AN ACCESSIBLE SOFTWARE INTERFACE FOR COLLABORATIVE MUSIC PERFORMANCE

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ABSTRACT

This paper describes an observational study focusing on an accessible musical instrument software prototype. This interface was designed, on the one hand, with no requirements concerning the level of musical knowledge and ability of users, and, on the other side, to overcome possible physical and cognitive impairments. Specifically, the software prototype implements a MIDI controller that supports a wide range of common input devices (e.g., joysticks, game controllers, keyboards, eye-tracking systems, etc.) to set musical parameters. The prototype was developed in *JUCE*, an open-source and multi-platform framework. The results of the observational study were expected to unveil how robust and ready-to-use the system was perceived by various categories of users. To this end, we involved both impaired and non-impaired users, moreover presenting different degrees of musical knowledge. Usability tests showed an average level of flexibility in supporting and mapping a wide range of heterogeneous controllers. The prototype was able to obtain preparatory feedback to broaden its development in the field of musical parameter control.

1. INTRODUCTION

Accessibility is defined as the ability of an individual to enter, navigate, understand, and use the characteristics of an environment, including physical, digital, and conceptual environments [1]. Within the broad scope of accessibility, computer applications impose highly specific demands [2]. According to [3], the majority of software tools operate under the assumption that users possess the capability to effortlessly execute tasks such as reading and responding to on-screen text and images, typing on a conventional keyboard, selecting text, images, and other data using a mouse, and responding to auditory cues. On the contrary, people with special needs may encounter challenges in performing one or more of these actions, thereby hindering their ability to utilize even widely adopted computer applications, either partially or entirely. Accessibility is a theme that also recurs in the development and implementation of musical instruments and interfaces. Musical activities, be it simply listening, composing, or performing a piece, are, in fact, known to produce benefits, since music is a source of pleasure [4] and a universal means of communication.

The term *usability* is frequently interwoven with discussions on accessibility, representing concepts such as fit to use, functionality, operability, serviceability, validity, and operationality. While usability primarily pertains to the satisfaction of functional requisites, it diverges from the concept of accessibility. However, certain scholars employ both terms interchangeably, positing that they are commonly delineated through observed task performance and collectively embody the notion of person-environment congruence [5]. A comprehensive exploration of accessibility, usability, and universal design is provided by Iwarsson and Ståhl [6].

Another important term underlying our research is *inclusivity*, understood to be a fair and equal treatment to all groups of individuals, without distinction of different races, ethnicities, religions, abilities, genders, and sexual orientations. [1] Accessibility, inclusivity, and usability are the pillars of our work.

Information technology can be an important facilitator of social inclusion for people with disabilities [7]. Thanks to digital technologies, users can overcome their impairments and can be put in the condition of creating and playing music using their physical and/or cognitive abilities. Unfortunately, digital technologies for music expression are limited in number and often expensive, due to their restricted market, the request for high specialization, and the expected return on investment from the industry.

From these considerations arises our mid-term design goal of breaking down the barriers to the musical expressiveness of people with disabilities. The project involves the design, implementation, and release of a hardware

[1] https://dictionary.cambridge.org/

and software platform, called *Inclusive MIDI Controller*, which acts as a multi-layer ecosystem that includes an operating system, a vocal assistants to support and profile users, MIDI communication capabilities, data-collection APIs, and AI-based features. The long-term goal is to create a solution that can scale up to sustain the abilities and overcome the disabilities of users, allowing them to employ the interface devices to which they are already accustomed in their daily activities. For this purpose, we also plan to exploit the capabilities of MIDI 2.0, and, in particular, the discovery feature that allows devices to communicate and exchange information each other. In fact, MIDI 2.0 devices can automatically configure themselves to work with each other, reducing the need for manual setup and configuration. The focus of this paper is to test a prototype implementation of *Inclusive MIDI Controller* with some representative users as it regards accessibility and usability.

This work arises from the collaboration of three institutions. *Musica Senza Confini* [2] is a musical project that addresses children and adults with psycho-physical disabilities and deals with inclusive music production. Based on the experience with people in condition of quadriplegia, amyotrophic lateral sclerosis, and different types of cerebral palsy, *Musica Senza Confini* provided the concept and designed the software prototype of the accessible musical instrument described in this paper. *Audio Modeling* [3] is a company specialized in expressive digital emulation of acoustic instruments. One of their products is a multi-platform application for live performances that supports the connection of hardware and software plugin instruments and the integration of musical scores. Audio Modeling is developing and planning to release the platform described in this study. The *Laboratory of Music Informatics* (LIM) at the University of Milan [4] provides expertise in sound and music computing. In the framework of this project, the lab's activities focused on software development, usability tests, accessibility research, and MIDI communication among devices.

