MusiCane: an Accessible Digital Instrument inspired by the white cane

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ABSTRACT

We introduce the design and implementation of MusiCane, a musical device with the aim of creating new accessible avenues for music-making to promote mutual engagement across diverse social groups. MusiCane offers the possibility for active participatory music making, thereby broadening electronic music interactions and aesthetics. It seeks to bridge different communities through playful and engaging means, particularly including individuals who face barriers in traditional music-making practices. This Accessible Digital Musical Instrument (ADMI) is conceptualized based on insights derived from discussions and meetings with blind individuals and therapists. Its primary objective is to explore the creative potential of the white cane as an interactive medium. The design process involved incorporating feedback and perspectives from these stakeholders, to ensure the device's relevance and effectiveness in addressing the unique needs and experiences of users with visual impairments. To realize these objectives, a musical interactive installation has been produced, marking the first iteration of a prototype for a multi-user experience. The project not only contributes to the inclusive design of musical instruments, but also strives to create an environment where individuals from various backgrounds can come together, fostering collaboration, creativity, and engagement in the realm of music.

Author Keywords

ADMI, Musical interaction, Mutual engagement

CCS Concepts

•**Applied computing** → **Sound and music computing;** •**Human-centered computing** → *Interaction devices;*

1. BACKGROUND

1.1 Motivation

This project is a continuation of the research of MultiSensory lab (ME-lab) of Aalborg University that the author was part of during his internship. The starting points of the project were to investigate recent advancements of music technology in the field of ADMIs, and insights from a visit with a small team of researchers who work in ME-lab in the Blindecenter Bredegaard located in Fredensborg.

The visit to the center for the blind involved an introductory discussion on the challenges faced by visually impaired individuals with multiple disabilities, discussing therapeutic strategies and individualized goals. The researchers met the residents, shared their work on inclusivity practices, and observed daily life and creative activities within the center. This provided valuable insights into therapeutic practices, addressing individual needs and disabilities through creative multimodal therapies. Creating a daily routine to stimulate senses and enhance the quality of life for people with multiple disabilities is complex, and varies among individuals. The visit highlighted well-being inequalities, particularly the social isolation faced by the community, a challenge observed in various communities of individuals with different disabilities[15].

Based on this initial research, the design goals of the project were determined:

- Inclusion of visually impaired people to electronic musical practices with a collaborative instrument.
- Social inclusion of sighted and non-sighted novices through active music making.
- Bridge the communities of normal sighted people and visually impaired people.
- Help the non-visually impaired people to be more empathetic towards visually impaired people.
- De-medicalization of creative therapeutic practices.

1.2 Design notes

There is growing interest within the NIME community in creating ADMIs, promoting the inclusion of individuals with impairments in musical activities [5]. The concept of using music technology for inclusion can be traced back to the creation of the Rhodes electric piano, and with the advancement of technology, it is now possible to customize ADMIs to meet the specific needs and abilities of individual users or groups. In fact, some ADMIs even have the capability to adjust the interaction for each user in real-time[5].

Designing such instruments could make the music making experience more accessible to impaired people by eliminating physical and intellectual barriers that people are experiencing with traditional musical instruments, although different social and technical barriers are being created.

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Physical barriers are easier to identify and therefore easier to tackle, analyze, and create interactions and designs. The intellectual barriers have a tendency to withdraw themselves from the observer, and consequently the design process needs a more dialogical and iterative approach[8] [20].

In this project, we present the first iteration of a prototype collaborative ADMI between visually impaired people and sighted people, taking into consideration that each design element needs to include the disabled people's feedback without having the approach of 'fixing the problems of impaired people' through the prism of non-disabled researchers. It is important to have an active dialog between users, therapists and designers to explore different affordances of different communities, and overcome the fear of using and testing new electronic musical devices[20] [9].

