# Designing an Augmented MIDI Keyboard for a Musician with Amniotic Band Syndrome

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**Abstract**

Amniotic Band Syndrome (ABS) leads to congenital defects of distal segments including the hands and fingers. Such malformations can limit hand dexterity, making it difficult for musicians with ABS to span the width of a chord on a musical keyboard. Research also shows that those with hand mobility differences are lacking an accessible solution in the musical keyboard space. After a productive interview with a professional musician who has ABS, the team hypothesized that the creation of an accessible musical keyboard, the AugMIDI, could reduce hand strain and the amount of playing error for those with ABS or similar conditions. The AugMIDI prototype inputs consist of a layout of buttons to easily play, modify, extend, and transpose chords; a joystick used for pitch bending; and a potentiometer slider to change the velocity of notes. To determine if the AugMIDI reduces hand strain and playing error, a study was proposed for participants with and without ABS to compare playing a normative MIDI keyboard and the AugMIDI. If the team's hypothesis is confirmed, the AugMIDI will be shown to augment the keyboard playing performance of all users by lowering the threshold of dexterity required to play chords.

## I. Introduction

Amniotic band syndrome, also known as constriction ring syndrome, is caused by the development of "fibrous bands that encircle, strangle and even amputate some parts of the fetus," and has an incidence rate of "1 in 1,500 to 15,000 live births." [1] This condition affects activities of daily living including the ability to use computer interfaces and musical instruments. Current normative musical instruments are inadequate and impractical for many consumers such as those with ABS. There is a lack of accessible musical instruments on the market, and the few devices available are expensive. Therefore, the team aims to design a more accessible device to create music in the hope to support musicians with better tools.

### *A. Background*

A keyboard instrument is generally defined as a musical instrument that possess a set of keys, push buttons, or parallel levers that can pressed to make different music notes. The keyboard gained great significance due to its ability to allow a performer to play many notes in a close proximity. Since the keyboard was invented it has greatly influenced the composition of music. As digital music began to progress, several commercial instrument manufacturers agreed on a way to connect instruments together to work in conjunction with a personal computer which led to the Musical Digital Interface (MIDI) and has since become universally accepted. MIDI instruments allow anyone with a personal computer to digitally perform and record music in a way that was previously only available in professional recording studios – therefore helping to democratize music. MIDI instruments interact with personal computers through a type of program called a Digital Audio Workstation (DAW) – common DAWs include Logic Pro X, Ableton, and Garageband. These programs have virtual instruments allowing a user to completely customize the sound they create; for example, someone with a MIDI keyboard can make an entire instrumental song on their own by playing drums, guitar, bass, and piano virtual instruments on the DAW. On MIDI-only keyboards, such as the AugMIDI and most entry-level MIDI keyboards, the sound is generated on a computer via a DAW as the keyboards themselves do not have speakers nor produce sound - only digital output.

While MIDI keyboards have succeeded to a commendable extent in democratizing music, barriers to entry for playing the keyboard still exist. More specifically, playing a normative keyboard without risk


Fig. 1. The MPKMini MIDI piano keyboard, owned by the need-knower, is a good example of a normative MIDI piano keyboard. [2]

of injury requires a minimum hand span. A research study using biomechanical techniques to identify the effects of hand span and right/left hands on the kinematic and kinetic performances of piano playing found that musicians with smaller hand span are more prone to hand injuries, and that these injuries can happen from improper contact forces between a pianist and the keys. [3] For those with conditions such as Amniotic Band Syndrome that limit hand and finger size, using normative musical keyboards increase likelihood for hand strain or injury. Thus, there exists a significant opportunity to design a more accessible keyboard that enables musicians of all hand sizes and compositions to play and practice music more easily and reduce the risk of hand strain or injury compared to a normative keyboard.

### *B. Overview*

The team hypothesizes that the AugMIDI, a device designed for musicians with Amniotic Band Syndrome, will be shown to elevate the keyboard-playing performance of any user with similar hand dexterity limitations. In order to develop the device, the team interviewed a need-knower who stated that he needs an accessible keyboard that allows him to play chords easily. The preliminary results section describes key interview insights along with customer requirements that were incorporated into the design. Within the methods section, the team provides the details of the device, which will be used in a pilot study to test the efficacy of the design. Next, the intellectual merit is covered, outlining the significance of how device layout impacts the playing performance and hand strain of musicians. Finally, the broader impact is discussed including how the AugMIDI can serve as a catalyst for change toward a more accessible global music community.

