Adaptive Music Technology Using the Kinect

by

Kimberlee Graham-Knight
BMus, University of British Columbia, 2004

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Supervisory Committee

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Abstract

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The field of Adaptive Music Technology is rapidly expanding and evolving. While there have been a number of theses and dissertations devoted to the study of new computer music instrument design for persons with disabilities, there is, as yet, no comprehensive study of all of the instruments that have been developed, along with recommendations for how to develop future musical instruments given rapid changes in technology. In this thesis, a comprehensive literature review of previous instruments developed is presented, along with personal interviews of developers where literature has not yet been published about a given instrument. Then recommendations for future development of instruments based on this information are presented. Finally, a case study of the development of one such instrument using the Microsoft Kinect is undertaken, and observations and conclusions based on this research are drawn.

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Dedication

To all of the Adaptive Music Technology Instrument creators and performers. You are heroes and pioneers in a very new field, and your work opens doors to some very impressive musical moments. May this thesis provide a record of some of your achievements, and may they be remembered as seminal in the history of Computer Music.

Chapter 1: Introduction

The field of Adaptive Music Technology (AMT) has been growing since the late 1980's.[1] Before then, advances in adaptive technology (such as electric wheelchairs) and music technology (such as the Theremin) laid the groundwork for AMT. The field is important because it provides a way for people with physical and cognitive disabilities to play music they could not otherwise play (Schalberg 1990). It opens up music making to many people who would otherwise not be able to participate. Benefits of music making for the disabled can include increased self-awareness, increased agency, and increased control of one's surroundings (Swingler and Brockhouse 2009). Further, with adaptive music, "[w]here there is a potential for artistic collaboration, there is also a potential for such engagement to enhance an individual's experiences of social inclusion" (Challis 2011).

According to Anderson (2015), "People with the most severe physical disabilities, for example, who are only able to move their eyes, are at most risk of being left in the margins of society" and "the challenge is to design an analogous music system to enable them to learn about, explore, and create music, so as to communicate and connect with others in a more universal way."

Because it is so important to develop new instruments that people with disabilities can play, it's key to develop a set of considerations to use when making a new instrument. This can be done by evaluating cases of pre-existing adaptive musical instruments and how they were developed, as well as by surveying some of the literature about AMT.

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[1] Some material in this thesis, including some tables and figures, was modified from two published papers by Kimberlee Graham-Knight for ICMC 2015 and PETRAE 2015.

AMT can be defined as the use of digital infrastructure to allow a person who cannot otherwise play a traditional musical instrument, to play music unaided by another person.

This is in contrast to purely mechanical solutions such as a stand that holds up an acoustic flute for a one-handed player. While all devices that aid the disabled in playing music are valuable, for the purposes of this thesis, only ones that use modern computing will be examined.

There have been comprehensive reviews of the history of music technology (see http://120years.net/), but there is a gap around the history of AMT. Tim Anderson (2015) notes “literature about 'assistive music technology' in general is very limited.” This thesis addresses this gap by providing a view of the current state of AMT instruments.

The benefits of music therapy for persons with disabilities have been discussed widely in the literature (Ansdell 2002, Baker et al. 2013, Crystal et al. 1989, Farrimond et al. 2011, Lem and Paine 2011, Samuels n.d., Watts and Ridley 2007). Some of the most effective music therapy situations are where the participant is actually able to make sound and control it. The complex nature of music stimulates the brain and the body in remarkable ways. It may also help reduce device abandonment to produce AMTIs. A well-designed musical instrument affords many possibilities over the lifespan of the user, and these may keep the end user interested in using an adaptive device in the long-term.

There are a number of MIDI devices that can aid a disabled participant in making musical sounds, such as the Canstrument, the Skoog, and the Jamboxx. These all have a computer at their heart, and produce digitally synthesized sound, as opposed to acoustic sounds of traditional musical instruments.

One computational device that shows a lot of potential for music-making is the Microsoft Kinect camera. This device, which was initially released in 2010, has an infrared depth sensor, an RGB camera, and a microphone that can perform speech detection. The Kinect is the first infrared depth sensor that was made available to the public with an SDK for programming. Because it can be triggered without holding, plucking, or otherwise physically touching it, which can be difficult for people with manual dexterity problems, the Kinect is a potential candidate for an adaptive musical technology instrument.