The remainder of the paper is structured as follows. Section 2 presents an analysis of the scientific literature on the subject, surveying the state of the art and identifying current trends and innovations. Section 3 delves into *Inclusive MIDI Controller*, delineating the design of the interface and the technologies employed. Section 4 focuses on an observational study conducted on three subjects, addressing the research question, research protocol, testing methodology, and results obtained from empirical observations. Lastly, in Section 5, we synthesize our discoveries and offer conclusive insights drawn from our exploration.

2. STATE OF THE ART

In this section, we will analyze some relevant examples of digital technologies and tools to overcome impairments in the music experience and expression.

Accessible digital musical instruments (ADMIs), intended as accessible musical control interfaces used in electronic music, inclusive music practice, and music therapy settings [8], are becoming more and more investigated in the scientific literature [9]. One of the pioneering examples was a "biocontroller" designed in 1990 to increase the performance of musical instruments and to regain the pleasure of making music in people with motor impairment [10]. In a recent publication [11] the authors propose a formal tool to explore the main design aspects of ADMIs based on Dimension Space Analysis. Such a form of analysis, a well-established methodology in the literature on interfaces for musical expression, aims at an effective visual representation of the design space.

A relevant ADMI category is based on tangible user interfaces (TUIs). This type of interface offers an alternative to graphical user interfaces, commonly used in information systems, by incorporating physical objects into interaction mechanisms. Such an approach gives digital information a tangible form, providing both representation and control capabilities. With TUIs, users can manipulate digital data using their hands and engage with them through their senses. The scientific literature reports several examples of music TUIs. For example, Paradiso *et al.* focused on the adoption of magnetic tags [12], Newton-Dunn *et al.* described how to control a dynamic and polyrhythmic sequencer using physical artifacts [13], and Schiettecatte and Vanderdonckt presented a distributed cube interface for sound design [14]. A successful case of commercially available music TUI is the *Reactable* [15], a backlit translucent tabletop surface equipped with a grid of LEDs and an underlying camera-based tracking system that recognizes specially designed physical objects and combines them with real-time digital audio processing and visual feedback. Finally, it is worth mentioning several approaches based on building blocks, e.g. LEGO bricks, to control musical parameters [16–18]. In general, music TUIs have been studied as alternative ways to control music parameters, mainly to foster creativity via embodiment or support music education. Nevertheless, they have been analyzed also in the context of ADMIs, for example for musical co-creation in families with impaired children [19] and for cognitive and motor rehabilitation of vulnerable users [20].

Another ADMI category utilizes gaze-based control [21]. This approach is, in a certain sense, complementary to the previous one as it is mainly directed towards users with motor difficulties. The possibility of tracking eye movements and detecting other facial gestures opens a number of ways to control the sound and music parameters. Many experiments have been conducted in this field [22–24]. Unfortunately, the poor capabilities of standard webcams push toward specialized hardware, i.e. eye trackers, which are expensive and not commonly found in computer systems. Hopefully, this limitation will be overcome by future technical advancements.

Nowadays, more attention is also paid to usability aspects within music-oriented software not specifically designed for impaired users. An example of this emerges from the

[2] `https://www.musicasenzaconfini.com/`
[3] `https://audiomodeling.com/`
[4] `https://www.lim.di.unimi.it/`

Figure 1. An ensemble music session involving a musician with impairment using a crafted version of *Inclusive MIDI Controller*, a guitarist, and a singer.

work by Pedrini *et al.* [25], which addresses the problem of evaluating the accessibility of digital audio workstations for blind or visually impaired people. The paper also contains the results achieved with three popular DAWs, namely *Cockos REAPER*, *Avid Pro Tools*, and *Steinberg Cubase*.

