Technology for Music Therapy

Undergraduate Thesis

By

LEYA BREANNA BALTAXE-ADMONY

Department of Computer Engineering
UNIVERSITY OF CALIFORNIA SANTA CRUZ

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Abstract

Music therapy is utilized worldwide to connect communities, strengthen mental and physiological wellbeing, and provide new means of communication for individuals with phonological, social, language, and other communication disorders. The incorporation of technology into music therapy has many potential benefits. Existing research has been done in creating user-friendly devices for music therapy clients, but these technologies have not been utilized due to complications in use by the music therapists themselves. This paper reports the iterative prototype design of a compact and intuitive device designed in close collaboration with music therapists across the globe to ensure usefulness and usability. The device features interchangeable interfaces for work with diverse populations. It is portable and hand-held. A device which incorporates these features does not yet exist. The outlined design specifications for this device were found using human centered design techniques and may be of significant use in designing other technologies in this field. Specifications were created throughout two design iterations and evaluations of the device. In an evaluation of the second iteration of this device it was found that 5/8 therapists wanted to incorporate it into their practices.

Dedication and acknowledgements

I would like to thank Professors Sri Kurniawan and Mircea Teodorescu for their guidance throughout this project and my undergraduate career. I would also like to acknowledge and thank Takuichi Nishimura, Tom Hope, their respective labs, and the music therapists for their collaboration - they made this work possible. Finally, I would like to thank my friends and family for their support even when I cancel our plans to spend late nights in lab.

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Chapter 1

Introduction

Music therapy is utilized worldwide to connect communities, strengthen mental and physiological wellbeing, and provide new means of communication for individuals with with phonological, social, language and other communication disorders. Music therapy practice promotes health using "music experiences and the relationships that develop" through those experiences [5]. Most music therapy sessions involve a client's participation in the creation of music. A description of a typical music therapy session can be found in Section 2.1.1. There are as many applications of music therapy as there are methods. Technology in music therapy has great potential, allowing therapists to catalog their client's actions in real time and cater to clients with limited mobility. The use of electronic music technologies and resources in music therapy practice has been of increasing interest over the last two decades. Music technologies useful for clinical settings include computer-based applications such as software devices using musical instrument digital interface (MIDI) and assistive devices to trigger musical applications [15].

New and interesting musical interfaces may be used to keep clients with Autistic Spectrum Disorder focused [27], and let clients without a musical background create complex music [25]. The applications of such technologies seem endless, but we have found that very few music therapists utilize a significant amount of technology in their practice. Because it is such a widespanning practice, creating a fit-all device is nearly impossible. However, by involving a diverse group of music therapists in the design process, we found that we are closer to creating a piece of technology that meets their shared needs.

This document describes the requirements acquisition for and iterative prototype design process of a modular and customizable device for use by music therapists.

1.1 Background

This work blends human computer interaction with music and hardware design. In this section I will discuss the basics of the hardware components used, music theory, music therapy, and technology that has already been developed for use in Music Therapy.

1.1.1 Microcontrollers

Microcontrollers are small, single-chip computers. Similar to microprocessors and digital signal processors, they have one or more central processing units (CPUs) on-board. Microcontrollers also include memory and input/output interfaces [7]. Including more of the architecture on-board allows for abstraction and specialized use. This project utilizes the Raspberry Pi 3b and the PSoC 5LP.

The Raspberry Pi 3b has a Quad Core 1.2GHz CPU, giving it the high processing power needed for processing audio signals. Multiple cores give the ability to work on multiple tasks in parallel. Its 40 GPIO pins are utilized for sensor input in prototype one and then solely for the touchscreen in prototype two. The Raspberry Pi 3b includes an HDMI input and four USB 2.0 ports that are utilized for standard peripherals (a monitor, mouse and keyboard) in prototype one and for development purposes [26]. It also includes a 3.5mm jack, allowing therapists to use their own audio equipment in prototype one. The breadth of the Raspberry Pi was helpful in this project because it allowed me to continue developing new interfaces based on the input of music therapists without having to change the underlying platform to meet their needs. The trade off for a microcontroller with so much breadth is the efficiency - so many resources have the system spread thin. For example, in prototype two, the touchscreen displays simple shapes and colors on startup. It is not necessary for an entire operating system to be running to accomplish this.

The PSoC 5LP is used to interface with the sensors in prototype two. It was chosen for its low cost and ability to communicate via Full-Speed USB 2.0 with the Raspberry Pi 3b. It will be useful in future iteration of the project for more complex sensor integration, with multiple filters and analog to digital converters on board.

1.1.2 Sensors

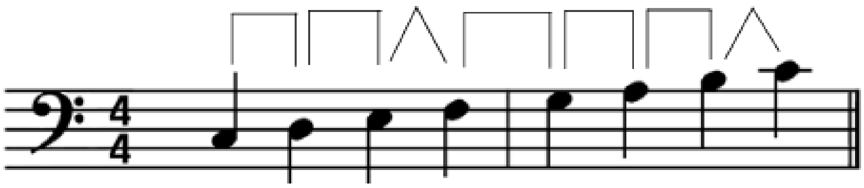
Sensors allow a system to observe and interpret the outside world. A sensor is defined as "a device that responds to an outside signal or stimulus" [10]. Furthermore, it transforms an outside signal or stimulus into electric energy. Once the energy is in this state, it may be processed and used as an input to a system - in our case the signal is input into a microcontroller.

Sensors measure three categories of phenomena: Physical, Chemical, and Biological [10]. Sensors have been developed for almost any application imaginable within these categories. This document only discusses physical sensors, but future iterations of the project may benefit from the integration of biological sensors for biofeedback. Physical sensors can be used to detect vibrations, pressure, temperature, displacement, and much more. This document describes push buttons, capacitive sensors and ultrasonic sensors.

The pushbuttons used are mechanical, they act as a switch that completes a circuit when pushed. These are already used in therapy practices, low cost and very simple to integrate, but they require a degree of physical ability that all users may not have. For this reason, in prototype two, a capacitive touch sensor is also integrated. The slightest touch triggers a signal with no force needed. Capacitive sensors detect a change in capacitance within a system. Capacitance varies when the two sides of a capacitor are brought closer together and the distance between them changes using the formula $C = \frac{\epsilon A}{d}$ where C is capacitance and d is distance [2].

To translate larger motions into signals, an ultrasonic sensor is utilized. This sensor can pick up the distance between an object and itself. For more mobile users, this can be used with the waving of a hand, or holding the sensor while approaching another object (like a wall) by jumping, walking or running. Much like bats, ultrasonic ping sensors actively produce high frequency audio waves and "listen" back for them to determine the distance of surrounding objects. The

Figure 1.1: An ascending C major scale. Squares denote whole steps, and triangles denote half steps [11].



ultrasonic sensor used is the HC-SR04.

1.1.3 Music Theory

In western music, the major scale is the basis for nearly all familiar music [11]. Other scales are described based on their relationship to the major scale. This scale is made up of a full octave of notes. An octave of a major scale is a set of 8 notes, for example from C to C in Figure 1.1, containing both half steps and whole steps. In western music, notes' relation to one another can be described in either "half" or "whole" steps. A half step can be though of as the "difference in pitch between two adjacent keys on a piano." Two half steps make a whole step[11]. Any major scale can be created by starting on one note and following the same pattern of whole steps and half step shown in Figure 1.1 (Whole Whole Half Whole Whole Whole Half). Songs can be described as monophonic, or polyphonic. Monophonic tunes use only one tone at a time, while polyphonic music uses multiple notes at once to create chords. Instruments such as flutes or trumpets are monophonic, while instruments such as piano and guitar have the ability to play multiple voices at the same time and are polyphonic.