2. RELATED WORK / STATE OF THE ART

Assistive Music Technology (AMT) is an established field with significant contribution from the music therapy community, although within Computer Music literature much of the work is considered relatively unexplored[5][10]. Recent literature and discussions about designing musical interactions for disabled people question the usage and the impact in their users. This leads to more broad questions in human centered design about the *design savior* complex[2].

In [20] they present a middle ground in the dipole of "tokenistic" and "participation-ism" forms of the designer's role. The work suggests using a dialogic design approach when it comes to create musical interactions, overcoming the problems of misinterpreting the true needs of the user's because of the designers' idea *of what is like to be.* And also, the dictating approach of designing without outer influences. Simplifying this idea, the designer should be part of the designing cycle and not in the top of the pyramid when a design decision must be taken.

Another vital discussion in the literature [5], [7], points out that it is crucial to form a distinction between which theoretical model (Social model or Medical model of Disability) is more inclusive when developing a design for musical practices. The medical model suggests that a disabling barrier lies on the user, and therefore puts the user in a position that there is something wrong within him/her, while the social model suggests that dictating affordances of musical interfaces and exclusive attitudes are the disabling factors, therefore invention of new musical devices that will serve the affordances of each specific community or user can be conducted. Within the same conceptual realm, Frid proposed that the terms *assistive* and *adaptive* fall into the medical model, because they put the stakeholders in the position that they need/seek for help and that the designers adapt existing technologies for specific users/disabilities.

Recent ADMIs focus on specific abilities of particular groups, using a wide range of different technologies and touchless or tangible interactions[8], like eye sensors[1], touch sensors[1], breath sensors, etc. It is promising that there are commercial products released in the form of ADMIs. One of them is the *eye harp*, where an eye sensor detects the movement of the eyes and maps it to various audio parameters via computer software. Another product is the *skoog*, which consists of a cube where the user triggers audio events from the 5 surfaces through embedded touch sensitive sensors. The cube is connected to an app, and the user has access to different abstractions for musical training and entertainment. Based on the design, it is possible to have one or more users with one or multiple cubes.

[1] `https://eyeharp.org/`

An additional ADMI with a design focused for Special Educational Needs (SEN) schools is the *LoopBlocks*[8]. This apparatus is a DIY tangible wooden step sequencer with photoresistors as the sensors for interaction. By blocking the light with a rounded token, the user unmutes the assigned step of the sequence to trigger musical events. It consists of 4 different rows, with each of them representing an audio cue, and allows interaction between multiple users.

In current studies, there is a shift towards multimodal designs like the installation *Sound Forest* that is presented in [6]. The installation consists of laser-emitting interactive strings and vibro-tactile platforms and speakers. The interaction was placed in a room of the Swedish Museum of Performing Arts in Stockholm, and it was tested with individuals from different abilities and ages. Musical interaction came from the excitation of virtual strings, by triggering audio events/samples in a pre-made composition, a technique called *adaptive music* which is being used widely in video games. The users received multimodal feedback in the form of vibrations, sounds and visuals. The haptic feedback was a whole body experience, with the vibration being produced in the floor by 2 tactile loudspeakers.

3. ETHICAL STATEMENT

While MusiCane's final target group includes a socially vulnerable minority as one of the stakeholder groups, testing with blind users was omitted due to the limits of our scaled-down prototype. We endeavor to include the full spectrum of needs and backgrounds, providing inclusive access to our design in the near future - when we have a full-scale prototype. In this way, all individuals will be able to access and benefit from the technology, and be able to take part in our research. As blind user's needs are not evaluated in this paper, we acknowledge this as a limitation of our research outcomes, instead of a limitation of the people or boundary on the people who might like to use it.

4. DESIGN

When creating an DMI, one significant consideration is the causal relationship between action and sonic outcome. For ADMIs, this relationship needs to occur automatically, especially when users don't have any experience performing electronic instruments. To reduce the cognitive load of interacting with an ADMI and create a causal relationship experience, some design conditions need to fulfill:

- Direct mapping between input and output.
- Multimodal feedback.
- Comprehensive and known affordances.