3. INCLUSIVE MIDI CONTROLLER

Inclusive MIDI Controller aims to be a versatile software application designed to facilitate MIDI control on multiple platforms. Its design was born from the idea of one of the present authors, founder of *Musica Senza Confini*. During his work on accessible ensemble music, he needed to find musical performance strategies for a user capable of moving only the fingers, toes, and eyes. Such a user-tailored solution included the use of the digital audio workstation (DAW) Logic PRO, the visual programming language for music and multimedia MAX Msp [5], and a manual setting of each track of the songs to be played to allow non-ordinary interactions. As shown in Figure 1, the user was able to play the controller in an ensemble, together with a guitarist and a singer. Specifically, the user could exploit an eye tracker to select the colored buttons on the screen and micro-muscular sensors to trigger controllers that were mapped on notes, chords, short MIDI sequences, or other sounds.

The next goal was to transform this crafted solution into a customizable software able to adapt to the user's characteristics and offering several pieces to play. This was the origin of the *Inclusive MIDI Controller* project. A schematic example of the proposed system is shown in Figure 2: *Inclusive MIDI Controller* runs on the computer in the middle, is controlled by a number of different input devices, and sends MIDI messages to a DAW running on another system. A multitrack project is loaded into the DAW, and each track in the project can be played by one of the connected devices, thus allowing collaborative music performance.

[5] `https://cycling74.com/products/max`

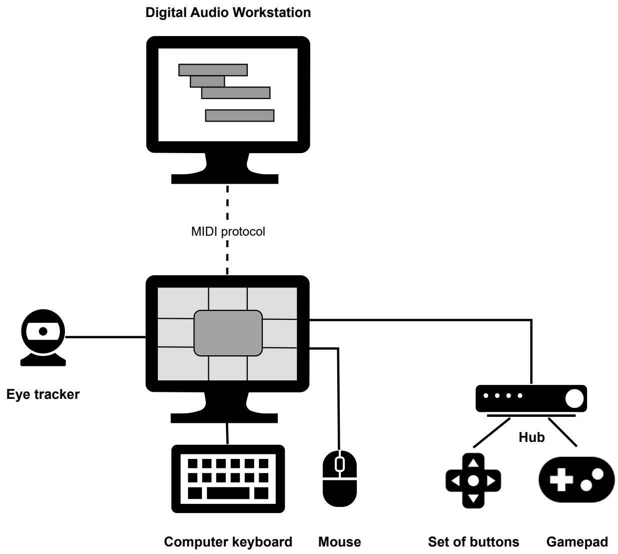

Figure 2. Scheme of the proposed system.

Programmed in C++ and leveraging the *JUCE* framework, [6] *Inclusive MIDI Controller* was designed to offer a seamless experience for both macOS and Windows users. As shown in Figure 4, *Inclusive MIDI Controller* basically provides a standalone interface equipped with a series of colored pads (whose number can be set from a minimum of 2 buttons per screen to a maximum of 12 buttons per screen), each capable of activation through standard or special input devices, thus facilitating accessibility to music and sound control.

The Settings menu allows the user to configure each colored button, and in particular:

1. the event to associate (MIDI Note, MIDI Control Change, Chord, MIDI Sequence, or page to select);
2. the behavior of the event (*Trigger*, i.e. sound activated on mouse hover; *Hold*, i.e. sound activated on mouse hover and deactivated when the mouse leaves the area; *Latch*, i.e. sound activated on mouse hover and deactivated by next mouse hover);
3. the MIDI channel;
4. the MIDI note;
5. the velocity value;
6. the release-velocity value;
7. a delay in milliseconds to apply to MIDI Note-On and Note-Off messages;
8. the color of the button;
9. the first and second keyboard shortcut;
10. an additional keyboard shortcut to repeat the latest note, which provides an aiding tool for some user categories (e.g., eye-tracker users).

[6] *JUCE* is an open source and C++ codebase framework for audio application and plug-in development. Web site: `https://juce.com`

Figure 3. The interface to configure settings.

Figure 4. Layout of the *Inclusive MIDI Controller* interface.

The Aux Pads menu presents further buttons, identical in appearance and configuration to the colored ones, but visible only through this specific menu. They can be activated via keyboard shortcuts only. The screen to set the parameters listed above is shown in Figure 3. The interface allows the user to save each setting locally, load it later, and reset each pad. The latest configuration is saved for future sessions.

Upon activation, these pads trigger the generation of MIDI messages received by other MIDI devices in the setup (e.g., a synthesizer or a DAW). The way such controls are activated depends on the hardware equipment (Human Interface Devices, HIDs) or software aiding tools in use on the user's system. The idea later explored in the observational study (see Section 4) is to test the accessibility of some functions of *Inclusive MIDI Controller* when this tool is matched with the input devices users are accustomed to.