1.1.4 Music Therapy

Music has been used in healing practices for 20,000 years [4]. Music Therapy is utilize in an abundance of contexts, from physiological, cognitive, and emotional wellbeing [18] to development of communication skills [21] and strengthening of community relationships [3]. There are two overarching types of music therapy - active and receptive. In receptive music therapy, the therapist plays music for their client while they listen and absorb or draw. In active music therapy, the client takes part in musical creations. This document focuses on active music therapy.

Music therapy sessions today are wide ranging in practice. It is common today for one music therapist to work with many populations and have different protocols for each.

1.1.5 Existing Technologies in Music Therapy

Many devices exist specifically for use in music therapy settings. Although the devices which exist are relevant to the needs of the field, average music therapists have been reluctant to adopt them [16], possibly due to a lack of confidence using technologies that are too technical or confusing for them [23] as validated by our interviews. Several of these devices are described below. Featured similarities of these devices are shown in Table 1.1.

Table 1.1: Reoccurring similarities of the technologies described in Section 2

Trait	Number of Technologies (of 8)
Visual feedback	4
Physical movement	4
Buttons and switches	3
Desktop	3

1.1.5.1 BendableSound

BendableSound is a tactile interface for children with Autistic Spectrum Disorder (ASD). Visuals are projected onto a canvas screen at the height of the child. Audio plays as the child interacts with the surface. A computer is used to control the music and take motion input from a Xbox Kinect. The sounds are projected from speakers behind the canvas screen. This device is highly novel and has been proven to keep the attention of children with ASD [8]. However, it requires an array of specialized and large equipment and has not been made available on the market.

1.1.5.2 Soundbeam

Soundbeam translates body movement into sound. Ultrasonic sensors pick up body movement such as waving gestures and proximity to the sensor. This is the most commonly used New Interface for Musical Expression (NIME) in music therapy[16] as of 2006, but it is fairly expensive and only available in the UK. Soundbeam is great at making complex compositions a possibility to those without any musical background [25]. However, there are limited options for those with mobility issues who cannot wave at the system to create sound.

1.1.5.3 Music Care [1]

Music Care is a web-based application that provides a self-assessment tool for individuals and music fit to relieve pain, to help with sleep, or to help stay awake. Data is kept on a user's account based on music listening sessions. Music therapy has been shown to be a useful tool for improvement of sleep quality, reduction of anxiety [12] and pain management [17]. This tool is helpful for finding appropriate music for these ailments and tracking a users self-reported statistics, but is used at-home. It is not a tool for creating music.

1.1.5.4 MIDI-Based devices

The following devices for music therapy are built using the Musical Instrument Digital Interface (MIDI) standard.

CAMTAS, Shell Instrument, MidiGrid and MidiCreator were developed by researchers from the University of York [14]. A Computer-Aided Music Therapy Analysis System **"CAMTAS"** was developed in the mid-90s. It is a MIDI-capturing tool that can be used to capture music therapy sessions for later playback. CAMTAS also includes some data visualization based on the recording. This was the first analyses tool of its kind, but was only a prototype [24].

The **Shell Instrument** is a tactile instrument which translates vibration on its surface into sound. This exploration into tactile instruments showed the benefit of giving a NIME "character" for the performer to relate to [14] but also did not make it past the prototyping phase.

MidiGrid is a computer software developed in the 90's. It allows the user to play their keyboard as a musical instrument by changing settings on screen. It is an inexpensive software, but needs to be run on a full computer, which a travelling music therapist may not always have access to.

MidiCreator utilizes an array of dedicated switches and converts their signals into MIDI notes and chords for use with MidiGrid. Of these, MidiGrid and MidiCreator are the only commercially available systems.

1.1.5.5 VESBALL

VESBALL is a ball-shaped instrument for group music therapy. The ball features a touch sensor and an accelerometer which trigger sounds when caught and thrown [20]. This system requires very little technical knowledge to set up. However, VESBALL only offers two methods of interaction for two sound modes. Users may become tired of the same sounds and interactions quickly. It has not been released passed the prototyping phase.

1.2 Paper Organization

This research has been conducted over the span of one year, beginning in Summer 2017. This project was conceptualized and initiated during my stay as collaborator in Tokyo with the National Institute of Advanced Industrial Science and Technology and Tokyo Institute of Technology. An explicit effort is made to use technologies available internationally and design the device using overarching concepts in music therapy with the hope of creating a device that could be used by therapists world-wide.

This document outlines the design of two prototypes. Chapter 1 has given a general overview of necessary background information. Chapters 3 and 4 discuss the design process of prototypes one and two respectively. Chapter 5 concludes the text and suggests future work on the project.

Chapter 2

Prototype One

The first prototype of the device was designed with knowledge gained from the initial literature review, similarities between existing technologies, initial interviews and observations of music therapy sessions. After the device was prototyped, music therapists were interviewed about the usefulness of such a device and specific desired features. Design considerations for the next prototype of the device were extracted from these secondary interviews.

2.1 Human Centered Design

It is clear from Section 1.1.5 that musical devices have been and continue to be developed for therapy settings. They offer a wide range of benefits when included in therapy sessions. Why then are those devices not being utilized in the industry? I hypothesize it is because the device must be designed with the music therapists as the primary users of the product. Keeping the therapist involved at all design stages could help a technology fit within the field and encourage its adoption. Working with therapists at the forefront of the project also insures that we do not overstep our bounds as designers. The therapists have extensive experience working with their populations that gives them a better understanding of the nuances of working with their clients than we can project.

I observed several therapists at work in person and through video recordings of their sessions to understand music therapy sessions and the interactions between therapists and their clients. The first prototype was made at this point. To better understand the needs and technological proficiency of music therapists, I conducted a series of interviews with six music therapists around the world. All of the interviews were performed either in person, on the phone, or through VoIP media such as Skype or Google Hangouts depending on the therapists' location. I decided to involve music therapists from more than one geographical location to ensure that the system we propose will have broader applicability for global music therapy practices.

2.1.1 Observations

Observations of music therapy sessions were made both in person and via video recording. In person observations were made using the Fly on the Wall technique (FoW) [22]. FoW is similar to watching a video of a session - the observer simply watches and does not interact with anyone involved. Three sessions were observed in person in this way. These sessions included group therapy in an elderly community center and at-home therapy with individuals. Some music therapy sessions did not allow onlookers, so video recordings of the full sessions were made by the therapist for viewing. The therapist then outlined particular sections of interest within the video.

These observations were helpful in contextualizing the use of technology in a music therapy setting. Witnessing the flow of sessions and interactions between therapists and clients informed the first prototype. Of particular interest were the multitude of instruments used for different contexts. Clients had various ranges of motion and attention spans. The therapist monitors the setting and chooses a fitting instrument.