The definition of disability

Throughout this thesis, the term persons with a disability will be used. It is important to define this as we move forward, as there is often confusion around it.

The definition of disability, according to the United Nations, is “Any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered normal for a human being” (Kaplan 1999). Kaplan goes on to note that the definition of disability is not clear and straightforward. In fact,

> Most people believe they know what is and is not a disability. If you imagine "the disabled" at one end of a spectrum and people who are extremely physically and mentally capable at the other, the distinction appears to be clear. However, there is a tremendous amount of middle ground in this construct, and it's in the middle that the scheme falls apart. What distinguishes a socially "invisible" impairment - such as the need for corrective eyeglasses - from a less acceptable one - such as the need for a corrective hearing aid, or the need for a walker? Functionally, there may be little difference. Socially, some impairments create great disadvantage or social stigma for the individual, while others do not. Some are considered disabilities and some are not (Kaplan 1999).

So it is important to consider the social context of disability, along with the limitations of the player, when designing a new music instrument. This includes creating something that people can listen to and understand at some level, while still being enjoyable and playable by the person with a disability.

Contributions

The thesis statement here is as follows: It is possible to develop an artistically expressive instrument for a person with a physical disability using the Microsoft Kinect camera. This process can be studied and documented.

The researcher has worked with a person with a physical disability to develop an interface with the Kinect camera for the purposes of artistic expression as well as for therapeutic benefits. She has also catalogued all known AMT instruments, classified them, interviewed their makers, and gleaned themes from the development of such instruments, provided in the recommendations of Chapter 3.

The hypothesis to be tested is: The Kinect camera can improve artistic expression for an individual with a disability. This will be tested by building a system of musical sounds with the Kinect for the participant to try, and videotaping the result. The results will be evaluated using Utilization-Focused Evaluation, for which the priority evaluation questions are latency, repeatability and training time, and artistic merit questions.

Developing instruments for persons with disabilities requires special considerations compared with developing computer music instruments for people with a standard range of movement. It is important to document the differences in this process so that more instruments for people with disabilities can be produced, to increase the musical expression possibilities for people with mobility impairments.

The main goal is to test whether the Kinect is a useful tool for developing a musical instrument for a person with a disability. This objective will be met if proper evaluation metrics of the Kinect camera are applied, based on existing instruments and their development methods.

The process of developing a new musical instrument using the Kinect for a person with a disability has not been fully documented. This will be the first time to the researcher's knowledge that such a process has been documented in a structured way.

The researcher is primarily a musician with knowledge of computer science for the purposes of creating music. She has fused these disciplines to create a new instrument, and documented its various iterations.

My thesis lays down a preliminary road map to how to develop new musical instruments for persons with disabilities. Possibilities for building on this research are outlined in Chapter 5.

Chapter 2: Related Work

A comprehensive examination of adaptive music technology instruments (AMTIs) that have been developed by other researchers is presented here. A combination of online research and emailing (and in some cases interviewing) instrument makers was used to amass this list. First, an examination of what makes a computer music instrument adaptive, including factors in the development process that may be different than for non-disabled people, is undertaken. Then, a taxonomy of all of the AMTIs known to the author is presented in Table 1. Then, a list of AMTIs for which additional information is known is given. Finally, two tables providing information about instrument inception dates and links and papers for further information are provided. Special note is given to TempleTap.com, curated by Cynthia Jacobs and Bill Stern, which lists the instruments available as of the 1990’s (see Table 3).

