessibility, Graphic Scores, Blind People, 3D-printed Supports

CCS Concepts

•**Human-centered computing** → **Accessibility design and evaluation methods;** *Empirical studies in accessibility;* •**Applied computing** → Fine arts;

1. INTRODUCTION

In recent times, the topic of accessibility has become increasingly central to research, reflecting a growing awareness of the importance of inclusivity in different human activities. According to the World Health Organization, at least 2.2 billions people suffer from some kind of visual impairments, and around 40 millions are blind. These numbers are likely to almost double by 2050 [8].

Since most interfaces and musical notation systems are based on symbolic abstractions of visual nature, it is necessary to develop new means to facilitate access to musical expressiveness and creativity for Blind and Visually Impaired (BVI) people. With the progress of studies in the field of Human-Computer Interaction (HCI), new technologies, interfaces and tools have been successfully deployed. Many innovative researches relies on haptic or vibro-tactile feedback conveying non-visual information, and their practical application has been investigated towards educational purposes [19, 20], assistance to composing or editing [24, 26, 30], and musical performances [5, 31].

Regarding musical notation, being Braille the standard reading/writing system specifically designed for BVI people, several protocols for translation from music notation to Music Braille Code (MBC) [3] have been proposed (e.g. [11, 15, 14]), along with softwares for automatic Braille music scan and acquisition (e.g. [6]). However, besides being difficult to learn, read, and translate, as suggested by several researches such as [22, 23], MBC is prone to a number of problems due to its poor flexibility. Moreover, during the XX century, Western musical semiography has been enriched with a plethora of new symbols, given the need for composers to represent on the scores increasingly subtle musical parameters, extended techniques, or electronic sounds, for which traditional notation proved inadequate. A peculiar case of such semiographic experiences is constituted by graphic scores [10, 28]. Often related to aleatoric music, such scores imply the adoption of visual and geometric elements underlying musical structures and gestures. They do not represent precise musical parameters, rather provide a set of high-level abstractions which can be interpreted following a set of given instructions: therefore, executions of the same piece could be quite dissimilar. Because of their intrinsic nature, graphic scores are not only a form of notation, but also constitute a form of visual art by themselves, which cannot be fully appreciated by the sole listening of their audio counterpart: as such, BVI people are excluded from access this repertoire.

To initiate a discussion on the accessibility of graphic scores, in this paper we propose the design of tactile supports based on three scores from the literature. Throughout a four-day workshop with four blind musicians, we collected feedback and suggestion about design improvements, and evaluate their effectiveness and practical implications during side-by-side study sessions, rehearsals, and a final concert.

[1] `https://www.uicibrescia.it/`

NIME'24, 4–6 September, Utrecht, The Netherlands.

2. BACKGROUND

2.1 Graphic Scores

Graphic scores are a form of musical notation highly influenced by visual art, representing high-level musical events that are pseudo-random or impossible to notate otherwise. Indeed, such scores often deals with musical gestures rather than precise sounds, and provide indications and formal development for musical performances, generally expressed through the use of geometric shapes or abstract symbols, along with several preliminary instructions.
Graphic scores became popular around the 50s thanks to the works of Earle Brown, who consider standard notation as "a relatively inefficient and incomplete transcription of the infinite totality which a composer traditionally hears" [28]. Other noticeable examples are Schafer *Epitaph for Moonlight* (1968), where graphical objects constitutes a sort of guidance for choir improvisation, Maderna's *Serenata per un Satellite* (1969), in which standard notation is present but arranged in a way that its displacement, describing trajectories in space, acquires an additional semantic function; or interactive scores such as *Fontana Mix* (1958) by John Cage and *Ink Bops* (2017) by Ellen Burr, where the aleatoric combination of individual elements results in ever-evolving musical structures.
Due to their effectiveness in graphically describing musical movements within a composition, they can also take on the function of 'descriptive scores' [12], often applied to computer music: an example being the accompanying visual score created by Rainer Wehinger [18] on Gyorgy Ligeti's *Artikulation* (1958).

Being unique works of visual art per se, their fruition is strictly linked to being seen. Furthermore, the interpretative freedom often delegated to the players, combined with the absence of a univocal sign-sound correspondence, makes it almost impossible to fully appreciate the composer's intent simply by listening to an execution. Therefore, BVI people cannot access graphic scores in their native form: this motivated our research on tactile supports.