2.1.2 Interviews

Two sets of interviews were conducted. Both sets of interviews were held via Skype and phone. Interviews were recorded and transcribed for analysis. The first round of interviews were non-directed (unstructured) sessions [6]. Non-directed interviews were chosen for this first round to foster a space where ideas and reservations could be openly discussed without the perceived

Table 2.1: Data collected from interviews with select participating Music Therapists

	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4	Interviewee 5	Interviewee 6
Years as a practicing music therapist	14	30	28	27	37	11
Location	Japan	USA	Australia	Canada	USA	USA
Main client populations	Neuropsychiatric, Children, Physical impairments	Neurological, Psychodynamic, Children, Elderly, Communication	Adult mental health, Brain injury rehabilitation	Children and adults with severe behavioral issues	Children with developmental disorders	Memory, Brain injury, Mental health, Team building
Individuals or groups	Primarily groups of 3-8, Some individuals	Primarily individuals, Some groups of 6-10	Groups	Individuals and groups	Individuals	Individuals and groups
Session Duration	1 Hour	$\frac{1}{4}$ - 1 Hour	2 - 3 Hours	1 Hour	$\frac{1}{2}$ Hour	$\frac{1}{2}$ - 1 Hour
Where sessions take place	Client homes, Community centers, Care facilities	On site	Community center	Client homes, Care facilities	On site	Client homes, Community centers, Schools
Instruments used	Piano, Vocal, Bells	Listening, Vocal	Improvisational percussion	Vocal, Percussion, Improvisational piano, Vibrations	Piano	Piano, Guitar, Percussion, Vocal
Technology already used	None	BioDex Music care	None	None (tried and stopped use)	iPad for looking up lyrics	Musical iPhone app
Data collection	Video, Counting expected behaviors	Music care	Video Voice recording of reflections on session	Quality and length of playing, Behavioral data	None	Behavioral data
Specified design needs	Single tone instrument for groups, Ease of use for clients with limited mobility	Data acquisition for insurance	Tempo analysis for multiple improvisers	Small form-factor for ease of transport, Ease of use for clients with limited mobility	Holds children's interest	Breath and heart rate recording No tangled wires

pressure of a structured interview or questionnaire. The non-directed interviews consisted of five phases. A full layout can be viewed in Appendix A. The phases were:

- **Introduction:** Background on individual and their intentions in therapy
- **Warm Up:** Walkthrough of a therapy session, specific emphasis on methods and tools used
- **General Issues:** Discussion of technology's status in their practice and as perceived throughout the industry
- **Deep Focus:** Introduction of a technology that could assist them in their work with discussion of applications and downfalls
- **Retrospective Wrap-Up:** Reflection on the discussion and additional comments

From this process, we were able to uncover the backgrounds of the interviewees, their current practices, their receptivity towards technology, and their thoughts on incorporating technology into the field. This information is used in order to understand the applications of technology in their everyday work.

The second round of interviews was structured and was focused only on device specifications. To create a grounded approach, this structured series of interviews also involved questioning the interviewees about the interview itself. After each interview, the questions were altered according to their responses in order to maintain only the most appropriate questions and add questions we may have originally overlooked. Information on music therapy practices and device specifications obtained from these interviews can be seen in Table 2.1.

As a whole, we found that the main similarity between therapists is that they incorporate a wide range of methods for a wide range of clients. Additionally, there are some common design features that transcend geographical boundaries in terms of the music therapists' location. They are listed in the next section under "Primary Design Considerations."

2.2 System Design

The design of the first prototype was created after an effort to understand the needs of the field through observing music therapy sessions, speaking with music therapists about their work and doing a literature review of technology in music therapy practices.

2.2.1 Hardware Design

The first iteration of this design is a desktop interface. This decision was made based on the existing technologies in Section 1.1.5. I decided on a modular input due to the highly diverse nature of music therapists today. Modularity allows the user to decide on the best interface to be used for any given client in any given surrounding. The therapist is free to decide based on their experience what sensors and audio/visual output is appropriate.

As shown in Figure 2.2, the first prototype can be used with a proximity sensor, buttons, and computer peripherals such as a keyboard, monitor, and mouse. The system is powered with a wall charger and can be used with external speakers or headphones. This system does not have an enclosure. Table 1.1 shows that movement is a useful trait for devices in music therapy. To fulfill that trait, we chose the proximity sensor. We chose buttons because of their ease of use and presence in other musical devices. Each sensor shield can be plugged and unplugged seamlessly without restarting the system. The platform used is the Raspberry Pi 3b. It was chosen because it is a small but powerful computer that allows for growth in future data analysis for the project and it is available worldwide. A block diagram of prototype 1 can be seen in Figure D.1.

2.2.2 Software Design

The raspberry pi takes in the sensor data via general purpose input/output pins (GPIO). The RPi.GPIO python library is used for GPIO handling. The mode (indicating which sensor is currently attached) is determined by the status of two GPIO pins. Each sensor is given a two bit identification. Each of the sensor shields has the mode pins hardwired to Vdd or Ground depending on their identification, allowing the raspberry pi to determine which sensor is plugged in.

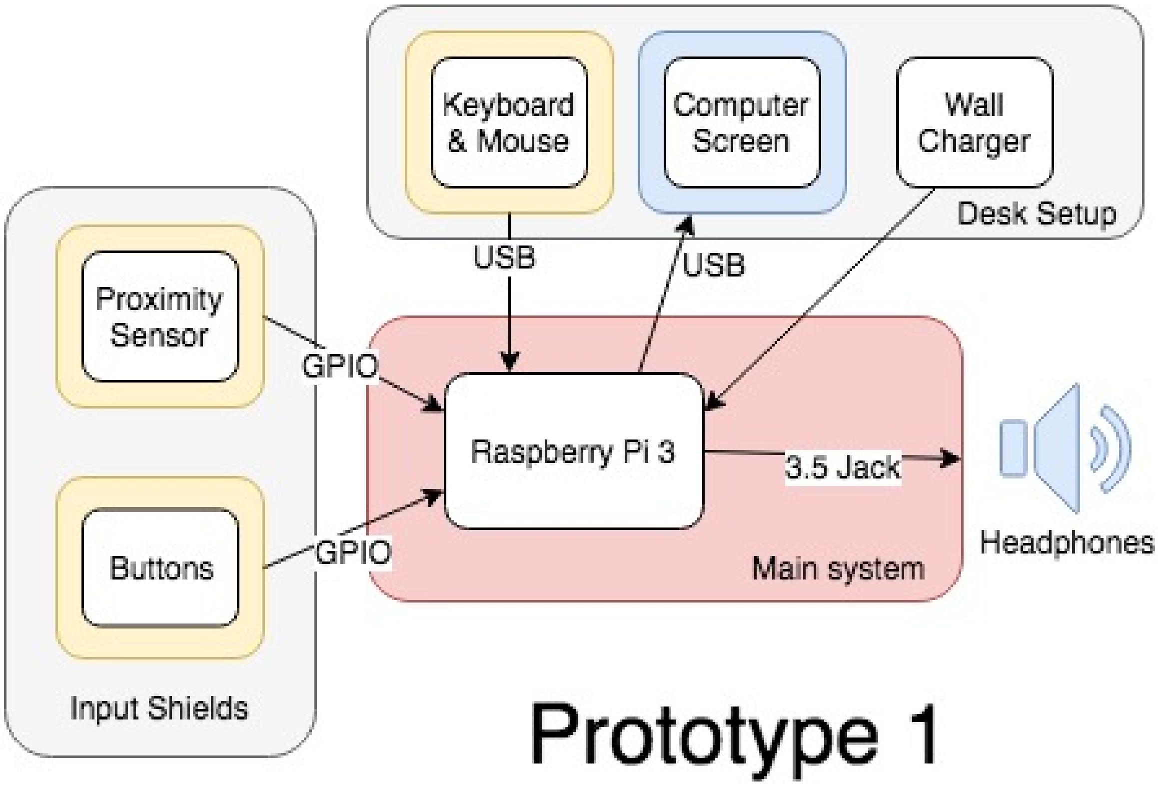


Figure 2.1: Block Diagram for Music Therapy Device prototypes two. Blue indicates output, yellow input.

