Bernadotteprogrammet 2020

Exploring the Potential of Haptic Feedback in Digital Musical Instruments for Music Installations in Public Settings

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The purpose of this project is to explore how haptic feedback can enhance music interfaces, thereby making them more accessible for children with special needs. The following report presents preliminary results of ongoing work based on a collaboration with the school Dibber Rullen and the composer Claudio Panariello. The conducted work is centered around a group of children at Dibber Rullen and how we can design musical interfaces for this group, based on their abilities, needs and musical preferences. Future work involves organizing music listening sessions focused on musical haptics with this group. The goal of the work is to organize a workshop in the multisensory music installation Sound Forest, with customized haptic music and interactions designed specifically for the students at Dibber Rullen.

1 Background

Everyone should have the right to participate in the cultural life of the community and enjoy arts and music. Despite the fact that active participation in musical activities can be considered an essential part of human rights and freedom of expression, many people are still largely excluded from the artistic practice of music-making [1]. While the field of computer music is far from new, relatively little work in this domain has yet focused on aspects of inclusion and diversity. For example, little research on Digital Musical Instruments (DMIs) has focused on persons with visual- or hearing impairments, young children, or elderly people [2]. This despite the fact that modern technologies allow for development and customization of interfaces that can be readily adapted to each and every musician's needs: music technology can be designed, programmed, hacked, and customized to become more inclusive.

In [1], I propose to promote inclusion and diversity in music-making through the design of Digital Musical Instruments (DMIs) in the form of rich multisensory experiences allowing for multiple modes of interaction, depending on the player's capabilities and needs. This involves presenting music not only in an audible form, but also through visuals and haptic sensations which can be felt through the body. The term *haptic* in this context refers to the sense of touch, i.e. the tactile sense [3]. Haptics is the field of research dedicated to touch that focuses on technology that can create touch experiences by applying forces, vibrations and motions to a user. The haptic sense is essential for our communication with (and understanding of) the physical world around us; especially in musical interactions with acoustic – vibrating – instruments.

The fields of music and haptics are tightly connected in numerous ways. Sound is the auditory counterpart of vibration and vibrations play a significant role in the perception of music. Musical experiences involve both perceiving airborne acoustic waves and vibratory cues conveyed through air and solid media [4]. Haptic technology can assist musicians in making gestures [5] and the importance of vibrotactile feedback in music interface design has also been stressed [6]. It has been shown that amplifying certain vibrations in a concert venue or music reproduction system can improve the musical experience [7]. Research has also suggested that haptic (or visual) feedback can enhance musical experiences for persons with hearing-impairment [8]. Despite these findings, surprisingly few Digital Musical Instruments provide active haptic feedback; in the review of 83 accessible interfaces for musical expression (Accessible Digital Musical Instruments, ADMIs) only 14.5% were found to provide feedback through the sense of touch [2]. The full potential of haptic feedback when it comes to promoting inclusion in music-making has not yet been fully explored. We hypothesize that persons with visual impairments or hearing loss may benefit from the presence of haptic feedback when interacting with a DMI and that translating audible sound into alternative representations could be a beneficial way of presenting music if one modality is better functioning than others.

2 Aim

The aim of this project is to promote inclusion and diversity in musical interactions in public settings (e.g. in public music installations) through the design and development of multisensory Digital Musical Instruments (DMIs). More specifically, the aim of the Bernadotte project is to explore how haptic feedback can be used to enhance musical experiences for children with special needs. The project focuses on identifying challenges that underrepresented groups face in the contact with music installations in museums in order to be able to work for increased representation and participation, and on developing design guidelines for haptic music interfaces and Accessible Digital Musical Instruments (ADMIs). Conveying music not only through sound, but also through the sense of touch, can hopefully make the experience of interacting with a music installation more accessible for persons with diverse abilities.

Figure 1: The Sound Forest installation.

Figure 2: The haptic platforms providing whole-body vibrations in Sound Forest.

3 Methodology

We propose to explore how the haptic modality can be used to promote inclusion in public music installations by further developing the music installation Sound Forest (Ljudskogen, see Figure 1) and by creating new music for this installation. Sound Forest is a long-term project between researchers in the Sound and Music Computing group at the Royal Institute of Technology University (KTH) and the Performing Arts Museum (Scenkonstmuseet) in Stockholm (see [9]). It is a multisensory music installation that occupies an entire room. The installation consists of five light-emitting strings made of fibre optics, 15 loudspeakers and two mirrored walls. Museum visitors can interact with the strings and receive feedback via music from loudspeakers, light from strings, and vibrations that can be felt through the floor. Sound Forest is unique in that it consists of an entire room where multiple people can create music together while feeling the music in the form of whole-body vibrations through the floor (see Figure 2). Although previous research has explored whole-body vibration to some extent, such work has traditionally focused exclusively on industrial applications rather than musical interaction, and more research is needed in this area.