2.2 Accessibility of Music Notation

The literature regarding music notation for BVI people mostly deals with the direct transcription of Common Western Music Notation (CWMN) into Music Braille Code (MBC) [3] compliant with the Unified English Braille (UEB) [29] standard. In Braille music notation, pitches and durations are encoded into a standard Braille cell (six embossed dots in a 2x3 matrix), along with other specific encoding for clefs, time signatures, accidentals, dynamics, etc. This process is quite time-consuming and traditionally carried out by experts [1] requiring specific preparation [2].
As such, several methods and protocols for automating such translation have been proposed. For instance, [14, 15] rely on the MusicXML [13] encoding to automatically operate the translations via software and improve portability. Efforts to enhance the accessibility of music notation have also been made on the input side: for instance, in [4] the authors proposed an open-source interface for rendering both CWMN and MBC in the browser along with auditory feedback; the last release of MuseScore[2] provides typing support for Braille notation; innovative hardware with improved access surfaces to facilitate the music writing have been recently introduced [27].
However, such works are centered on CWMN: besides forms of traditional notations belonging to non-western cultures still being clearly underrepresented [17], there is a profound lack of researches oriented towards the accessibility of non-conventional notations, with only few performance-oriented experiences relying on audio or tactile triggers, and musicians' interplay (e.g. [25]). To the best of our knowledge, only Karpodini & Michailidis [16] explicitly include graphic scores: in *Logothetis Sound*, they extrapolated several shapes from the score of Anestis Logothetis' *Odysee* (1963) into 3D-printed objects which can be explored via interactive sonification.

As such, with this paper we aim to encourage debate on possible solutions to fill this gap.

3. METHODOLOGY

The experience here presented was structured in the form of a four-days, in-person workshop hosted by UIC in Brescia, Italy. The meetings were led by the first author of this paper, who has a strong background in twentieth-century compositional practices. In order to provide the participants with practical perspectives and an enriching experience, during the last day we organized an informal concert based on three historical scores analyzed during the workshop.
The four attendants were all volunteers, all of them were blind from birth, the average age was 50,5. Three of them were professional musicians, one had musical studies as amateur. None of them had previous experience with graphic scores. The resulting ensemble consisted of piano, trumpet, voice and accordion.
Suggestions and comments from the participants were collected in a series of semi-structured interview or emerged from spontaneous moment of discussion during the days spent together, from which we extracted relevant themes according to Braun & Clarke's [7] thematic analysis. The dialogues have been transcribed and progressively harmonized into themes, reported in Section 4.

3.1 The Scores

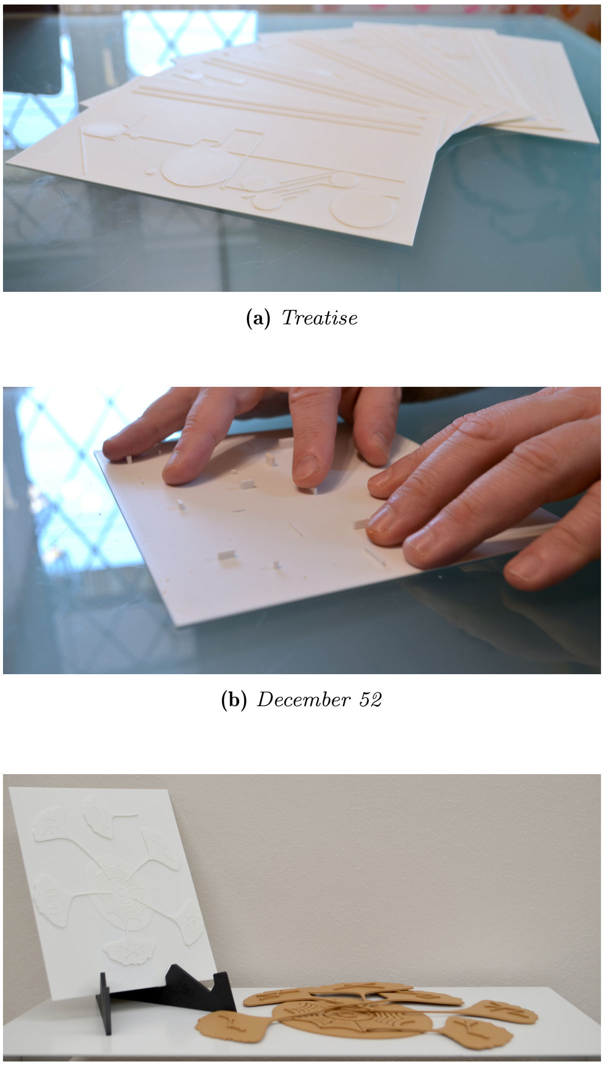
During the workshop, we worked on three graphic scores from the historical repertoire: a selection of six pages (130-135) from *Treatise* (1967) by Cornelius Cardew; *December '52* (1952) by Earle Brown; and *Gingko* (2007) by Jon Raskin.
In order to allow the participants to access the graphic repertoire, we relied on 3D-printed supports representing the original scores, which they can touch and explore freely. For the production of supports, we digitally screened the original scores, converted into .svg format, extruded as 3D files, and printed. We used Linearity Curve[3] for .svg conversion, and Blender[4] for 3D modelling. We printed the scores in PETG/PLA - a hard, enduring, and recyclable material. For the final supports, we adopted an A5 format with standard 0.6mm Braille measure for the extruded parts (comments about previous prototypes and why we choose these sizes are reported in Section 4). Each score have been provided with a guide file containing indications from the composers (where present) along with examples and suggestions for their interpretation. The final supports are shown in Figure 1.