In order to examine these instruments, it is important to develop a taxonomy for classification. Rolf Gehlhaar has done this in a book chapter from 2014 (Gehlhaar et al. 2014). His system, the only one developed specifically for adaptive instruments, is as follows:

- Special Needs Typologies
    - Physical difficulties
        - Head movement as sole input for computer interface
        - Semi-controlled movements of arm, excluding hands and fingers
        - Semi-controlled movements of fingers
        - Impaired/lack of vision
    - Mental difficulties

        - Mild learning/attention difficulties
        - Severe learning/attention difficulties
- Instrument Typologies
    - Physical instruments
        - Physical instruments with mechanical assistance via sensors
        - Physical instruments with a programmable robotic element, played via sensors
    - Digital interfaces requiring only simple physical manipulation
    - Digital hands-off interfaces
- Application Typologies
    - For individuals but also applicable also in a communal context
    - For several players simultaneously (communal).

Gehlhaar does not explain the terms used in this classification system, and it was difficult to classify all AMTIs in it. The author proposes the following categories, which seem to encompass all of the AMTIs that have been developed as of the writing of this thesis:

Table 1: Categories of AMTIs

Touchless
Video-based
Adaptive Use Musical Instrument (AUMI)
Movement to Music
Sound=Space
Infrared
Kinect
Benemin/Octonic
Beamz
Dimension Beam/Body Harp
Ultrasonic

Soundbeam
MidiGesture
MidiSensor
Microphone-based
Ernst
Breath Pressure Sensors
Flote
Eigenharp Pico (with clamp)
Doozaphone
Head=Space
Jamboxx
Magic Flute
Yamaha WX5
Gloves and Handheld Devices
mimu gloves
Canstrument
WiiMote
Switch-based Interfaces
Skoog
InGrid
Lynstrument
Filisia Cosmo
Xylotouch
TouchTone
Instrument A
Matrixx
Alphasphere
Brain-computer Interfaces
BioMuse
Brainfingers
Interactive Brainwave Visual Analyzer (IBVA)
Adaptable software and hardware environments for switches
Apollo ensemble
E-scape
I-CubeX
MidiCreator
MidiWing
MIDIGrid
STEIM SensorLab
Immersive systems
MEDIATE
Mandala VR
Very Nervous System

Synth A Beams
Eye Trackers
Eagle Eyes
EyeMusic
EyeGuitar
Eye Harp
String Instruments
SuperString
Kellycaster

Moog notes there are “three diverse determinants of musical instrument design and musical instrument structure. The first is the sound generator; the second is the interface between the musician and the sound generator; the third is the [...] visual reality of the instrument” (Farrimond et al. 2011). It is useful to look at the technologies that have led up to the design of the adaptive musical instruments listed in Table 1.

The GROOVE system (Generated Realtime Operations On Voltage-controlled Equipment) of Max Matthews could be considered a predecessor to some AMT instruments,[2] It allowed a performer to control some musical parameters with an analogue synthesizer, connected to a computer that took over certain parameters. This led to a “conductor”, and later a “sequential drum” program where the notes were stored in memory and a performer could “play” the notes in sequence. This realization of a computer storing musical information for live playback in order to give the performer more control over the parameters they choose is part of the underpinnings of AMT. It harnesses what the performer can do, and uses the computer to support this.

Perhaps the single biggest development that has made adaptive music technology possible is the advent of MIDI in 1983. This allowed for rapid and simple transport of musical commands. Shortly after that development instruments such as the

[2] Bell Labs, 1970. http://120years.net/groove-systems-max-mathews-usa-1970/

Soundbeam, which is an ultrasonic beam that triggers MIDI events when interrupted, and the Magic Flute, which triggers MIDI notes using a breath pressure sensor, began to be introduced. Other AMTIs that use MIDI include the Head=Space, the Doozaphone, the Jamboxx, the Yamaha WX5, the Canstrument, the Dimension Beam, the MidiCreator/MidiGesture/MidiSensor, the Optivideotone, the Synth-A-Beams, the Skoog and the AUMI.

MIDI provides a simple way to represent data, which lends itself well to the often simplified interfaces required for people with disabilities to be able to play music.The makers of the Soundbeam cite the Thereminovox as an ancestor and inspiration. Indeed, the idea of a no-touch instrument makes sense for many disabilities. Instruments such as Moog's Ethervox have evolved from both the Theremin and from MIDI.