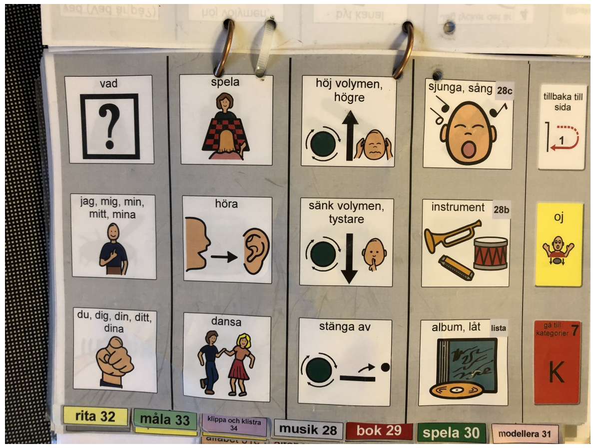

Figure 3: Example page from the PODD communication tool.

We have previously invited adults with physical and intellectual disabilities to explore the multisensory experiences provided by Sound Forest, with very positive results [10]. We have also invited students from the Master's program in Music Production at the Royal College of Music (KMH) to create haptic music for the installation [11]. The Bernadotte project represents an attempt to take these shorter studies a step further, by working in long-term collaboration with a group of students with special needs enrolled at the school Dibber Rullen[1]. Dibber Rullen is a special education school focusing on children with complex needs; their students have moderate to severe intellectual challenges and multifunctional physical challenges. The children are mostly non-verbal, and the communication with the educators is therefore based on a communication tool called PODD (Pragmatic Organisation Dynamic Display)[2]. PODD is a way of organising whole-word and symbol vocabulary in a communication book to support understanding (see Figure 3). We are currently working with a smaller group of 5 students at Dibber Rullen. These students are between 10 and 13 years old and have different diverse abilities, such as motor control difficulties, visual impairment and hearing loss. The purpose of the project was to develop new interfaces for this particular group of children, based on their abilities, needs, and musical preferences. Our research is based on a user-centered perspective in which the children are informing the development of musical interactions and systems. Every aspect of the research is conducted in close collaboration and dialogue with the pedagogues at the school.

The importance of designing DMIs that allow for adaptation based on user capabilities has been stressed in previous literature on Digital Musical Instruments for users with special needs (see for example [1, 12]). Since haptic perception can differ greatly between individuals, user studies are required to understand how to best present haptic music to different persons. Translating musical information into haptic feedback requires, in addition to an understanding of Digital Musical Instruments and haptic

[1] `https://dibber.se/skola/rullens-sarskola/`

[2] See `https://novitatech.com.au/equipment/podd-communication-books/`.

interfaces, also an understanding of composing music for the sense of touch. When it comes to the creation of music material for the project, the work is carried out in collaboration with the composer Claudio Panariello.

A summary of the research process used in the Bernadotte project, divided into separate steps, is presented below:

1. **Physical characterization of haptic floor:** This part of the project focused on examining the frequency responses of the vibrating platforms in the Sound Forest installation. This information is important since it can inform the design of whole body vibrations (i.e. haptic music) that will be presented through the floor.

2. **Interviews with pedagogues 1:** The purpose of this step was to get a better understanding of the pedagogical approaches at Dibber Rullen and the communication tools used.

3. **Questionnaire about music:** A questionnaire was distributed to the parents of all the students at Dibber Rullen. The main aim of this step was to survey if the students played any instruments, what type of music that they usually preferred to listen to, and to identify potential obstacles that prevented them from participating in music-making. The parents were encouraged to fill out the form together with their children.

4. **Observation study 1:** This step focused on attending a music class at Dibber Rullen in order to get a better understanding of the type of music material that the students usually interacted with during their music lessons and the musical interactions taking place during these sessions. It also involved documenting pages in the PODD books that were specifically dedicated to music [3].

5. **Observation study 2:** One conclusion that could be drawn from the previous observation study was that a clear rhythm seemed to be an important aspect of all the music that was used. This was also confirmed by the questionnaire results. We therefore created two music playlists to explore how the children reacted to music with different rhythmic structures. The two playlists of 10 minutes each, with six sound excerpts in each list, were played to the students twice. The reactions were filmed and the pedagogues annotated reactions to the different sounds. After the recorded sessions, we watched the videos together and discussed the results.