## II. Preliminary Results

Before creating the AugMIDI, the team interviewed a professional musician with ABS who regularly performs live concerts and plays instruments daily. A 90 minute virtual interview was conducted to learn about the individual's job as a musician, pains in his music creation process, and needs that the team could address in a device to improve his playing performance. Throughout the interview, the team implemented contextual inquiry by observing how the interviewee performed different tasks in his music creation process. From the interview, the team extracted key customer requirements for a device that could amplify playing performance.

TABLE I
THE CRITICAL NEEDS OF OUR CUSTOMER.

| Question/Prompt | Customer Statement | Interpreted Need |
|---|---|---|
| How do you play chords? | I can play part of a chord, using my left hand and then go back and record over with the other part of the chord. | I need a solution that allows me to record a chord in one take and takes less time and focus to record multiple parts. |
| How could we augment the keyboard to make it more accessible? | If there was a way to, I don't know, maybe have the root of the chord, like the one three and the five (major or minor), be able to be controlled by my right hand. I can press a button for an E minor, and, you know, I could use my left hand to do the melody part - that would be pretty interesting. | If I could somehow span the important notes of a scale with my right hand using an augmented keyboard, I would be able to play key-bass in a much less restricted way than with a normative keyboard. |
| What would you like to see in a MIDI keyboard that you currently do not? | So maybe I can be playing those things at my own discretion with my left hand, the one that actually does have mobility, while still being able to maintain the primary chord structure by the press of a button, if that makes sense. | I need a system with accessible buttons to maintain the primary chord structure and it has to be in a place reachable and controllable easily and quickly. |
| How do you play the key bass? | I can't play a super good key bass because the pitch bending wheel is usually always on the left side and the pitch bend on will always be on the left side. So I would typically have to cross my hands over to use it. Kind of gets in the way of my field of vision there. So I guess basically a left handed keyboard is what I'm looking for. | I need a switched handed orientation where tools on the left side can be switched to the right side without the need to cross over hands and allows for a quicker and easier control of tools on the keyboard. |
| What features do you want in a performance musical keyboard? | I want it to be portable, rugged, low-latency, and have MIDI output. | I need a keyboard that meets the same quality standards as a standard commercially-available MIDI keyboard. |

During the interview, the individual expressed desire to play keyboard bass which is a MIDI keyboard used in place of a bass guitar. However, the need knower described several challenges when playing the keyboard bass with a normative MIDI keyboard. The team then asked the need knower to show how he currently plays the keyboard bass. From observation, the team learned that the need knower can only play chords and basslines with his left hand, and that he has to cross his arms to use the pitch bend knob (normally located on the left side). After asking clarifying questions, the team learned that the individual would benefit from a way to span the critical notes of chord with his right hand with a modified keyboard.

Next, the team inquired about the musician's routine when performing live. The team learned that the he currently does not play the keyboard bass live but would if it were easier. Since the musician balances playing multiple instruments live, we learned that he would benefit from a keyboard that plays chords with a single button. Time of play was also discussed with the need-knower, as a normative keyboard takes too long to play chords when recording in the studio (requiring multiple looping layers of single finger note presses). Thus, a device allowing to record chords faster and in one "take" would be ideal. Lastly, the need knower desired a keyboard with the same robust quality standards as the MIDI keyboards on the market. However, the team has decided to focus on function over quality for the initial prototype. Critical customer needs relevant to the hypothesis can be viewed in Table I. From the needs discovered, an augmented MIDI keyboard that allows for chord play at the press of a button will elevate the keyboard-playing performance of the need-knower.

## III. Methods

*Device Concept:* AugMIDI, the device the team designed, is designed to be an easy-to-use, accessible USB MIDI keyboard that replaces the normative MIDI piano keyboard. The most important enabling element of the AugMIDI design is the unique key button layout, enabling chords to be triggered with far fewer fingers than required on a normative MIDI keyboard piano. More specifically, AugMIDI allows simple chords (groups of 3 notes) and more complex extended chords (groups of 4 notes) to be played with 1 finger, making chords much more accessible to individuals with limited hand dexterity (such as the team's need-knower) than normative MIDI piano keyboards, where every note corresponds to a finger. The AugMIDI keyboard is highly optimized for playing chords with minimal effort. The keyboard has five main groups of inputs: velocity slider, chord keys, mod keys, pitch bend knob, and transpose keys.