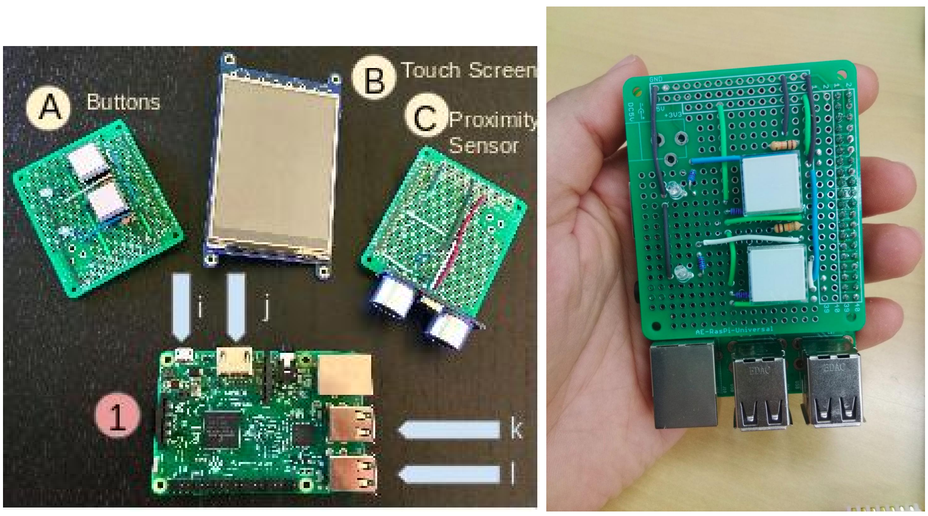


Figure 2.2: Prototype one of the device for music therapy. The raw device features multiple shields (A,B,C above) which can be swapped on and off the main device (1 above) for ease of use. Prototype One does not include B. Peripherals such as a keyboard and mouse can be attached to ports i-l above. The device assembled with one shield is pictured below.

Based on sensor data, tones are played using mpg123, a free and open source audio player [13]. This is done by sending subprocess calls to the command line and killing them when the audio clip is finished playing or just before another clip begins.

Using the sensor data, visualizations are created using pyGame. PyGame is a free and open source library for creating multimedia applications and games [19]. PyGame was chosen for its straightforward interface and the wealth of documentation present on it. When any of the sensors or keyboard (when no sensor is plugged in) are interacted with, colors and shapes that correspond to the tone being played display on screen. With the buttons, these shapes grow as you hold the button and the tone gets louder.

2.2.3 Sound Design

The audio used in this project is monophonic - only one tone is played at a time. Simple musical creations are often monophonic. For example, the children's tune "Mary had a Little Lamb." uses only one voicing. This was chosen for usability in group music therapy sessions. In the observations (Section 2.1.1) the therapist used bells with a large group, allowing individuals only one voice. This format is similar to a wind ensemble, where many musicians with individual parts make up a more complex composition.

It may be useful for future iterations may implement polyphonic (multiple tones that play at once) options for the interface for use in individual sessions.

2.3 Description of Interaction

The desired sensor shield can be removed or clipped on to the main system by way of header pins. The button shield features two buttons. When either is pressed sound is emitted from the system and a colored square shows on the computer screen. As the button is held, the sound grows louder and the colored shape grows. For the proximity shield, sound is emitted based on the distance between the device and any other object. 8 tones corresponding to the C major scale are played based on the distance from the device. This sensor could be used by waving your hand, walking closer to the device, or pointing the device in different directions.

2.4 Results and Discussion

The following design considerations were found through the interviews described in Section 2.1.2. The first prototype fulfills some of these considerations, but falls short of others. For example the device is fairly easy to use, but is not standalone. These shortcomings are further addressed in Chapter 3 with the design of a second prototype.

2.4.1 Primary Design Considerations

The most important common needs of the therapists for a device as determined by the interviews are as follows. The italicized quotes within these design considerations are direct quotes from the interviewees.

- **Versatility** - All of interviewees catered to multiple client populations. According to one interviewee, a device must work with many groups of people to be worth using because he *"love(s) working with a really large diverse pool of patients"*

- **Form factor** - More than half of the Interviewees traveled to different locations to perform music therapy, and all interviewees had done this at some point in their careers. It was particularly important to one Interviewee 4 that the device be something she could *"throw in her purse and easily carry"* from client to client *"because most [music therapists] are moving around a lot"*.

- **Ease of Use for Therapist** - The interviewees described troubles with existing technologies. They are *"difficult to operate and take too much time"* for the therapist to figure out and set up. Because of this, one interviewee says she has stopped using tech in her practice 2.1. Another interviewee specifies that he does not want any wires that he would have to untangle just to use the device. Furthermore, *"wires would inhibit the patient experience."*

- **Standalone** Many existing technologies require a computer, television screen, etc. in the space where therapy is being conducted. However, because therapists go to many different places, theses amenities are not always available. One interviewee stopped using a device because *"it really needed a huge monitor to really make it work well."* A standalone device or a device that can be used with peripherals when present is necessary to continued use for a majority of therapists.

- **Data collection** - Most interviewees interacted with insurance companies or hospitals in some capacity. Because of this, data collection was important to them. A few stated that if a device could gather quantitative data for them, it would be helpful for reporting to hospitals and insurance agencies. Any therapist who *"Working in a facility"*, has clients *"convered by insurance"* or practices *"neurological music therapy would always want data."* However, one therapist specifically stated that she does not and would not like to collect any data on her clients, making her practice as close to a music lesson as possible because *"Parents don't want [evaluations and data], all they want is a musical experience for their kids."*

CHAPTER 3

PROTOTYPE TWO

The second prototype was designed with the therapist's design specifications in mind. The second prototype is a 13cm, standalone device that can be recharged between uses. The device is shown in figure 3.2. It keeps the same interface as Prototype One, with plug-in sensor shields, but has the discussed in section 3.1. The changes in system design are then discussed in Section 3.2.

3.1 Alterations to Prototype One

From interviews and the questionnaire in Section 2.4, it was shown that therapists would benefit from a system with that is Versatile, has a small Form Factor, is Standalone, can be Easily used and can collect data.

Standalone- Therapists requested a device that could be used without the constraint of having a desktop computer or being in a specific space for every session. To address this issue, the following changes were made. Instead of a desktop screen, the second prototype includes a small touch screen for visualization. Instead of powering the system via wall outlet, a rechargeable portable battery has been integrated into the system, which makes the device entirely untethered. No other software is needed to use the device, simply turn it on and the program will start up.

Versatility- A touchscreen was added to the integrated sensors. The sensors now include a motion-based interface, clickable buttons, and a touch capacitive sensor. This capacitive sensor does not require any force for "clicking", and could be used for individuals with very limited range of motion. More interfaces can be integrated in the future. The three that are integrated here serve as a proof of concept. Further research into the desired interfaces of music therapists will need to be done before development.

Form Factor- The device is no longer desktop based, and can be easily fit into a handbag or purse. It measures 13cm in width. The first rendition of an enclosure has also been made for the device to allow for portability.