In these studies [3] [10] the work presents a set of principles and considerations for the development of musical instruments for people with disabilities. Extending these principles, Frid made a collection of properties for designing and evaluating an ADMI. These 9 properties are *Expressiveness*, *Playability*, *Longevity*, *Customizability*, *Pleasure*, *Sonic quality*, *Robustness*, *Multimodality* and *Causality* [7]. Other aspects of the design can be considered as well, such as the educational possibilities, to be plug-and-play, to adopt the musical preferences of the users, to inspire derivative designs, and to be low cost.

4.1 Initial Idea

Our design approach centers around exploring music interactions with the white cane, recognizing its unfamiliarity to the majority despite being indispensable for the visually impaired. Different types of canes serve distinct purposes, but primarily navigation and obstacle avoidance. The white cane's unique affordances are often misunderstood, compounded by its limited perception as a functional assistive device due to medicalization.

To enhance interaction with the MusiCane, designated spaces with distinctive tiles or steps are incorporated, creating an auditory landscape for users. Each tile offers unique sensory cues, allowing visually impaired individuals to navigate with auditory/tactile feedback. This design aims to creatively use the white cane, familiarize sighted individuals with it, and bridge the gap between blind and sighted communities. The shared experience promotes mutual understanding and empathy, fostering open conversations about diverse perspectives.

4.2 Current Iteration

The authors employed an iterative design process to assess usability and address challenges. A key obstacle was the technological limitation of achieving a wide detection ranges for tiles. To overcome this, the prototype was scaled down, featuring a custom cane with haptic and auditory feedback, a tactile surface, and an iOS musical application. Initial usability testing focused on individuals without visual impairments to evaluate basic functionality before accommodating visually impaired users. This approach ensures a controlled assessment and valuable insights for further refinement.

4.3 Tangible Interaction

The musical interaction involves a custom cane, a tactile surface, and an iOS application. The cane, equipped with sensor technologies, generates unique sonic events based on its placement on the tactile surface. The surface, designed for tactility, creates a dynamic environment responsive to the cane's movement.

The iOS application enables dyadic interaction in this iteration of the project, allowing a second user to actively participate. Using the iPad's touchscreen, this second user (normally sighted) manipulates parameters, influencing the auditory landscape created by the cane's movements.

4.4 Sound Synthesis

For sound synthesis, a straightforward subtractive synthesizer was implemented, allowing users to control various parameters. The initial user selects a path, and the second user activates MIDI notes corresponding to each step on the chosen route. The synthesizer, serving as the foundational tool, enables dynamic adjustments to filters, oscillators, and envelopes, adding musicality to the navigation process and introducing users to basic sound synthesis.

In practice, the chosen path determines the sequence of MIDI notes triggered by the custom cane on the tangible surface. These notes are interpreted by the synthesizer, creating a real-time auditory representation. The second user can then creatively modify the sonic characteristics through the iOS app.

4.5 Feedback design

Multimodal feedback is important for the design of DMIs in general [17]. Acoustic instruments include a variety of multisensory instant feedback (haptic/visual/sonic). Potentially, multisensory feedback enhances the musical interaction and the sensation of controlling the sonic outcome. Recent studies suggest that vibrations play a significant role in music perception and improve the music experience [16].

The audio output consists of a single channel, which plays synthesized notes triggered by user actions. Haptic feedback is provided through a vibro-tactile sensation in the cane handle, activated when users make incorrect steps on the surface. The surface, designed for tactile feedback, responds to both cane contact and direct touch. This streamlined system offers an auditory and haptic experience, guiding users through navigation with a combination of synthesized sounds and responsive vibrations.

4.6 Mutual Engagement

Building upon the insights from [4] [18], design features are incorporated to foster mutual engagement in music creation. Our approach was guided by the following design principles:

- Mutual awareness of action.
- Shared and consistent representations.
- Mutual modifiability.