Breath pressure sensors contain a membrane that has a pressure differential across it when blown into. The ones made for the use of disabled humans typically have a range of 0 to 1.5 pounds per square inch. Quadriplegics often lose lung capacity due to inactivity, so breath pressure sensors incorporated into instruments may actually increase lung capacity with use over time (Buell 2007).

There are a number of AMTIs that have been developed, and they fall into five broad categories: brain interfaces, blowing interfaces, touchless interfaces, switch interfaces and smartphone/tablet interfaces. Some examples of blowing interfaces include the Magic Flute, the Jamboxx, and the Head=Space. These all contain breath pressure sensors which give control over numerous parameters of the instrument, including pitch and volume. The main benefit of breath pressure sensors is that they do not require hand or limb dexterity to play; in fact, the Head=Space, for example, was designed for a player named Clarence Adoo who cannot move except for his head but retains control over his breath.

The premier adaptive switch interface is the Skoog. It is a cube with brightly coloured buttons on each side, and squeezing, pressing, or otherwise manipulating it creates MIDI output. Switches can be customized to operate with any part of the body, including the side of the head and the bottom of the foot, which makes them ideal for many disabilities including large motor limitations and dexterity difficulties. They are highly adaptable. Most non-commercial musical applications for people with disabilities use switches, because they are easiest to implement and understand. However, simply pushing a switch may not provide a lively musical performance, complete with gesture, and can be limiting.

Brain interfaces require no movement or dexterity at all, but do require control over brainwaves, which can be extremely difficult. They also, as of yet, do not provide precise control over musical parameters such as pitch; it is not possible to think a note and have the interface detect it, for example. However, they require absolutely no movement at all, which makes them beneficial for people with physical impairments. Two examples of brain interfaces are the BioVolt and Brain Machine.

Interfaces using tablets and smartphones can provide intimate control and sensitivity. The Canstrument, for example, uses the inner accelerometer of the iPhone to trigger MIDI events, and can be adjusted for sensitivity. Touchless interfaces include the Dimension Beam, the EMS Soundbeam, the AUMI, and the Kinect, and use video, infrared or sonar technology to detect movements by the player. The AUMI, for example, is entirely video-based, while the Dimension Beam uses infrared. These range widely in functionality and accuracy. An instrument that doesn't need to be plucked or otherwise manually touched has many potential benefits for people with disabilities who do not have fine motor control or breath control.

What makes a computer music instrument adaptive

According to Matossian and Gehlhaar (2015), “the disabled encounter many obstacles in their quest for self-expression through music. Most musical instruments are difficult to use. They are the result of hundreds of years of an evolutionary process that has favoured able-bodied skilled performers.”

One central question to the development of AMT is, what makes it different than other music technologies? That is, is the process of creating a music technology instrument for someone with a disability different than creating one for an able-bodied person, and if so, how?

Axel Mulder (1996) lists two of limitations of “traditional and new musical instruments” to wit Inflexibility and Standardization. He states, “Due to age and/or bodily traumas, the physical and/or motor control ability of a performer may change,” and this may cause the instrument to be no longer playable by the performer. The player may change to another instrument, but in the case of movement disability this may not be possible, and even if it is, “[a]cquired motor skills may be lost in the transition[.]” Further, Mulder notes that “Most musical instruments are built for persons with demographically normal limb proportions and functionality.” Tellingly, “[t]he capability of musical instruments to accommodate persons with limb proportions and/or functionality outside the norm is relatively undeveloped,” and this can leave persons with disabilities struggling to play instruments that were not designed for them.

So an adaptive instrument will endeavour to remedy these problems. It will be able to change with the physical and motor control limitations of the performer, and will adapt to different limb proportions.

Further, new musical instruments are often designed by the performer to be played by him or her (El-Shimy and Cooperstock 2016). The designer intrinsically knows the limitations and capabilities of the performer, because they are the same person. This is often not the case with AMT. Here, the performer has specific abilities and difficulties that make designing an instrument unique, and which must be clearly understood by the designer in order to fully capitalize on the abilities of the performer.

There are a number of adaptive devices that can make music playing possible for disabled musicians, such as a larger guitar pick that allows for a better grip, or a stand for people who cannot hold up the weight of instruments such as a saxophone. While these are important for people with disabilities to be able to play music, they are not explored in this thesis because they are not, on their own, self-contained musical instruments.