Ease of Use- When a sensor is not plugged in, the system defaults to touch screen mode, taking input from on-screen colored keys like a piano. Similar to Prototype One, If the therapist wishes to use a different sensor, they can plug it in and do not have to make any changes for the system to work. The software automatically changes for use with the chosen sensor. By hiding the underlying hardware, the enclosure may also make the device seem more approachable and straightforward to use by the music therapist as well as their clients.

Data Collection- Data collection was not addressed in this prototype due to the controversial nature presented in Section 2.4.1. If determined useful in future iterations, it may be useful to publish data on the length of use, and perhaps even recordings of the musical creations made.

3.2 System Design

As discussed, several design changes were made. This section illustrates their effects on the system hardware and software.

3.2.1 Hardware Design

As shown in Figure 3.1 Prototype 2 incorporates a second microprocessor for the sensors. The second microprocessor is the PSoC 5lp. This microprocessor was chosen for its configurable GPIO options and low cost. Having two micros allows us to dedicate GPIO pins on the Pi to touch screen use for the portability requirement. It also keeps the sensor input separate from the functionality

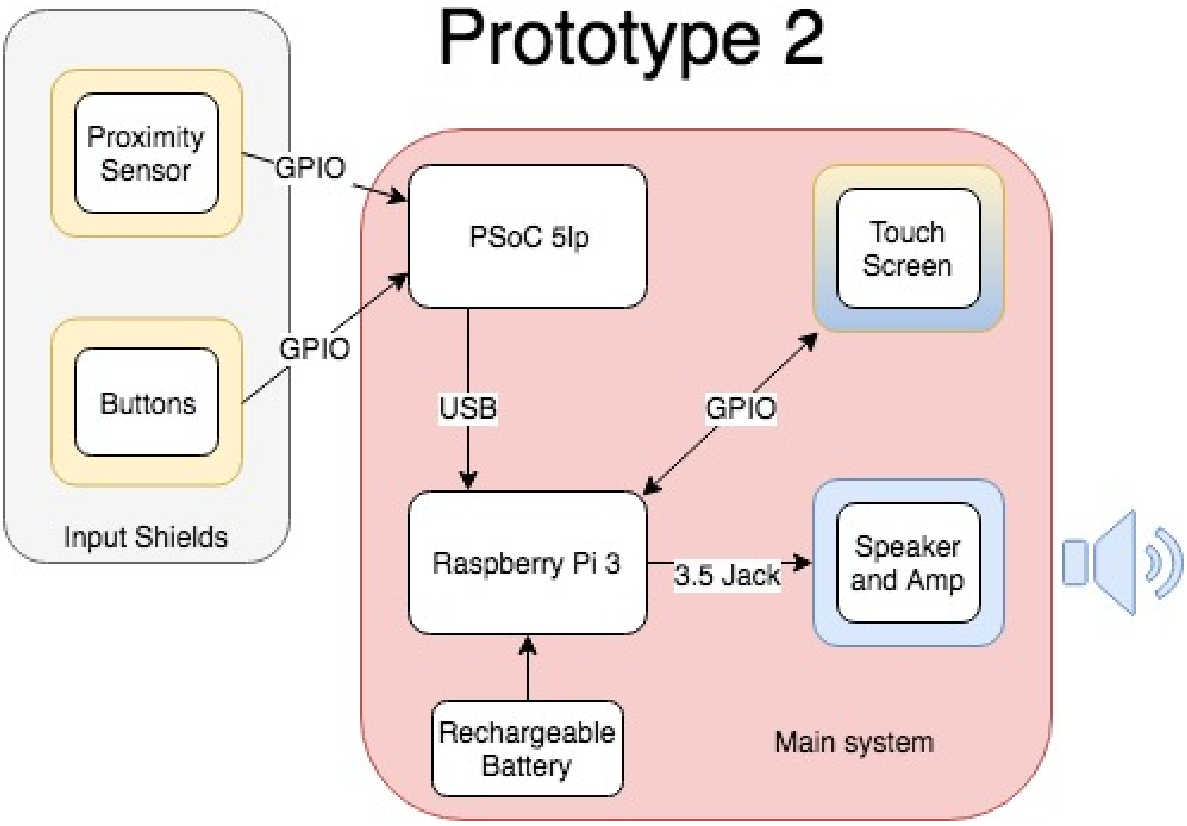


Figure 3.1: Block Diagram for Music Therapy Device prototype one. Blue indicates output, yellow input.

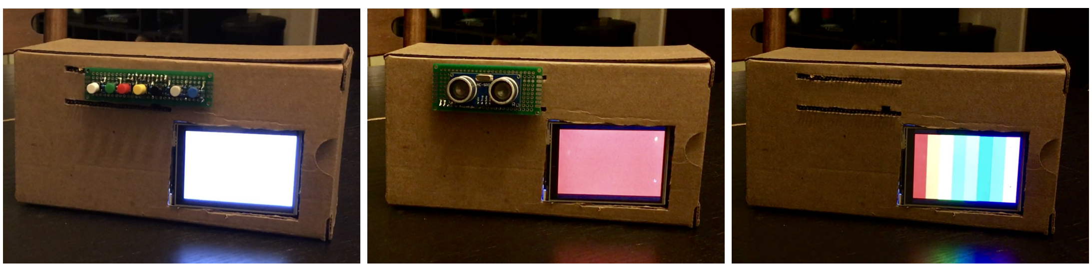


Figure 3.2: Prototype 2, pictured in three different modes. Button, Proximity, and Touch (from left to right)

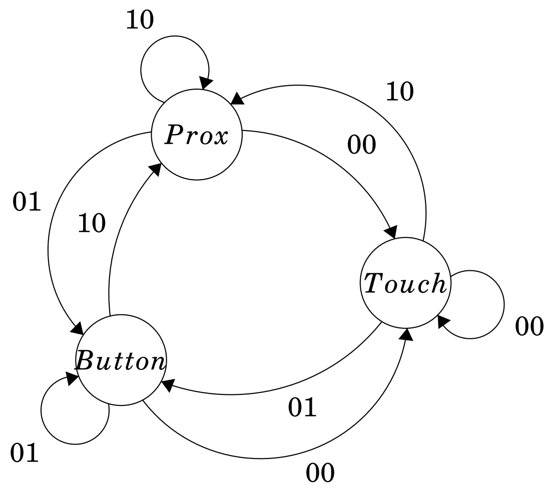


Figure 3.3: A representation of the state machine determining which mode the device is in based on the sensor's two-bit identification

of the device. Future sensor shields can be developed and used with the system with no change to the system running on the Pi. I can create new sensors while the current sensors are tested with music therapists on the device. If a new sensor is requested by a therapist, I can provide it after the basic device principles have been learned by the user.

The two microcontrollers are communicating via Universal Serial Bus (USB). The PSoC records sensor data, interprets it, and transmits it to an endpoint dedicated to that sensor. The raspberry pi receives that data and uses it to determine the device's mode and sensor states.

Mode is determined by the status of two GPIO pins on the PSoC. This is shown in Figure 3.3.

3.2.2 Software Design

The software is similar to Section 2.2.2 with the addition of a touch screen and communications via USB. The full code for the Raspberry Pi can be seen in Appendix B. The code and pin schematic for the PSoC microcontroller can be seen in Appendix C. USB communications on the raspberry pi are done using PyUSB, an open source python library which utilizes libUSB, an open source C library [9]. The PSoC includes a USB interface, allowing you to transmit and receive data. Data is transmitted using bulk transfers of up to 8 bytes.