6. **Observation study 3:** This step focuses on introducing haptic technologies and the concept of musical haptic to the students. Three haptic devices will be used for this purpose: one haptic pillow that plays music and vibrates, one haptic strap

[3] The PODD books are individual and they may therefore differ between students, depending on their interests.

that you can place on the body to feel vibrations, and one custom-built haptic device with a built-in tactile transducer and small speaker cone that you can hold to feel and hear vibrations. An important aspect of this step is to start talking about the sensation of musical haptics with the children using different pictures from the PODD book, and perhaps create new pictures if that is required.

7. **Creating (haptic) music**: Informed by the steps outlined above, we will create a music piece that is made specifically with the children at Dibber Rullen in mind. The idea is to first make shorter excerpts of a larger piece, which can be tested with the students in their school environment using the interfaces described in step 6, before inviting the students to experience the music in Sound Forest. We believe that it is important to introduce the sounds that will be used in Sound Forest also before the children come to interact at the museum, since repetition is an important aspect of the music pedagogy at Dibber Rullen. This approach will also enable us to try out which sounds and haptic sensations that work well, before the final workshop in Sound Forest is conducted.

8. **Workshop**: This step is the main goal of the project; the student group and the pedagogues will be invited to visit Sound Forest and explore the sounds and multisensory experiences of the music installation. The final structure and protocol for this workshop is yet to be defined, based on findings from the experiments on haptic music listening conducted at the school, before this event.

9. **Interviews with pedagogues 2**: This step will be carried out after the final workshop session. The idea here is to not only analyse videos from the workshop, but to also discuss the experiences of the students. In particular, we want to focus on what the students communicated to the pedagogues about their musical experiences, using PODD.

4 Preliminary results

The COVID-19 pandemic has posed some constraints on the project in the sense that it has not been possible to conduct any on-site studies in the installation at the museum. In other words, it has not been possible to physically meet the students either at the school or to invite them to the Sound Forest installation to try out music material, haptic representations of such music material, or to explore interactions with haptic music interfaces. As a result, the results presented below are the results of work carried out remotely, with the use of online tools allowing us to view, interview and follow the children's music sessions at Dibber Rullen through Zoom or recorded videos.

Despite the fact that the Museum of Performing Arts was closed to the public because of COVID-19 restrictions, the physical characterisation of the vibrating platforms in Sound Forest could be carried out. Measurements were taken using accelerometers placed on the surface of the vibrating platforms, while exciting both tactile shakers attached to the platform using a sine sweep from 10 to 10 000 Hz. This procedure was repeated for three conditions, with a person 1) standing on the platform, 2) lying on the platform, and 3) sitting in a wheel-chair. A microphone was placed at the ear of the person to capture the audible output for each measurement. An example output is shown in Figure 4.

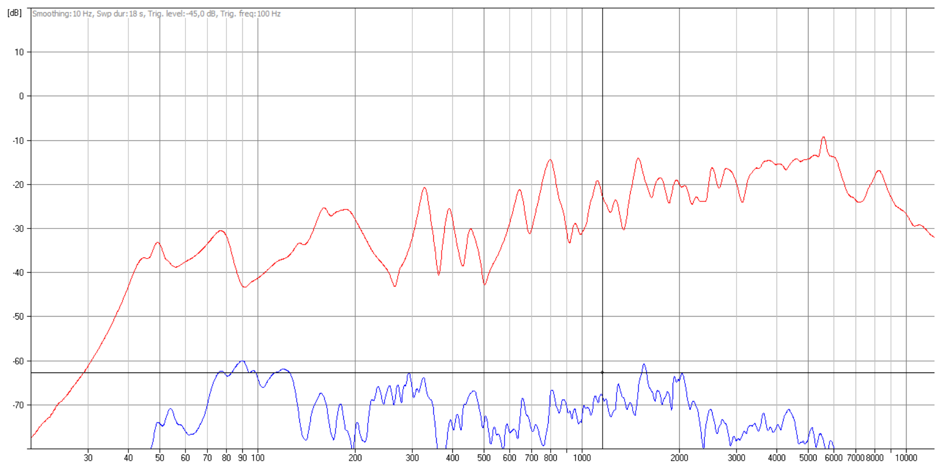

Figure 4: Results from accelerometer measurements on one of the small haptic platforms in Sound Forest. The red curve corresponds to audio captured using a microphone placed at the ear of a person sitting in a wheel-chair, on top of the platform. The blue curve corresponds to the signal recorded by the accelerometer.