The score of *Treatise* is composed of black, mostly geometric

[2] https://musescore.org/

[3] https://www.linearity.io/

[4] https://www.blender.org/



(a) *Treatise*

(b) *December 52*

(c) *Gingko*

Figure 1: The 3D-printed tactile supports of the three scores examined during the workshop.

elements (lines, squares, circles) on a white background. An empty double staff lies on the bottom of the page for the whole length of the score. There are no indication about instrumentation or possible interpretations of the shapes. Given its geometric nature, in our rendering we simply extruded the various elements.
In *December '52*, for one or more instruments and/or sound-producing media, the composer imagines an exploration of a 3D space, allowing the musician to move in any direction from any point. The score shows 28 rectangles of different width and length, defining musical parameter such as pitch, dynamics, duration, and proximity. In our design, the sense of depth was rendered through five different thicknesses, in this case increased by 1mm each to compensate for the rarefaction of the elements.
The score of *Gingko*, for various instrumentation, is composed of a wooden piece with inlay lines surrounded by five ginkgo leaves, with dots and lines leaning their stems to the wooden element. A sixth leaf lays on the bottom of the score, disconnected from the central piece. According to the composer, the musicians arbitrarily assign a sound to each dot and follow the connections provided by the lines. The central element represents a group improvisation. In this case, we slightly simplified the drawing, reporting the leaves' contours without internal textures.

3.2 The Workshop

Day 1-2 and 3-4 were grouped together, with a one-month break in between. The four meetings were organized as follows.
During the first day, we provided a brief historical introduction about aleatoric music and graphic scores, focusing on the evolution of the literature from the XX century to nowadays. Given the participants' musical background, this introduction aimed at bridging the gap between their familiar repertoire and the new one. Therefore, we listened and analyzed some historical pieces from the literature, discussing ways to decode the scores and how to interact as an ensemble. The lack of any kind of transcription for the analyzed repertoire made us rely on verbal description of what the scores represented. In the last part of the meeting, we discussed several initial 3D-printed score prototypes, designed based to Braille standards and of different sizes, asking the participants for feedback to improve our design according to their haptic habit (see Section 4).
After such preliminary evaluation, the second meeting was focused on the exploration of the tactile supports. In this phase, we're interested in refining our design and evaluate the effectiveness of the supports, identifying common problems which can occur and possible solutions according to the participants' experience. As such, we discussed clarity, resolution, and portability in both studying and performance scenarios. At the end of the meeting, we planned a short rehearsal with the musicians in order to make them comfortable with the repertoire from a practical perspective.
Between the second and the third meeting, we first finalized the design of the 3D printed score following the participants' feedback and suggestions. Then, we provided the musicians with personal copies of each scores and guide files, so they could study individually at their pace. During the one-month break, we kept in contact with them, providing support for their study and discussing strategies for memorizing and performing. We also organized individual rehearsal in which the musician played their parts along with a piano accompaniment. This helped them to be more confident with the new repertoire.
In the third meeting, the musicians rehearsed the pieces together. At this stage, we simply guided the executions and stimulate the discussion regarding strategies they used during the individual study, encountered difficulties, and musical ideas emerged from the scores, with particular focus on the use of the provided supports.
Finally, in the last day we had a general rehearsal (Figure 2) and properly set the stage for the concert scheduled for the same evening. We asked the participants for some general remarks on the whole experience. The concert was held in the presence of musicians' relative and friends and UIC personnel; we summarized the experience and introduced the repertoire.

4. THE MUSICIAN'S PERSPECTIVE

In this section, we report the outcome of the thematic analysis over the discussions emerged during the experience. Themes are reported in bold, and direct quotes has been translated in English from the original Italian, with the four participants referred as P1, P2, P3, P4. For the purpose of this paper, we only report themes concerning the the tactile supports, their design, and their practical implications.