Recognizing the potential cognitive overload associated with implementing all proposed design features, we strategically divided tasks and interactions within the system [4].

For the first principle, mutual awareness of action, we achieved this by configuring the system to trigger audio events. Subsequently, the other user gains the capability to sculpt these events, allowing for a dynamic and collaborative musical experience.

To address the second principle, shared and consistent representations, specific parameters of the shared experience were mapped to each user, remaining unchanged over time. This approach ensures that users can intuitively comprehend their individual contributions to the sonic outcome throughout the interaction.

Lastly, for mutual modifiability, each user was assigned parameters of the sound synthesis to enable the modification of their shared sonic output. This division of responsibilities facilitates a collaborative and dynamic environment where both users actively contribute to shaping the musical experience.

4.7 Hardware and Software Design

The ADMI, initially envisioned as a standalone wireless musical instrument with Bluetooth, utilizes the RFID reader for tile/step detection and as a controller for external musical equipment. It supports various protocols for controlling software applications (OSC, MIDI), digital synthesizers/effects, and synthesizers

Converting RFID tags to MIDI allows exploration of different mappings, unlocking creative possibilities for musical interactions. To receive audio and vibro-tactile output, a Bluetooth-enabled microprocessor development board was integrated into the cane, enhancing flexibility.

In software design, *Pure Data* (PD) and *MobMuPlat*, a mobile music platform, were employed for prototype user interfaces and audio engines.

5. IMPLEMENTATION

In this iteration, a bespoke cane was crafted using a laser cutter, featuring embedded microprocessors to transmit data from the ground— an acrylic surface—to the iPad. Simultaneously, it receives the audio and vibro-tactile feedback generated by the interaction of users with the iPad application and the cane. The elements of this interaction are visually represented in the accompanying Figure 1.

The first user engages with the iPad application by selecting a specific path (see number 1 in the Figure 1), while the second user tries to trace and activate the desired path in the acrylic surface (see number 2 in the Figure 1) by triggering MIDI notes using the cane (see number 3 and 4 in the Figure 1). Through the activation of these notes, the first user gains the ability to interact with the music application, modifying parameters of the sound synthesis. Also, the second user controls a parameter by adjusting the timing that triggers the next note.

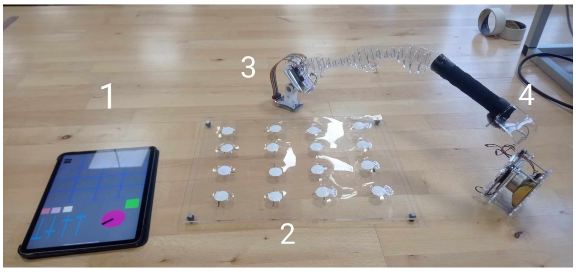

Figure 1: The first iteration of the prototype.

5.1 Hardware Implementation

5.1.1 Tip of the Cane

The central interactive element of the ADMI is the RFID reader module placed in the tip of the cane (as it is illustrated in Figure 1 number 3), and it is capable of detecting the RFID tags where are located in the acrylic surface. The module is designed around the MFCR-522 chipset. In the module, a PCB antenna is integrated which generates a high frequency electromagnetic field to detect tags. The module utilizes SPI protocol for data transmission to a microcontroller. The RFID module at the tip of the cane is connected to an ESP32 Thing Plus microcontroller. This board was selected because of its wireless connectivity features based on the ESP32-WROOM, a generic Wi-Fi, Bluetooth, and BLE (Bluetooth Low Energy) MCU module.

5.1.2 Wireless Audio and Vibro-tactile feedback

To establish a solid and wireless playback sound produced by the iPad application, the ESP32-Audio-kit development board was chosen. This audio board allows receiving and transmitting high fidelity Bluetooth audio. We used an ESP32-A1S board with an internal AC101 codec and a development board that includes a headphone jack for audio output alongside pin-headers for left/right speakers. This hardware was configured as a Bluetooth receiver for both haptic and sonic feedback by adapting Phil Schatzmann's *basic-a2dp-audiokit.ino*. In the Left Speaker output of the board a speaker was connected to provide the audio output and in the Right Speaker output a tactile audio transducer was connected to provide the haptic feedback.