Just as there is not a clear line between able-bodied and disabled people, there is not a clear delineation between traditional musical instruments and adaptive ones. For example, a piano may be adapted to one-handed playing by writing appropriate sheet music for it, such as left-handed etudes. The piano itself could be considered an adaptation, instead of a wind instrument, for someone with poor breath control. And the piano can be an adaptive device for someone with Alzheimer’s, who has played all their life but now has very little memory left; they may still be able to play piano regardless of memory deficits (Crystal, Grober and Masur 1989). Likewise, a Theremin, which was not specifically designed for persons with disabilities, may be adaptive for those with inability to grip, due to being "touchless".

Because nearly any musical instrument could be considered adaptive in some way, it is important to distinguish exactly what we are talking about when we say adaptive music technology. There are a number of factors that may suggest that a musical instrument is adaptive. Two are notable for our purposes.

First, if it is possible to identify certain disabilities for which the instrument may be of benefit. These may be mobility impairments or cognitive differences; as defined above. For example, the Magic Flute can be played by someone with no limbs at all, and the Soundbeam can be played by a person with a very small range of motion.

Second, if the instrument was designed with a person or persons with a disability in mind. As was previously stated, this is not always the case with adaptive instruments, such as the Yamaha WX5, a wind MIDI controller, which can be played one-handed and is used by persons with disabilities. But for the most part, adaptive instruments were designed with certain limitations in mind.

In order to better consider these factors in determining whether a new musical instrument is adaptive, we will examine one such instrument: the EMS Soundbeam.

The Soundbeam is a touchless MIDI controller with its own built-in sound module. It consists of an ultrasonic sound wave projector and receiver in the shape of a flashlight, which detects when the beam of waves is being obstructed. Its first version was developed in 1989 by Edward Williams, and subsequent versions have improved on the first. It was initially designed for dancers, but its potential for helping the disability community made it a mainstay of adaptive music technology. So, in terms of the criteria, it was not initially designed for persons with disabilities in particular, although it was later adapted to the feedback of persons with disabilities. Perhaps most importantly, it addresses a number of disabilities, with its ability to be adjusted to a small range of motion, and no need for the player to hold the instrument.

The One-Handed Musical Instrument Trust

The One-Handed Musical Instrument Trust (see www.ohmi.org.uk) seeks to encourage development of new musical instruments, which can be played with one hand, modelled on traditional instruments such as a flute or guitar. Many of the instruments listed on their website are not designed with persons with disabilities in mind, but may be used adaptively, such as the Yamaha WX5, which can be played with one hand or programmed to only use certain keys to create a scale.

TempleTap

Another resource when searching for adaptive musical instruments is TempleTap.com, a website by Cynthia Jacobs and Bill Stern. It lists a number of touchless MIDI instruments for people with a range of disabilities, and investigates them for usefulness. Cynthia is a Master’s of Digital Design candidate (1997) and Bill is a computer programmer who has worked on such projects as BeamZones software for the Soundbeam, which allows the Soundbeam to be played with samples instead of MIDI tones.

Considerations when developing an adaptive musical instrument

It is important to develop a set of considerations instead of rules when looking at the development of adaptive music instruments, because as discussed earlier, there is no clear line between adaptive and non-adaptive instruments.

Identifying the different ability to adapt to

This is a central issue when designing new music instruments, and is especially relevant when designing adaptive ones. Some of the limitations addressed by the instruments listed below are:

- reduced range of motion (including severe reduction in range of motion)
- inability to depress a key (lack of finger dexterity)
- ability to move the head only
- shakiness
- inability to move at all (use of other means of sound generation such as breath pressure sensors or brainwaves)

Note that for many AMTIs, these were not explicitly set out in the beginning. The Eigenharp, for example, was not exclusively designed for people with disabilities, but for "musicians, all of them."[3] However, the Eigenhap engineers skilfully solved the problem of not being able to apply much force to a key by creating the eigenkey, which can be activated by a depression as small as the width of a cell.