One of the key features of this application is the integration of MIDI. Being a standard communication protocol, the MIDI messages generated by the system can be seamlessly routed to a Digital Audio Workstation (DAW), a plugin host, a music application, or even a hardware device, thus enhancing workflow flexibility and compatibility. To establish MIDI connections, *Inclusive MIDI Controller* adopts platform-specific methods. On macOS, the application exploits the virtual MIDI ports provided by CoreMIDI, ensuring communication with MIDI-enabled software and hardware. Conversely, on Windows systems, users may need to install additional drivers such as LoopBe [7] or LoopMIDI [8] to facilitate MIDI connectivity.

The cross-platform nature of the application, coupled with its interface and MIDI capabilities, makes *Inclusive MIDI Controller* a tool for musicians, producers, and audio enthusiasts seeking enhanced control and flexibility in their MIDI workflows. This software permits users to express their creativity triggering samples, controlling virtual instruments, or manipulating effects.

[7] https://nerds.de/en/loopbe1.html
[8] https://www.tobias-erichsen.de/software/loopmidi.html

4. OBSERVATIONAL STUDY

In this section, we will describe the methodology adopted to carry out the observational study. An observational study is an empirical investigation that attempts to estimate the effects caused by a process when it is not possible to perform an experiment [26]. This phase of the project is currently in progress and the end is scheduled for December 31, 2024.

Regarding the categories of individuals involved in the research, the following roles have been identified:

- Participant – An individual aged 18 or older;
- Supervisor – A designated individual collaborating on the research project.

For experimentation, each participant is associated with a numerical identifier whose purpose is to link the various data collected to the same participant. Associations between participants' first names and their respective numerical identifiers are stored only in paper format and are securely kept by the data controller. The personal data gathered from each participant are listed in Table 1. They are not expected to be disclosed or transferred to third parties. If this need emerges in the future, such data will be made strictly anonymous and/or presented in an aggregated form.

4.1 Research Question

The research question (RQ) and the hypothesis (H) underlying this observational study are the following:

- RQ — Can *Inclusive MIDI Controller* be understood and used by people with different abilities?
- H — There is no specific user target for *Inclusive MIDI Controller*. Each user can configure the software to employ the physical devices that she already knows or finds most congenial.

Figure 5. Partecipant 1's expanded keyboard with keyguard and mouse with joystick.

The basis of this question is the perspective that led to the design and implementation of *Inclusive MIDI Controller* as an accessible tool to include the largest part of individuals, overcoming their possible physical, cognitive, or social impediments.

4.2 Research Protocol

The research protocol consists of the four phases detailed below.

Phase 1: Initial questionnaire and instrument setup — The supervisor collects the participant's personal data through a specific questionnaire. During the administration of the questionnaire, the supervisor takes note of any additional comments from the participant. Subsequently, the supervisor configures the devices required for the study, including standard equipment (a computer and an audio interface) and, potentially, user-specific input devices. The software installed on the computer is the DAW *Ableton Live*, *Inclusive MIDI Controller*, and *Open Broadcaster Software*, a free and open source software for video recording and live streaming. In general, the computer equipment and software are provided by the supervisor, but users are requested to bring their own hardware tools in case of special needs.

Phase 2: Training — During the training phase, the participant is guided and assisted in choosing the hardware device to use for the observational study. If the participant is already used to a specific tool and such a tool is available among the options, it will be employed; otherwise, the participant is asked to bring their own device or assistance will be provided in selecting an appropriate tool for the purpose. The same applies if the participant has never used any specific hardware tool before. Next, the software is presented, and its purpose and usage are explained. However, further details about the controls offered by the software are not provided to participants, as the test focuses on the user experience and aims to assess the design choices.

Phase 3: Test — During the test phase, the participant is asked to perform certain actions on the software without prior knowledge of its structure. The exercises planned during the study are shown in Table 2. During the testing phase, monitoring tools will be used to enable data collection [27]. Activity logging will be implemented within the software used for the test to track user activities on it. Additionally, an audio (microphone) video and screen recording tool OBS (Open Broadcaster Software) will be utilized. Notes will be taken for each participant.

Phase 4: Questionnaire — At the end of the test phase, a questionnaire is administered to participants to investigate the perceived experience and gather their feedback. The questionnaire includes some closed responses on a 5-point Likert scale, where 1 implies "very little" and 5 means "very much," as well as some open responses. The questions are shown in Table 3.