5.2 Software Implementation

5.2.1 UID (Unique IDentifier) to MIDI

To create a wireless communication and convert the UIDs to MIDI information, a custom code in the *Arduino IDE* was created, which was flashed in the ESP32 Thing Plus board. Three main libraries were used to create that code, the *MIDI* library, the *BLE* library and the *MFRC522* library.

After this, the RFID reader was enabled to scan and detect the UID tags. Each UID is converted into MIDI note on information. In more detail, code was created to translate each UID to a different MIDI note, and inside these statements MIDI messages for note-on and note off are established with an assigned MIDI note.

5.2.2 MobMuPlat

MobMuPlat [12] is a platform for running Pure Data (Pd) patches on mobile devices. It handles Pd patches, user interfaces, networking, mobile hardware interactions, and communication with external devices like MIDI and HID. The GUI is customizable, and MobMuPlat supports iOS, Android, OSX, and cross-platform (Java Swing) editors for development and distribution.

For the creation of the GUI, a 4x4 grid with on-off switches was created in the upper side of the screen. The grid replicates the tiles/steps in the acrylic surface and by activating them, the specific note is enabled and will be reproduced when it will be triggered. At the bottom, four faders, 3 additional buttons and one knob were placed to control the parameters of the subtractive synthesizer.

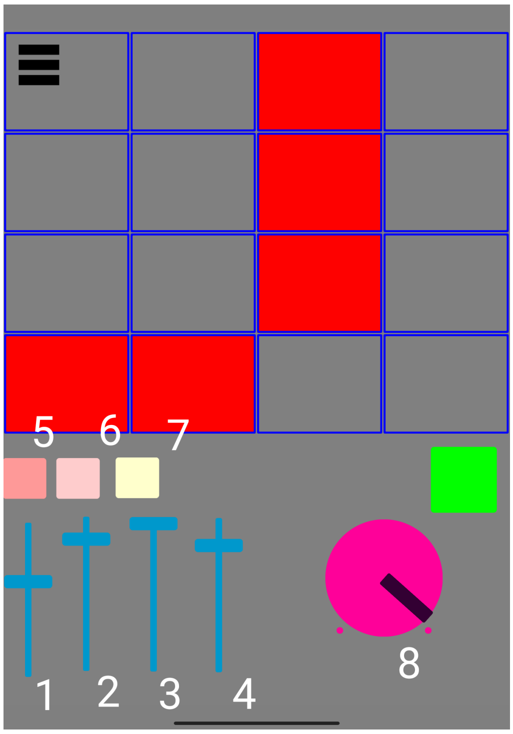

Figure 2: The GUI of the musical application. In the upper part the Grid is placed for choosing the path. And in the bottom part there are the parameters of the subtractive synthesis. 1-4 are the ADSR parameters, 5-7 are the wave form selection and 8 is the filter cut-off.

Inside the *Pure Data* patch, the information from the custom GUI is being received in the form of OSC messages. The states of each particular step in the grid are stored in a buffer and then are unpacked to match a specific MIDI note. Then by inserting the MIDI notes into the patch are being separated using an if statement. The logic of the if statement is that if a specified midi note and a specified point of the grid are activated, then this note is triggered. In the same spirit, the vibro-tactile feedback is produced, again if statements are used to filter the MIDI information and trigger the oscillator that is mapped to the haptic feedback. The statement was build around the idea that when a midi note is trigger from the RFID reader, but the assigned point on the grid is deactivated, then the fixed time envelope of the oscillator is triggered. One oscillator is a sine wave using the object `[osc ~]` with a fixed frequency of 220Hz, which is around the peak frequency of the tactile sensitivity [?]. The audio engine consists of a custom subtractive synthesizer. Then main elements are three oscillators with different waveforms, sine, triangle, and square. The pitch of the oscillators is controlled by the MIDI notes that have been passed from the if statement and are converted to frequencies. Then these oscillators are interconnected with a filter, followed by an amplification stage. In this stage, an ADSR envelope is connected and also an LFO (Low Frequency Oscillator) was added to the final stage in order to create an amplitude modulation effect.