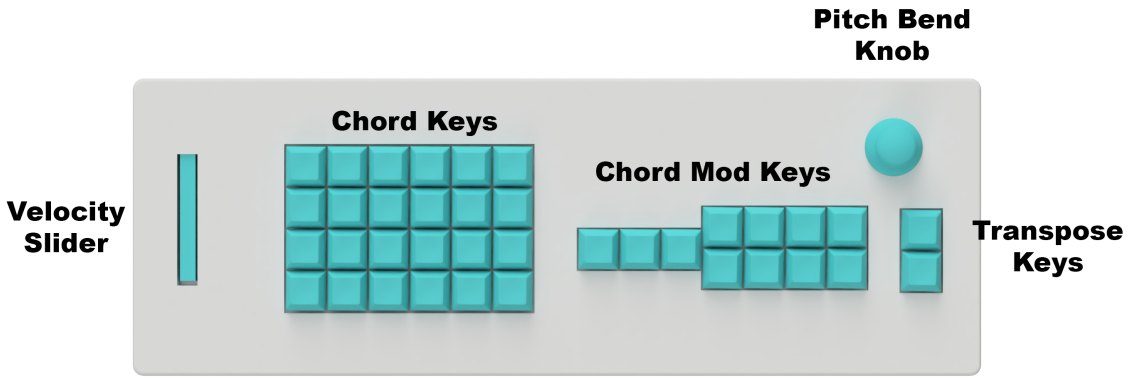


Fig. 2. The AugMIDI keyboard completely replaces the normative MIDI piano keyboard with a more accessible, ergonomic design.

- *Velocity Slider:* The velocity slider consists of a linear slide potentiometer that allows the velocity parameter, intensity of the note, sent over MIDI to be adjusted.
- *Chord Keys:* The chord keys consist of a 4x6 grid of 24 keys, with the 24 keys corresponding to the 12 major chords and 12 minor chords that comprise all possible chords. This powerful layout allows all chords to be played with a single finger which is significantly more accessible than the full hand span required to play chords on a normative keyboard.
- *Mod Keys:* The mod keys serve to modify chords triggered by the chord keys by either changing notes or adding notes. The left 3 keys are the diminished, augmented, and suspended chord mod keys. A press of these buttons allows a user to play 3 note chords with slightly different constructions and more unique sounds than standard chords. The 8 right keys include 4 major and 4 minor extension keys which can be played multiple at a time to make standard chords more complex by adding additional notes.
- *Pitch Bend Knob:* The pitch bend knob is a spring-loaded joystick potentiometer that allows for the fine modulation of pitch up and down.
- *Transpose Keys:* The transpose keys allow the user to move up and down octaves to increase or decrease the pitch of the notes played, allowing +/- 4 full octaves of transposition.

The AugMIDI keyboard runs on an Adafruit ItsyBitsy M0 Express microcontroller, which uses CircuitPython. This microcontroller is soldered directly to the PCB of the device, along with all of the input devices and the MIDI output jack, and surrounded by a 3D printed enclosure.

*Proposed Study:* The subjects in the study will be 5 professional and 5 hobbyist keyboardists with ABS or a similar condition that has resulted in finger dexterity limitations and the same number of musicians of without ABS or similar condition. The team organizing the study will partner with Motion Analysis Corporation to create and procure a motion capture system sufficient to extract data on the movement

of the fingers. Before running the study, the research team will construct and review a protocol before submitting it for review through the IRB for the Protection of Human Subjects. The team has completed the CITI training of Group 1: Biomedical Research Investigators as of 05/08/2022.

The purpose of the study is to compare the experience of playing a normative MIDI piano keyboard with that of the AugMIDI and obtain quantitative data on hand strain and playing error. Markers will be placed on the back of the hand as shown in Figure 4 to capture the abduction angle of the fingers over the course of the study. For each finger, one marker will be placed just above the metacarpal joints and there will be a sixth marker placed near the wrist. The ”baseline” will be the line from just above the metacarpal of finger 3 to base marker. The abduction angle for fingers 1, 2, 4, and 5 will be calculated from this baseline. The use of abduction angles to quantify finger strain in keyboard playing has been proven feasible by a previous study conducted by the Orthopedic Biomechanics Laboratory, Mayo Clinic, Rochester, MN [4]. Then, the participant will be introduced to the instrument they will be playing that session, either the AugMIDI or the normative MIDI piano keyboard. The participant will be instructed to play a series of chord variations as they appear on a display. As they play these combinations, the motion capture machine will gather data of the abduction angle of each finger. The number of times the player makes an error will also be documented to calculate the user's percent error for each device. Each user will play the same ten series of chord combinations on each device with the combinations increasing in difficulty from the first to the last.