This work may also be partly applicable to children because of their lack of fine motor skills. More research needs to be done to understand how the work outlined in this thesis could pertain to kids.

Keeping people with disabilities in mind

This is perhaps the most notable consideration when developing a new music instrument if there is any intention for the instrument to be used by persons with

[3] Personal email, June 20, 2016.

disabilities, and can mean varying things. The steps outlined in Chapter 3 offer a framework for participatory design with persons with disabilities.

It is also important to consider the social barriers of the people with disabilities when designing an instrument. As Swingler notes in his discussion of the Soundbeam, "As the children are able to learn and perform on an equal basis, the disabled/non-disabled barriers can be broken down" (Swingler 1998). So developing something that people with disabilities can play can have profound social implications.

A corollary to the social context of the person with a disability is the set of environmental factors that can make the disability more or less pronounced. According to Pope and Brandt (1997):

> [T]he amount of disability is not determined by levels of pathologies, impairments, or functional limitations, but instead is a function of the kind of services provided to people with disabling conditions and the extent to which the physical, built environment is accommodating or not accommodating to the particular disabling condition. […] Human competencies interact with the environment in a dynamic reciprocal relationship that shapes performance. When functional limitations exist, social participation is possible only when environmental support is present. If there is no environmental support, the distance between what the person can do and what the environment affords creates a barrier that limits social participation.

In the case of AMT, environmental factors include anything that makes it possible for the person to get to a place where they can play music, both externally including personal care supports, adapted building infrastructure, and family backing, and internally including the musician's personal attitudes. It is important to be aware of these factors when working with a disabled person to design an instrument.

Making something that can adapt over the lifespan of the disabled person

Arguably, the most important aspect of a new musical instrument is its enjoyment by the performer. According to El-Shimy and Cooperstock (2016), "Typically, musicians and artists express a greater interest in the hedonic aspects of their experience with a system than they do in the system's efficiency or practicality."

And while the instrument must be enjoyable, it must do so at every level of playing: "Wessel and Wright (2002) argue that although getting started with computer-based instruments should be easy, continued development of expressivity is a key factor in the adoption of these instruments" (El-Shimy and Cooperstock 2016).

To add to this, "Sidney Fels (2004) further expounded on this view, explaining that a 'well-designed instrument' is one comprising an interface that is constrained and simple enough to allow a novice to make sounds easily, while also remaining sufficiently challenging for the experienced player to explore a path to virtuosity" (El-Shimy and Cooperstock 2016).

The ultimate goal with an enhanced instrument is that the performer never run out of possibilities, that the instrument be such that "[g]etting started [… is] relatively easy but this early stage ease-of-use should not stand in the way of the continued development of musical expressivity" (Wessel and Wright 2002).

Considering how much control to give to the player

The challenge over the lifespan of the person playing the instrument goes hand in hand with another consideration, that of how much control to give to the player. As noted by Challis and Smith (2011):

> Where the performer is responsible for forming or triggering individual notes, the performance behaviour can be regarded as skill-based. Where the performer has no

> control over the system beyond starting and stopping playback of a predetermined piece, the performance behaviour can be regarded as model-based. A third performance-behaviour (rule-based) sits partway between these two extremes and encompasses systems and instruments that allow the performer to trigger and perhaps manipulate patterns based on predetermined rule-sets.

They further note, “it could be argued that the skill required by an able-bodied performer to play, for example, a chord shape on a keyboard at a specific time is comparable to another performer with physical and dextrous challenges pressing a single (and possibly quite large) switch within a quantised time-scale” (Challis and Smith 2011). It could further be argued that the skill required to play a piece is a determinant of whether or not it is considered music. The question of what is music is outside the scope of this thesis, but Cooke (1959) argues that it is an art that emotionally affects the listener.

So consideration of how much control to give to the player is an important aspect of instrument design, and one that will ultimately determine the aesthetic result of the playing.

The amount of control the player has over the instrument may also change due to the dynamic nature of disability. There are any number of factors that can contribute to the disability of the player including stroke, episodic disabilities such as epilepsy, cardiac events, and many others. It is outside the scope of this thesis to list all of the possible shifting scenarios, but it must be considered when designing an instrument that the musician’s ability to control the instrument may change over time and even within a session.