The initial interview with the pedagogues provided valuable insights about the pedagogical structure of the teaching at Dibber Rullen. For example, this step allowed us to get a better understanding for the thematic structure of their education. When it comes to the questionnaire about music preferences, which was distributed to the parents of all 19 students at Dibber Rullen, we only managed to collect 5 responses. Nevertheless, this provided some insights into the musical preferences of the children, who had rather broad taste in music. In addition, the replies suggested that most of the students whose parents had responded to the survey were very interested in music; on a scale from 0 to 10, where 10 was labeled *extremely interested*, values ranged from 6 to 10. The two students who played musical instruments played guitar and maracas. When it comes to obstacles that could prevent the students from participating in music-making, most of the comments related to the requirement of fine motor skills and precise coordination that is usually required to play music.

The observation of the music class at Dibber Rullen enabled us to get insight into the music practice at the school. The session focused quite a lot on aspects related to dance, with both pedagogues and students moving around in the room, dancing using hand gestures. Based on the observation of the music session, we created two playlists for the student group. The music was divided into three different categories: music with clear rhythmic structure (e.g. dances such as waltz), music with more complex rhythmic structure (e.g. an excerpt from a radical jazz improvisation session) and music with absence of clear rhythmic structure (e.g. ambient or drone). The playlist contained shorter music excerpts from songs with pauses in between. The conclusion that could be drawn from the discussion with the pedagogue about the reactions to specific sounds and songs in these playlists was that certain sounds appeared to be more popular than others; several students clearly showed that they liked certain music excerpts. They also clearly communicated which sounds that they did not like, using PODD. In particular, there was one song that was rather static, both in terms of rhythmical structure and timbre, that was not so popular.

The observation studies described above were followed by prototyping and design focusing on adapting existing haptic interfaces to the educational setting of the students at Dibber Rullen. This part of the project is still ongoing and involves, for example, to embed the haptic technologies that we are planning to use in soft materials. This will enable the students to engage with them freely however they want, regardless of preciseness of their motor control. The interfaces should be able to be tossed around without breaking. A possible direction that we have discussed with the pedagogue is to embed the haptic actuators inside plush toys, for example in the form of animals. We believe that this might be a good approach since it will also naturally invite to touch and interact with the tools, which will bring certain affordances based just on their visual and tactile design.

An important aspect of the work described in this report has been to discuss how we can communicate with the students about musical haptics. For example, how can we communicate about concepts such as the perception of touch? For this purpose, we suggested a set of categories of concepts that could be of interest: 1) places on the body (belly, chest, head, hands, arms, legs, and feet), 2) describing the sensation (pleasant or unpleasant, like or dislike, happy or sad), and 3) intensity (if you want the vibration to be stronger or softer). The music pedagogue then provided suggestions of pictures existing in the PODD tool that could be used, after discussing with the responsible for PODD at the school. An example picture is shown in Figure 5.

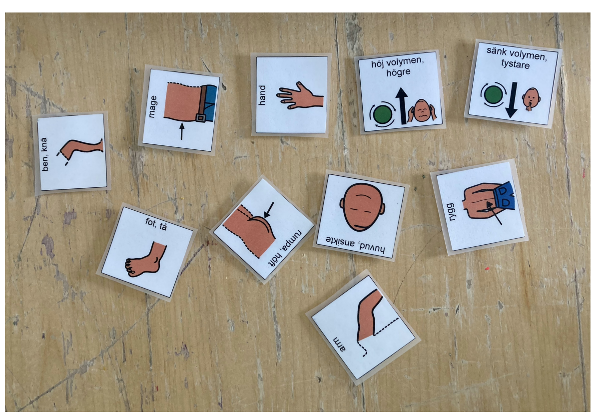

Figure 5: Example of pictures from PODD that could be used to describe haptic sensations.

5 Future work

The next steps of this work will focus on items 6-9 in the list presented in Section 3. More precisely, this work involves exploring how music listening interfaces providing haptic feedback can be designed to be durable, and how haptic representations of the composed music for Sound Forest should be designed to be comfortable. Moreover, the work involves summarizing the findings from all of the conducted work into conclusions and directives that will guide how the musical interactions in Sound Forest should be designed, for example when it comes to mapping actions to sounds. This work all leads up to the actual workshop in Sound Forest, where we will record the interactions and reactions that take place, as well as interview the pedagogues about the students' multisensory experiences.

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