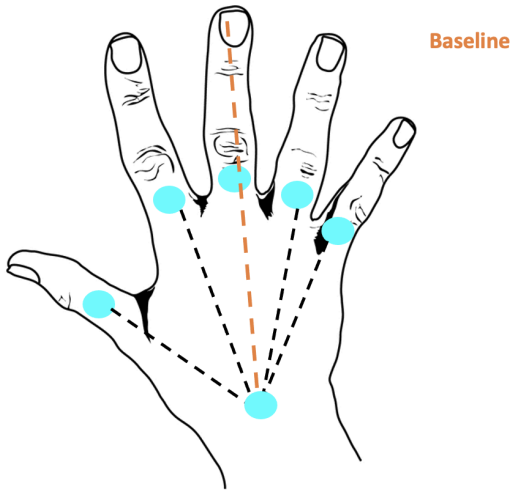


Fig. 3. Illustrates the marker placement on the hand.

Following the study, the team will have captured quantitative data on percent error and hand strain data for each instrument. The team will analyze this data to determine if the Augmidi reduces the playing error and hand strain as compared to a traditional MIDI keyboard.

## IV. Intellectual Merit

Through the completion of this study and creation of the AugMIDI, the impact of keyboard layout on hand strain and playing error can be recorded. If the hypothesis holds true, this body of work will add to the knowledge of how device layout impacts the playing performance and hand strain of users. Further, the procedure can be used by other scientists to perform similar studies calculating the playing error and hand strain of future accessible music devices. However, it is important to note that the first prototype of the AugMIDI was made specifically to address the needs of one need-knower. A large population sample will be needed to truly find the keyboard layout to minimize the playing error and hand strain of all potential users. If the null hypothesis is true, the same experiment could be implemented on modified

prototypes of the AugMIDI to determine the best keyboard layout that reduces playing error and hand strain for the original need-knower and the larger population.

## V. Broader Impact

Fig. 4. The AugMIDI keyboard in an at home recording studio set up.

The AugMIDI will allow those with amniotic band syndrome the ability to create music with less hand strain and fewer errors. Beyond helping this specific population, the AugMIDI can elevate the musical performance of any user with similar conditions or hand strain issues when playing a keyboard. The team may explore partnering with large music institutions and accessibility groups to share the work with a larger audience. Overall, the creation of the AugMIDI can be a catalyst for change in the music industry. By making musical instruments more accessible, the music industry can be elevated by allowing individuals to develop playing abilities previously inaccessible to them.

# REFERENCES


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## APPENDIX A
## DISCOVERY DECOMPOSITION

*1) Congenital constriction ring syndrome of the limbs: a prospective study of 16 cases:* [1].

- **What was known?** Amniotic band syndrome, also known as congenital constriction ring syndrome, occurs in every 1 in 1,500-15,000 live births, and is often associated with harmful lymphoedema, the swelling of tissue due to improper lymphatic drainage.
- **What was done?** Surgical intervention was used to address lymphoedema in children with amniotic band syndrome.
- **What was measured?** The success of these surgical methods were evaluated both qualitatively and quantitatively.
- **What was discovered?** Surgical intervention is effective in treating amniotic band syndrome for pediatric patients.
- **What is now known?** Earlier intervention is better than late intervention when it comes to treating lymphoedema for patients with amniotic band syndrome.

*2) Effects of hand span size and right-left hand side on the piano playing performances: Exploration of the potential risk factors with regard to piano-related musculoskeletal disorders:* [3].

- **What was known?** Hand anthropomentric issues can provide significant risk muskoskeletal disorders for practicing pianists.
- **What was measured?** They measured the effects of hand-span size and left/right hands on the kinematic and kinetic performances for pianists.
- **What was discovered?** They discovered that pianists with a smaller hand-span could be more prone to hand injuries during piano practicing.
- **What is now known?** There is preliminary evidence now that can prevent pianists from injuries and a new design can be done to prevent such further injury complications.

*3) The Musician's Hand, A Clinical Guide:* [4].

- **What was known?** Orthopedic surgeons and neurosurgeons see an abundance of musician patients who struggle with bone, muscle, and nerve issues with the limbs they use while playing their instruments.
- **What was done?** A comprehensive analysis was made of the state-of-the-art procedures and devices used to deal with certain medical conditions affecting the bones, muscles, and nerves of musicians.
- **What was measured?** The playing abilities of musicians with varying age and degree of hand deformity was observed.
- **What was discovered?** Anecdotally, musicians who were born with their hand deformities or acquired them at an early age tend to adapt more readily to novel playing techniques than adults who acquire their hand deformities at an older age.
- **What is now known?** Many musicians with hand deformities have specialized prostheses that they use only when playing their instrument, and normally use other prostheses or no prosthesis at all when not playing.