3.3 Description of Interaction

The button shield features seven buttons, corresponding to seven notes in the C Major scale. The touchscreen is lit up with eight different "keys" (sections of the screen) which correspond to 8 tones in the C Major scale. For both the button shield and the touchscreen when a key is pressed or tapped, sound is emitted from the system. For the proximity shield, sound is emitted based on the distance between the device and any other object. 8 tones corresponding to the C major scale are played based on the distance from the device. This sensor could be used by waving your hand, walking closer to the device, or pointing the device in different directions.

All sensors display a color that relates to the note being played. Colors are consistent among sensors. When a button is pressed, a square of color grows for the duration of the press. When a tone is triggered from the proximity sensor, the screen changes colors corresponding to the tone being played. Each color key on the touchscreen corresponds to a different tone that is played when the screen is tapped.

3.4 Results and Analysis

To gauge the success of the second prototype, the device was tested with music therapists. Ideally music therapists would test it in person, but due to the geographic location of the therapists, a video evaluation system was implemented.

3.4.1 Evaluation of System by Therapists

The system was evaluated by a group of 8 music therapists. A video recording of both iterations of the device in use was sent to these participants and they recorded their thoughts in a questionnaire. This questionnaire can be viewed in Appendix E. Italicized and quoted text in this section are direct quotes from responses to the survey.

- ***Usefulness of Device-*** Participants indicated interest in this device's further development and 5/8 indicated that they would like to incorporate this device into their music therapy sessions. Out of those three who indicated that they were unlikely to incorporate this device into their sessions,all indicated they did not understand the device's use. One indicated that they do not *"understand how this device relates to music therapy"*. This could indicate that some training on the device is necessary. Those who understood this device found it applicable to their practices. Conversely, three therapists give positive feedback on the straightforward interactions of the device. One notes that *"appears to be easy to use*.

- ***Features-*** Several music therapists indicated that they would like to be able to change certain features about the device. Four music therapists requested customizable tones and images. One specifies that *"more notes...different color schemes, images, [could] personalize it."* Another specifies that the would like *"a choice of various keys, or different tonalities (pentatonic, scale, blues)"* for the audio. One indicates that different pictures could be paired with the buttons. It could be *"useful for making choices"* for clients in therapy sessions. When asked what they would change about the device, three therapists indicated that they would like louder sounds. In future iterations, a volume knob should be implemented to allow the therapist to decide on the sound level.

- ***Sensor Interface*** Several therapists came up with their own ideas for sensor shields to integrate. Two therapist indicated that they would like a larger interface. One notes that *"For use with people with disabilities, I would make the push buttons very large."*. Another says that an interface would be useful if it was *"large enough for elderly to see"*. In future iterations, a large sensor shield should be developed. One therapist would like a sensor to *"read muscle movement"* and another to *"read breath."* Therapists coming up with their own sensor interfaces validates the usefulness of such a plug and play system. Therapists also had positive notes about the already integrated sensors. In particular, 5 mention the motion sensor positively.

- ***Aesthetics-*** Therapists found the connection between sound, motion, and color to be potentially motivating to their clients. One therapist says that *"children would be intrigued"* by such a device. One therapist indicates that they would like a nicer looking enclosure.

Chapter 4

Conclusion

Music therapy can connect communities, strengthen mental and physiological well-being, and provide new means of communication for individuals with phonological, social, language and other communication disorders, and various musical technological advances can help in automatic, recording, and analyzing music therapies. However, very few music therapists utilize a significant amount of technology in their practice, partially due to lack of familiarity of technology and partially due to the complex technology that discourages music therapists from using it.

In this document I have discussed the needs of the music therapists and outlined the development of several prototypes of a device to fit them. By keeping music therapists involved in the design process I believe the created prototype closely met the needs of therapists from various countries, music therapy practices and backgrounds. The takeaway that resulted from our interactions with music therapists is that while the design features of a useful music therapy supporting device vary wildly, there are some commonalities that contribute to the usefulness of the device, and those are:

- Versatility: The device must be useful for a variety of users with varying cognitive and motor abilities.

- Form factor: The device must be portable and small enough that it won't require a specialized transportation and carrying arrangement.
- Ease of use: The device must be usable with very minimal training for music therapists with diverse technological exposure levels.
- Standalone: The device must not require additional devices (e.g. a laptop) to run.
- Data collection: The device must be able to collect data that the therapists consider useful.

4.1 Future Work

It will be worthwhile, in the near future, to continue exploring these preliminary findings, develop more sensor interfaces aimed at specific populations, and to conduct a more rigorous study on the usefulness of such a device. The requests for future iterations of the system extracted from the results of survey responses by music therapists in section 3.4.1 are the following.

- In the future they would like to see a more aesthetically pleasing prototype. For this a new enclosure should be created. As it stands, the the device is fairly bare-boned and might not feel friendly in a therapeutic environment.
- Personalization was requested. It would be useful to integrate a volume knob, and a way to select desired scales and images.
- Therapists request more specific sensors. Continued development of sensor interfaces will be useful.

These recommendations will be useful in guiding the design of future iterations of this device or a device like this one.

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Appendix A

Introductory Interview Layout

Introduction

- Introduce self, background
- Could you tell me a little bit about yourself?
  - Where are you from?
  - How long have you been practicing music therapy?
  - Who do you work with?
  - Group size?
- Any practice style you adhere to? Active or reactive/passive?

Warm Up

- What activities do you currently do in your sessions? Why?
- Do you follow the same routine every session?
- What types of musical instruments do you use? Why?
- Who plays them? Why?

- Do you use any kind of technology in your sessions? Youtube, mic, recording, etc.

General Issues

- How do you define a client's progress?
- What methods of measurement do you currently use to tell you how a client is progressing / diminishing?
- How do you keep track of their data? When do you record it? File system etc.

Deep Focus

- Introduce a technology that could potentially collect data while being used
- Would data collection be valuable to the work you do right now?
- If it was available tomorrow, would you use it? Why or why not?

Retrospective Wrap Up

- What did you think of this interview?
- How would you change it?