During the first and second meetings, we focused on the **de-**

Figure 2: A photo of the musicians rehearsing.

sign of the supports, asking the participants for direct feedback and suggestions. We discussed several prototypes: a 15x9x1cm tile with elements of different tickness, and three A5, 1mm PLA sheets with respectively 1.5mm, 1mm, and 0.6mm (Braille standard) extruded elements. All the participants agreed on the latter being the best. Indeed, while evaluated as both lightweight and sturdy, this prototype was also the easiest to read: "the others are too much invasive to touch" - P1. Based on their daily habits, two musicians also noticed that the 0.6mm prototype presents a greater level of details: "having a finer grain, it's easier to outline the individual elements" - P3. However, the musicians suggest that every design should consider the characteristics of the original score. For instance, in *December '52*, the participants had difficulties in clearly deciphering the five height levels: therefore, larger incremental thicknesses (1mm) were necessary to compensate for the rarefaction of the elements. This impossibility of a priori relying on a standard due to contextual constraints (also highlighted in the literature, e.g. [9]) further emerged in relation to the size of the supports: although the A4 format is the most used, the musicians agreed on using smaller sheets: "in the case of proposed scores, [..] it's easier to manage a more compact surface" - P2.

When asked about a **comparison of the supports with the traditional paper**, all the participants preferred the tactile ones. Being the PLA sheets heavier and more stable, the reading experience has been evaluated as particularly comfortable. Moreover, the possibility of consultation during the performance has been compared with paper standard transcription, finding that the portability/handling would have been more secure while performing. Similarly to what is reported in [23], one musician suggested the possibility to "explore new ways for customized music transcription for blind people based on this same technology" - P1.

During the individual study sessions, the participants commented on the **effectiveness of the supports**. After becoming familiar with the scores for a couple of weeks, the participants expressed positive comments towards the supports, defining them as clear and philologically coherent. This was particularly valuable for us, as we were interested in preserving the very meaning of these scores as much as possible, without altering their primary modes of use as in [16]. Being graphic scores all-in-all visual means, the participants appreciated the 3D rendering, tracing parallelisms with some previous personal experiences such as "tactile maps in museums" - P3. Furthermore, they stated that most initial difficulties do not arose from support-related problems, rather from unfamiliarity with the repertoire (we argue that also non-blind musicians experience the same struggle when approaching graphic notation for the first time). Although they initially relied heavily on commentary sheets, they gradually began reading the score directly: "Practice made the exploration fast and easy" - P4.

Another theme emerged from the discussions while rehearsing is the possibility of **direct reading while performing**. At first, the response was negative: based on their usual practice, everyone aimed to rely on mnemonic patterns, "using the tactile score [...] only for studying" - P1. The main concern was related to the fact that they "need time to read the entire score to recall the point we're at" - P4. However, after some rehearsals all the participants changed their mind and started to actively use the supports, acknowledging that the scores provide many information by themselves - this is in line with the concept of 'descriptive score' [12]. Still, due to the nature of specific instruments, several impracticality were present: for instance, the trumpet player observed that he "need rests in order to follow the score", while the pianist could instead read the support easily while playing with just one hand (Figure 3).

Figure 3: The pianist reading a score while playing.

These practical considerations regarding their need to follow the scores results in **different performative/interpretative approaches**. P4 decided to rely both on mnemonic patterns and on our supports during the performance. P1 decided to assign known excerpt from literature to every graphic elements in order to better recall them (this also resulted in a sort of cueing for the other players). P2 and P3 used the support as an overall synopsis of the piece and their intervention, but opted for better memorizing the rehearsal recordings.

4.1 Overall Remarks

The overall opinion on the experience was positive and all the musicians shared the desire to repeat the experience again. They appreciated the introduction on graphic scores' literature and the approach to encourage BVI people accessing this repertoire. The tactile supports were assessed as extremely useful: the participants acknowledged it would not have been possible for them to fully appreciate the proposed repertoire otherwise. The consideration of their suggestions and feedback in the design of each score was considered particularly valuable. The 3D supports also originate curiosity on the possibility of new ways for music transcription, especially in relation to their portability and descriptive scores as high-level piece summaries.

5. CONCLUSIONS

In this paper, we presented the design and evaluation process of 3D-printed tactile supports in order to allow BVI people to access graphic scores. By collecting the direct suggestions and guidelines of four blind musicians through a practical musical workshop, we were also able to investigate how they related to the supports in relation to the historical repertoire. We hope that this work can be a starting point to suggest new solutions to make the many facets of the musical experience increasingly accessible for everybody.

6. ACKNOWLEDGMENTS

The authors would like to thank the entire staff and volunteer personnel of *Unione Italiana dei Ciechi e degli Ipovedenti ETS - APS* (UIC) - Sede di Brescia, for their kind help and enthusiasm in supporting this research.

7. ETHICAL STANDARDS

This research is compliant with the NIME ethical standard [21]. We declare no conflict of interest. The workshop here presented was made possible thanks to the support of *Unione Italiana dei Ciechi e degli Ipovedenti ETS - APS* (UIC), but no funds of any kind have been allocated. Participation was on a voluntary basis and each musician signed an informed consent form. No sensitive or biometric data were collected. The activities were carried out in the UIC spaces with the help and supervision of volunteer staff.

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