4.3 The Test

4.3.1 Participant Descriptions

Three users participated in the test activity, each with unique characteristics related to their age, sex, impairments, musical knowledge, musical experience, and tools used for computer interaction and playing digital musical instruments. The profiles of the participants are summarized in Table 4.

Participant 1 (P1) is a woman aged between 18 and 27 years old, who faces the challenge of quadriplegia. She declares an above-average level of musical experience and an average level of musical knowledge. Her computer interaction tools include an expanded keyboard with a keyguard and a mouse with a joystick (see Figure 5), facilitating her engagement with digital interfaces. For playing musical instruments, she uses a pedal lift for drums.

Participant 2 (P2), a man aged between 48 and 57 years old, experiences a light form of daltonism, a color vision deficiency. He possesses a good level of musical knowledge and an average level of musical experience. For computer interaction, he relies on conventional tools such as a mouse, keyboard, and trackpad, indicating proficiency in navigating digital interfaces. Although he does not use specific tools to play digital musical instruments, his participation provides insight into the experiences of people with light visual impairments in music-related activities.

Finally, Participant 3 (P3), a man between 38 and 47 years of age, faces the challenge of total blindness. He declares an average level of musical knowledge and musical experience. His computer interaction tools include a screen reader and a braille display, enabling him to access digital content and interfaces through auditory and tactile feedback. He does not utilize specific tools for playing musical instruments.

Participants in our observational study have been chosen to represent a diverse range of ages, genders, impairments, musical backgrounds, and technological adaptations, thus providing valuable perspectives for understanding accessibility and inclusivity in digital music activities.

4.3.2 Test Results

This section provides a description of the results obtained by participants P1, P2, and P3 in achieving the tasks listed in Table 2.

Table 1. User Profiling.

Personal Data	Response Type
Age	Range: "18-27", "28-37", "38-47", "48-57", "58-67", "68-77", "78-87", "88-97"
Gender identity	"Man", "Woman", "Transgender", "Non-binary/non-conforming", "Prefer not to respond"
Health conditions or impairments	Open-ended response
Musical knowledge	"Little or none", "Sufficient", "Average", "Good", "Excellent"
Musical experience	"Little or none", "Sufficient", "Average", "Good", "Excellent"
Tools used for computer interaction	Open-ended response
Tools used for playing digital musical instruments	Open-ended response

Table 2. Tasks for the Test Phase.

Level	Task	Description
Base	1	Press Button 1
Base	2	Maximize the window to full screen
Intermediate	3	Access settings for Button 3
Intermediate	4	Set the number of pads to 6 for page 1
Advanced	5	For AuxPad 1, set Event to "note", Type to "trigger", Key 1 to "cursor right", and Key 2 to "cursor left"
Advanced	6	Configure Pad 2 to navigate to Page 2

Table 3. Post Test Questionnaire.

Question	Response Type
How easy was the use of the software?	Closed response
How pleasant was the use of the software?	Closed response
How frustrating was the understanding of the software?	Closed response
How frustrating was the use of the software?	Closed response
What feelings or thoughts predominated your mind during the exercise?	Open-ended response

Table 4. Participant Profiles.

User	Age	Gender	Impairments	Musical Knowledge	Musical Experience	Tools for Computer Interaction / Musical Instruments
P1	18-27	Woman	Quadriplegia	Average	Good	Expanded keyboard with keyguard, mouse with joystick / Pedal lift for drums
P2	48-57	Man	Daltonism	Good	Average	Mouse, keyboard, trackpad / N/A
P3	38-47	Man	Blindness	Average	Average	Screen reader, braille display / N/A

Regarding *Task 1*, P1 successfully moved the joystick over Button 1 of *Inclusive MIDI Controller*, producing the expected sound. However, when attempting to play the button by typing Key 1 on the keyboard, this action did not yield the desired result. P2 executed the action correctly and swiftly. Finally, due to his specific impairment, *Task 1* was not testable for P3.

Focusing on *Task 2*, all participants performed the action accurately and promptly. However, P2 encountered a challenge when attempting to click the button used for enlarging a window to full screen, as it was disabled. Instead, he resorted to dragging the edges of the window until they reached full-screen mode. Finally, he noticed the dedicated "full-screen" button.