5.3 Mappings

One of the reasons for the creation of new instruments is to allow real-time control of new sound-worlds, and the control of existing timbres through alternative interfaces to enable individuals in the spontaneous creation of music [14]. In computer music, mapping is often used in relation to algorithmic composition, where a parameter with a particular set of values is scaled or transformed so that it can be used to control another parameter.

The decision was to use explicit mapping strategies, presenting the advantage of keeping the designer in control of the implementation of each of the instrument's component parts, and therefore providing an understanding of the effectiveness of mapping choices in each context. Also, well-defined mappings are one of the most important aspects when it comes to design an ADMI [8][3] to reduce the cognitive load of the user. A last key component for choosing explicit mapping strategies is the design principles for mutual engagement in music making that were presented is the in the Section **DESIGN**, followed by the literature [4]. We believe that for achieving shared and consistent representations and mutual awareness of action, that explicit mappings were the best choice.

5.3.1 Explicit mapping strategies

The available literature generally considers a good choice of mapping of performer actions to sound synthesis parameters as a *few-to-many relationship*. Considering two general sets of parameters, three intuitive strategies relating the parameters of one set to the other can be devised as [11]: *one-to-one*, where one synthesis parameter is driven by one performance parameter, *one-to-many*, where one performance parameter may influence several synthesis parameters at the same time, and *many-to-one*, where one synthesis parameter is driven by two or more performance parameters.

Concerning explicit mappings between two sets of parameters, many different abstractions of the performance parameters have been proposed, from perceptual parameters to focusing on continuous parameters to changes represented by gestures produced by the user [19].

5.3.2 Two and Three-layer mapping

For MusiCane's explicit mapping strategy, a two and three-layer model is being adopted. The first layer is interface-specific, converting GUI information into chosen parameters for sound synthesis. Two parameters are then mapped into a second layer for specific synthesis controls. This model allows flexibility in changing synthesis engines by addressing the second layer. We primarily use two-layer mappings for gesture-to-sonic output linkage in the subtractive synthesis. However, the grid for path selection and the RFID activation of MIDI notes involve three-layer mappings.

Attack	Blue fader 1 in the GUI
Decay	Blue fader 2 in the GUI
Sustain	Blue fader 3 in the GUI
Release	Blue fader 4 in the GUI
Sine wave	Button 5 in the GUI
Triangle wave	Button 6 in the GUI
Square wave	Button 7 in the GUI
Filter cut-off	Knob 8 in the GUI
MIDI note state (mute/unmute)	GUI Grid

Table 1: The two-layers mappings. All the parameters of the subtractive synthesizer mapped to the GUI elements (see also Figure 2).

The selection of the mappings between the users was made based upon the idea of what each of the users are interacting with, the number of the parameters of the synthesis and the mutual engagement. The user with the cane was controlling the :

- Trigger of the event
- Pitch
- Vibrato Rate

And the user with the iPad was controlling the :

- Midi Note state
- ADSR
- Different wave forms
- Filter cut-off

The third layer mappings hold the essence of our interaction — influencing the path formation, the cane interaction, and the tracing of the path. We've deliberately kept these features modular. The GUI grid and acrylic surface serve as the key elements, designed to carry MIDI information. This format flexibility allows integration with various sound engines without requiring adjustments. We feel that these mappings, for example the time difference mapped to vibrato rate, transforms the cane's identity from a navigation tool into a source of musical expression.