Appendix B

Raspberry Pi Main Code

```
#!/usr/bin/python

import pygame
import os
import sound
import subprocess
import sys
import time
import usbutton

#initialize pygame
pygame.init()
gameDisplay = pygame.display.set_mode((640,420),pygame.FULLSCREEN)
pygame.display.set_caption('Buttons')
clock = pygame.time.Clock()

#get window size and adjust keys accordingly
w,h = pygame.display.get_surface().get_size()
keysize = w/8
```

```
#----- global vars -----
running = True

BURST_WIDTH = 50
BURST_HEIGHT = 50
sizeInc = 0

#----- colors -----
BLACK = (0,0,0)
WHITE = (255,255,255)
RED = (255,0,0)
ORANGE = (255,128,0)
YELLOW = (255,255,0)
GREEN = (0,255,0)
TURQ = (0,255,255)
BLUE = (0,0,255)
PURPLE = (128,0,255)
PINK = (255,0,191)


COLOR = WHITE

last1 = 0
last2 = 0


#---define modes---
TOUCH = 0b00
PROX = 0b01
BUTT = 0b10
```

```
WAIT = 0b11

mode = WAIT
lastMode = WAIT

def off(flag):
   if flag == 'a':
      a.kill()
   elif flag == 'b':
      b.kill()
   elif flag == 'c':
      c.kill()
   elif flag == 'd':
      d.kill()
   elif flag == 'e':
      e.kill()
   elif flag == 'f':
      f.kill()
   elif flag == 'g':
      g.kill()
   elif flag == 'C':
      C.kill()
   return


flag = 'W'


start = time.time()
while(running):

   time.sleep(.05)
   if time.time() > (start + 1):
```

```
        mode = usbutton.get_state()
        start = time.time()

    #shutdown on request--------------
    ev = pygame.event.get()
    for event in ev:
        if event.type == pygame.KEYDOWN:
            if event.key == pygame.K_ESCAPE:
                running = False

    #button shield handling -----------
    if mode == BUTT:
        buttons = usbutton.get_buttons()

        if buttons == 1:
            COLOR = RED
            sizeInc = 2
            if flag != 'c':
                c = sound.play('c')
                flag = 'c'

        elif buttons == 2:
            COLOR = ORANGE
            sizeInc = 2
            if flag != 'd':
                d = sound.play('d')
                flag = 'd'

        elif buttons == 3:
            COLOR = YELLOW
            sizeInc = 2
            if flag != 'e':
                e = sound.play('e')
```

```
        flag = 'e'

    elif buttons == 4:
        COLOR = GREEN
        sizeInc = 2
        if flag != 'f':
            f = sound.play('f')
            flag = 'f'

    elif buttons == 5:
        COLOR = TURQ
        sizeInc = 2
        if flag != 'g':
            g = sound.play('g')
            flag = 'g'

    elif buttons == 6:
        COLOR = BLUE
        sizeInc = 2
        if flag != 'a':
            a = sound.play('a')
            flag = 'a'

    elif buttons == 7:
        COLOR = PURPLE
        sizeInc = 2
        if flag != 'b':
            b = sound.play('b')
            flag = 'b'
    else:
        if BURST_WIDTH > 0:
            sizeInc = -4
        else:
```

```
                sizeInc = 0
            off(flag)
            flag = 'w'

        BURST_WIDTH += sizeInc
        BURST_HEIGHT += sizeInc

        #display things
        gameDisplay.fill(WHITE)
        pygame.draw.rect(gameDisplay,COLOR,[320-(BURST_WIDTH/2),210-(BURST_HEIGHT/2),BURST_WIDTH,BUR

    #touch screen handling-------------------
    elif mode == TOUCH:
        for event in ev:
            if event.type == pygame.MOUSEBUTTONUP:
                pos = pygame.mouse.get_pos()
                print pos
                if 0 <= pos[0] <= keysize:
                    off(flag)
                    c = sound.play('c')
                    flag = 'c'
                if keysize <= pos[0] <= 2*keysize:
                    off(flag)
                    d = sound.play('d')
                    flag = 'd'
                if 2*keysize <= pos[0] <= 3*keysize:
                    off(flag)
                    e = sound.play('e')
                    flag = 'e'
                if 3*keysize <= pos[0] <= 4*keysize:
                    off(flag)
                    f = sound.play('f')
                    flag = 'f'
```

```
        if 4*keysize <= pos[0] <= 5*keysize:
          off(flag)
          g = sound.play('g')
          flag = 'g'
        if 5*keysize <= pos[0] <= 6*keysize:
          off(flag)
          a = sound.play('a')
          flag = 'a'
        if 6*keysize <= pos[0] <= 7*keysize:
          off(flag)
          b = sound.play('b')
          flag = 'b'
        if 7*keysize <= pos[0] <= 8*keysize:
          off(flag)
          C = sound.play('C')
          flag = 'C'

    gameDisplay.fill(WHITE)
      pygame.draw.rect(gameDisplay,RED,[0,0,keysize,h])
      pygame.draw.rect(gameDisplay,ORANGE,[keysize,0,keysize,h])
      pygame.draw.rect(gameDisplay,YELLOW,[2*keysize,0,keysize,h])
      pygame.draw.rect(gameDisplay,GREEN,[3*keysize,0,keysize,h])
      pygame.draw.rect(gameDisplay,TURQ,[4*keysize,0,keysize,h])
      pygame.draw.rect(gameDisplay,BLUE,[5*keysize,0,keysize,h])
      pygame.draw.rect(gameDisplay,PURPLE,[6*keysize,0,keysize,h])
      pygame.draw.rect(gameDisplay,PINK,[7*keysize,0,keysize,h])

  elif mode == PROX:

    distance = usbutton.get_prox()
    if 0 < distance < 200 and flag != 'c':
      c = sound.play('c')
      off(flag)
```

```
        flag = 'c'

        COLOR = RED
    elif 200 < distance < 250 and flag != 'd':
        d = sound.play('d')
        off(flag)
        flag = 'd'

        COLOR = ORANGE
    elif 250 < distance < 300 and flag != 'e':
        e = sound.play('e')
        off(flag)
        flag = 'e'

        COLOR = YELLOW
    elif 300 < distance < 350 and flag != 'f':
        f = sound.play('f')
        off(flag)
        flag = 'f'

        COLOR = GREEN
    elif 350 < distance < 400 and flag != 'g':
        g = sound.play('g')
        off(flag)
        flag = 'g'

        COLOR = TURQ
    elif 400 < distance < 450 and flag != 'a':
        a = sound.play('a')
        off(flag)
        flag = 'a'

        COLOR = BLUE
```

```
    elif 450 < distance < 500 and flag != 'b':
      b = sound.play('b')
      off(flag)
      flag = 'b'

      COLOR = PURPLE
    elif 500 < distance < 550 and flag != 'C':
      C = sound.play('C')
      off(flag)
      flag = 'C'

      COLOR = PINK

    #display things
           gameDisplay.fill(COLOR)
         #
            pygame.draw.rect(gameDisplay,COLOR,[320-(BURST_WIDTH/2),210-(BURST_HEIGHT/2),BURST_WIDT
           pygame.display.update()
    time.sleep(.2)


  #update for all shields ------
  pygame.display.update()


# on exit -----------
pygame.quit()
```

APPENDIX C

Raspberry Pi Helper Functions

The following is a helper function for playing sounds:

```
def play(a):
   filename = '../CPiano/MP3/' + a + 'a.mp3'
   sound = subprocess.Popen(['mpg123','-q',filename])
   print "new process with ID %s" % sound.pid
return sound
```

The following are helper functions for USB handling on the Raspberry Pi end:

```
def setup():
   dev = usb.core.find(idVendor=0x04B4, idProduct=0x8051)
   dev.reset()
   if dev is None:
      raise ValueError('DEVICE NOT FOUND')

   if dev.is_kernel_driver_active(interface) is True:
      dev.detach_kernel_driver(interface)
      usb.util.claim_interface(dev,interface)
```

```
    return

def reset():
    dev.reset()

def get_buttons():
    dev.read(0x83,1)
    buttons = dev.read(0x83,1)
    ret = 0
    if buttons[0] & 0x1:
        ret = 5
    elif buttons[0] & 0x2:
        ret = 4
    elif buttons[0] & 0x4:
        ret = 1
    elif buttons[0] & 0x8:
        ret = 3
    elif buttons[0] & 0x10:
        ret = 2
    elif buttons[0] & 0x20:
        ret = 7
    elif buttons[0] & 0x40:
        ret = 6
    return ret

def get_state():
    dev.read(0x84,1)
    state = dev.read(0x84,1)
    return state[0]

def get_prox():
    dev.read(0x82,4)
    prox = dev.read(0x82,4)
```

```
  ret =(prox[1] << 8) + prox[0]

  ret = ret/5

return ret
```