For *Task 3*, P1 thoughtfully moved the cursor to Button 3 of *Inclusive MIDI Controller*and activated it, she attempted to access the settings but seemed unable to find the desired options. Eventually, she located the sidebar with the list of buttons and accessed the settings for Button 3. Concerning P2, first, he unsuccessfully attempted to access the settings directly from the button itself, then he clicked the Option button in order to explore the possibilities offered, once again not finding what he was looking for, and he finally hit the Settings button, where he managed to perform the requested action. On the contrary, P3 performed the task accurately and quickly.

Regarding *Task 4*, all participants successfully opened the Page drop-down menu, even though the selected page was already correct. P3 encountered a challenge as the screen reader did not read the drop-down menu labels. Nevertheless, he completed the task swiftly, drawing on previous software experience.

P1 and P2 executed the action required by *Task 5* correctly and swiftly. P3 entered the correct settings, but he faced difficulty completing the task due to the screen reader not reading the labels of the drop-down menus. This problem also emerged during Task 4. The correct setting for *Task 5* is shown in Figure 3.

Finally, regarding *Task 6*, P1 was able to act correctly and swiftly. She only had to take a brief pause to figure out where to locate the command to navigate to a particular page. P2 initially attempted to set AuxPad 2 but corrected himself independently and was able to complete the task. Once again, P3 faced a similar challenge with the screen reader not reading drop-down menu labels, hindering task completion.

4.3.3 Post-Test Questionnaire

At the end of the test phase, a short questionnaire was administered to the participants to assess some aspects of the user experience (see Table 3). For closed responses, a 5-point Likert scale was adopted.

P1 reported a score of 4 for the ease of use and a score of 5 for the fun level. She expressed a level of frustration of 2 both in understanding and in using the software. She found the interface to be cute and fun, expressing a desire to use it again.

P2 reported a score of 5 for the ease of use and 2 for the fun level. He expressed a frustration level of 1 both in understanding and in using the software. In response to the last question, P2 remarked that he expected a behavior similar to his operating system, finding conversely some buttons unintuitive in their purpose.

Finally, P3 reported a score of 2 for the ease of use and a score of 3 for the fun level. He expressed a frustration level of 2 in understanding the software and a frustration level of 3 in using the software. For certain impairments, P3 experienced difficulty in discerning the current location within the interface and understanding the outcome of specific actions. He noted a lack of feedback following actions, leading to uncertainty about changes in state or context. These aspects resulted in an above-average level of frustration in using the software.

5. CONCLUSIONS

In this work, we presented a project addressing a potentially wide audience, without exclusion in the face of possible disabilities or impairments, and dealing with accessibility and inclusion in musical expression. The first step in evaluating the platform was to test the ability of heterogeneous users to complete selected tasks of increasing difficulty levels. In order to assess our approach, an extensive test campaign should be conducted. Unfortunately, finding participants with the required profile is not a trivial task. Indeed, to have a comprehensive overview, users should have various types of cognitive and physical disabilities, use heterogeneous input devices and tools, possess musical interests, and have diversified levels of musical skills. For this reason, we chose to carry out an observational study, as often proposed in the literature for collaborative interfaces [28]. Such a study gave us the possibility to observe the usability of *Inclusive MIDI Controller* perceived by different types of real users and gather some quantitative data to drive future improvements.

In particular, we implemented a prototype version of *Inclusive MIDI Controller* and conducted our observational study involving three users. The main advantage of such an approach is the ease of observing the effect of a specific variable as it occurs naturally, without making any attempt to intervene. Despite the limited number of responses, which cannot be considered representative of the entire target population, this study allowed us to validate the design and highlight some limitations.

The results collected so far reflect heterogeneous levels of success and challenges encountered by participants with different impairments. In general, most of the time, users were able to complete the assigned tasks in a short time. Anyway, some flaws emerged in the accessibility of interface elements for blind people, an issue that needs to be addressed before releasing the platform.

In the evaluation of the results, it is important to note that it was a blind test and that the participants had no previous training on the interface. A positive aspect emerging from the post-test questionnaire is the low level of frustration in understanding and using the software. In this sense, *Inclusive MIDI Controller* seems to be a promising tool in the context of accessible collaborative music performances.

The next steps will be the implementation of corrective actions to respond to user comments and observations, the organization of a campaign with a larger number of participants, and the field testing in a real-world scenario by connecting the controller to a music-making system.

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