6. EVALUATION

For the experiment, 22 people in 11 pairs (aged from 23 to 52, mean age: 28, with 10 male, 9 female and 3 other), were recruited on a voluntary basis. The participants were presented with the goal of the experiment and a written consent was obtained prior to each participation. The experiment was conducted at Aalborg University (campus of Copenhagen), in the Augmented Performance Lab.

The experiment involved each pair of participants in three phases. In the first phase, participants received an introduction to the ADMI system, its components, rules, and tasks. They explored the system to familiarize themselves.

In the second phase, participants chose initial roles; the user with a cane wore a blindfold for realism. They alternated roles, with the iPad user providing navigation instructions and adjusting synthesis parameters. The tasks were completed before they switched roles.

MIDI activation (Pitch)	acrylic surface
Vibrato Rate (LFO time)	Time difference of activation between current and previous note

Table 2: The three-layers mappings. All the parameters of the subtractive synthesizer that mapped to the Grid and the cane.

The final phase involved a questionnaire with 22 questions, divided into two parts. The first part, based on the System Usability Scale (in order to ascertain the interaction intuitiveness), included 12 questions with a 7-point Likert scale. The second part had 10 questions with a 5-point Likert scale, evaluating mutual engagement and social impact. Participants provided oral feedback. The experiment lasted 40-50 minutes per pair.

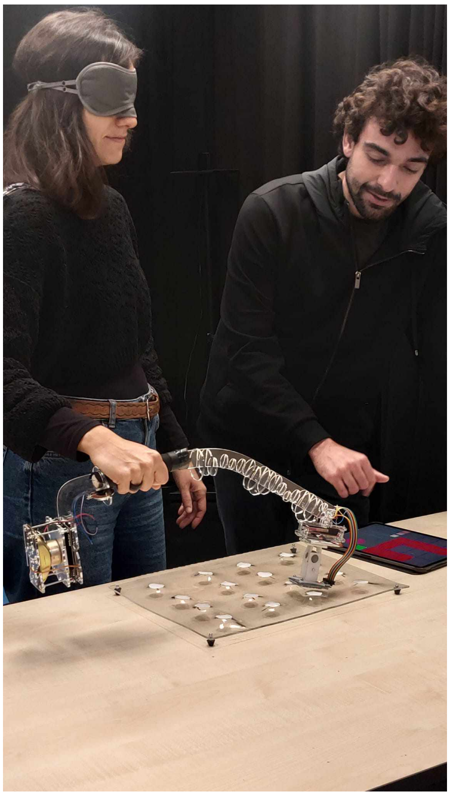

Figure 3: Two participants try the interaction.

6.1 Data Analysis

The overall score was 72%, rated as **GOOD** in the SUS scoring system. Regarding the statement, "I would like to use it again" 90.9% of the users had a positive answer. For the statement "I found the overall experience pleasant" 86.4% of the participants stated a positive answer, while 2 of them (9.1%) had a neutral response. In the statement "the interaction was too complex for me" 77.3% of the participants responded negatively, while 2 had a neutral response. In the statement "I perceived both the interactions with the stick and the app unresponsive and without coherence", 81.8% of participants stated a negative response, with 2 neutral responses. Lastly, towards the statement "I perceived both the interactions with the stick and the app unresponsive and without coherence", and "the interaction was too complex for me", 81.8% responded negatively about the incoherence of the system with 2 individuals neutral and 77.3% were negative towards over-complexity.

For the mutual engagement and the social impact part of the questionnaire, the quality of the responses was able to give various insights. Overall, the scores indicate a well-defined purpose for the system, evident not just from explicit descriptions but more importantly from seamless participant interaction. The project's objectives were effectively conveyed in the trials, as was demonstrated through engaged participant experiences. Notably, 21 out of 22 participants responded positively to trying it with a visually impaired person, with only 1 responding neutrally. Additionally, most participants did not feel discomfort or overwhelmed, with 6 responding positively, 1 neutrally, and 14 negatively to discomfort.