APPENDIX D

PSoC Code and Schematic

The following is the code used on the PSoC end of the second prototype system.

```
#include "project.h"

/* USB device number. */
#define USBFS_DEVICE (0u)

/* Active endpoints of USB device. */
#define IN_EP_NUM   (3u)
#define IN_EP_NUM2  (4u)
#define IN_EP_NUM3  (2u)

// Value read from TimeDistMeas, eg HC-SR04 PW returned, in 1 uS increments
uint16  TimeDistMeas  = 0;
uint8   distmeas[2]   = {0};




int main(void)
{
```

```
    CyGlobalIntEnable; /* Enable global interrupts. */

    //timer setup
    TimeDistMeas_Start( );

    //local variables
    uint8_t shield = 0;
    uint8_t b = 0;

    /* Start USBFS operation with 5V operation. */
    USBFS_Start(USBFS_DEVICE, USBFS_5V_OPERATION);

    /* Wait until device is enumerated by host. */
    while (0u == USBFS_GetConfiguration()){}

   // write data to USB forever
    for(;;)
    {

        /* Check if configuration is changed. */
        if (0u != USBFS_IsConfigurationChanged())
        {
            /* Re-enable endpoint when device is configured. */
            if (0u != USBFS_GetConfiguration())
            {
            }
        }

            //send mode
            /* Wait until IN buffer becomes empty (host has read data). */
            if ((USBFS_IN_BUFFER_EMPTY == USBFS_GetEPState(IN_EP_NUM2)) )
            {
                shield = (B_Status_Read() << 1) | P_Status_Read();
```

```
    USBFS_LoadInEP(IN_EP_NUM2, &shield, 1);
}

//send prox
/* Wait until IN buffer becomes empty (host has read data). */
if ((USBFS_IN_BUFFER_EMPTY == USBFS_GetEPState(IN_EP_NUM3)))
{

  while( DistOutHCSR04_Read( ) == 0 && P_Status_Read() ) {       //
      HC-SR04 ready for a trigger, to start new measurement cycle ?

      Triggen_Write( 1 );                    // Trigger the HC-SR04 to
          issue the 10 uS start pulse, and reset TimeDistMeas
     CyDelayUs( 10 );                        // Trigger high for 10 uS
   Triggen_Write( 0 );                       // Remove trigger and reset
       from TimeDistMeas
     CyDelay( 1 );                           // Delay 1 mS to see if
         HC-SR04 started a measurement, if not issue another trigger to
         HC-SR04

}
  while( DistOutHCSR04_Read( ) == 1 && P_Status_Read()) { };     // Wait
      until HC-SR04 finishes measurement cycle

TimeDistMeas = (65535 - TimeDistMeas_ReadCounter( ));  // Get timer
    value, PW in uS, of HC-SR04
distmeas[0] = TimeDistMeas & 0xff;
    distmeas[1] = (TimeDistMeas &0xff00) >> 8;

    USBFS_LoadInEP(IN_EP_NUM3, distmeas, 2);

    CyDelay( 100 );
}
```

```
            //send buttons
            /* Wait until IN buffer becomes empty (host has read data). */
            if ((USBFS_IN_BUFFER_EMPTY == USBFS_GetEPState(IN_EP_NUM)) )
            {

                b = buttons_Read();
                USBFS_LoadInEP(IN_EP_NUM, &b, 1);
            }


        /*   if (USBFS_IN_BUFFER_EMPTY == USBFS_GetEPState(POT1_EP_NUM))
            {
                uint8 potval = (uint8) POT_ADC_Read16(); //POT_ADC_GetResult16();
                USBFS_LoadInEP(POT1_EP_NUM, &potval,1);
            } */


    }
}
```

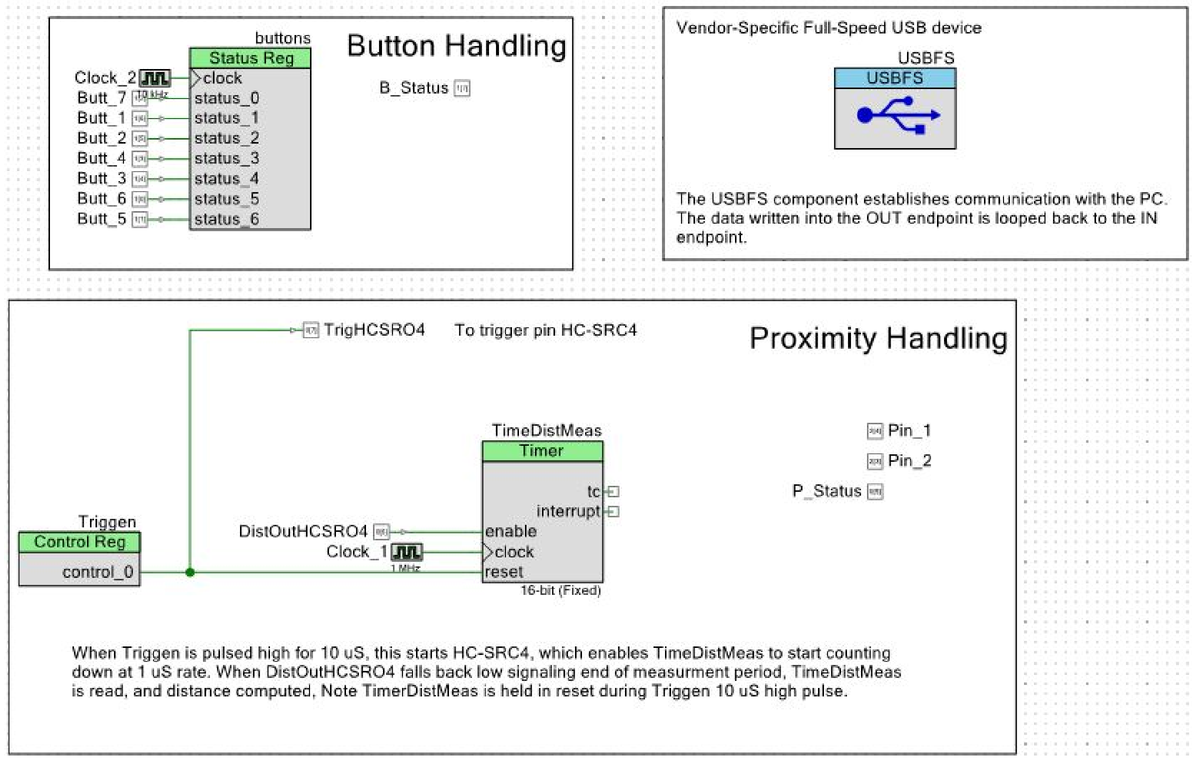

Figure D.1: PSoC Creator schematic for prototype 2. Takes in button and proximity statuses and initializes the Full Speed USB device.

Appendix E

Video Survey sent to Therapists

The following survey was sent to music therapists accompanied by a video of the device in use. Therapists were prompted to give their feedback in their own writing, or by selecting a number from 1-10 in questions six and seven. Feedback was recorded anonymously from eight participants.

1. Is there anything you do not understand about this device?

2. What would you change about this device?

3. Is there any features that you found particularly interesting / useful about this device?

4. What did you like about this device?

5. What didn't you like about this device?

6. On a scale of 1-10 How likely would you be to use this device in your practice in its current state?

7. On a scale of 1-10 how likely would you be to use this device in your practice with some modifications?

8. Are there any sensors/I put devices you would like to see utilized in future versions of this device?

9. Is there anything you would like to see on any device for music therapy in the future