The participants seemed to be highly engaged with their partners through the interaction. Regarding the statement "I enjoyed playing together with my partner", 20 out of 22 individuals replied positively and 2 replied neutrally. Towards "I didn't feel like interacting with my partner" 18 people replied negatively and 4 neutrally. And an interesting aspect is that 13 people felt more creative after collaborating with their partner, 5 had a neutral position and 4 negative.

In summary, all participants successfully completed tasks using both interaction mediums. Despite some challenges, participants actively engaged, investing time to become more familiar. The feedback from questionnaires, discussions, and observations bolstered our confidence to further develop the system.

7. DISCUSSION

MusiCane's overall construction was robust enough to be tested as prototype, including responsive hardware and software, and reliable Bluetooth communication. Participants didn't report latency issues in haptic feedback or audio. LiPo batteries were effective, though regular charging was needed for the high-power consumption of the speaker at loud volumes. The musical app's GUI showed stable responses, with minor bugs related to GUI scaling. Audio synthesis performed well, with no reported sonic or control issues during testing. Areas for improvement include enhancing UID to MIDI conversion, by incorporating MIDI off information when the card isn't detected. Exploring methods to store MIDI information directly as UID data on passive tags and adding MIDI velocity through distance detection or a second sensor could also be valuable.

User feedback, collected through questionnaires and interviews, was positive. The goals of promoting mutual engagement, introducing novices to electronic music, and exploring social impacts were successfully met. Users enjoyed the collaborative and unconventional nature of the interaction, rediscovering affordances by co-creating musical output. Technical aspects were recognized for improvement, also suggesting refinements in testing methodologies and questionnaires. The haptic feedback, even in its simple form, was found helpful for navigation, making sense of the interaction. Insights gained from user experiences provide a strong foundation for advancing and refining the MusiCane platform.

Completing the initial idea requires a careful, step-by-step design approach to address emerging issues, particularly for individuals with different abilities facing potential stigma. Addressing ontological uncertainties, or "unknown unknowns," involves creating low-functionality prototypes, focusing on key design features in an iterative process[13]. Future steps include exploring long-range RFID technology, testing Ultra-High Frequencies (UHF), and experimenting with conductive and flexible filament for 3D printed tactile layers on touch screens. Including more sensors like a gyroscope in the MusicCane is also planned in the future. These are very important to be completed before the next stage of evaluation, in order to build a full-scale MusiCane and a larger interactive (floor-based) zone, which can be then be evaluated by blind users as main stakeholders.

Software improvements involve creating more abstractions for sound synthesis, musical games, and multi-purpose interactions. Participant feedback suggested developing a heatmap-like system for vibrations, offering amplitude-sensitive haptic feedback based on tile distance from the desired path. To pursue these ideas, a dialogic design strategy involving people and therapists experienced in blindness is essential.

8. CONCLUSIONS

This work aimed to develop a first prototype of an ADMI inspired by conversations with blind people and focusing on collaborative music making practices between blind and sighted people. The MusiCane system consists of a prototype augmented cane, a surface and a musical app, where users mutually interact in pairs to co-create music with a subtractive synthesizer built with *Pure Data*. *MobMuPlat* was used to design an app running Pd, allowing users to create and find musical paths in the surface. The main goal of each pair of individuals was to create and find a path by activating MIDI notes, and then playing with parameters of the synthesis to create electronic music together.

An experiment was contacted to assess the usability of this creation, the mutual engagement and the potential social impact on the users. The evaluation contacted with 22 sighted participants in pairs of 11. The work contributes to a relatively new interdisciplinary research field, covering the areas of inclusion practices and NIME. It is hoped that the research done during this study can work as a foundation for future investigations in these fields, creating new engaging musical experiences resulting in new perspectives on musical expression, and new frameworks for musical collaboration between visually impaired and sighted people.

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