History of adaptive new musical instruments

In order to more fully understand the development of adaptive new musical instruments, it is useful to look at the development of various specific instruments over the last 30 years.

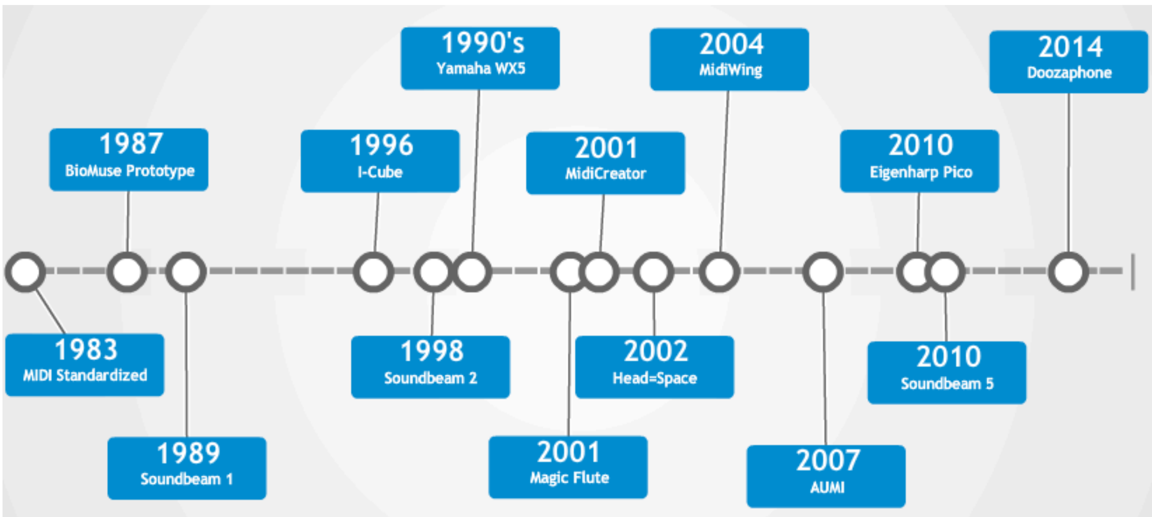

Figure 1: Timeline of Adaptive Music Technology Instruments

Good interface design benefits everyone, including people with disabilities, and the instruments discussed in this thesis are all examples of well-designed musical interfaces. They all allow for people with varying disabilities to play them, and most were designed (at least in part) with people with disabilities in mind.

The EMS Soundbeam

Figure 2: Soundbeam (livingmadeeasy.org.uk)

The Soundbeam is an ultrasonic beam that triggers MIDI events when the beam is obstructed (Swingler 1998b). The unit has a MIDI cable that plugs into its main device for sound synthesis. It was first introduced by composer Edward Williams at the Frankfurt International Music Fair in 1988 as Soundbeam 1. That version had a single ultrasonic beam with the ability to add up to three more slave beams, and a menu of ten preset scales with the ability to store an up to 16-note pitch sequence in volatile memory.

Soundbeam 2 was released in 1998 and remained in use until 2010 when Soundbeam 5 came out. It had non-volatile memory and tactile switches (as foot pedals) to alter the sound, and could allow for up to four sensors to be connected to the main unit.

Soundbeam 5 was released in 2010 after many iterations of user experience and feedback. It incorporates an internal synthesizer and sampler, dispensing with the need for external modules and sound synthesizers. An important development with Soundbeam 5 is the ability to store pre-set melodies and harmonies. This makes possible a more methodical and progressive menu of pre-sets (improvisations, tunes and themes) than was available with Soundbeam 2.

The Soundbeam 5 has a number of control parameters, which allow its range to be adjusted between 25 centimetres and 9 metres. This allows for performers who have a relatively small range of motion to be able to play a large range of notes, as the smaller range concentrates note information. There are also Mode settings which allow the player to adjust which notes are played (scales or arpeggios), how many notes can be played (from one to 64), and various parameters such as velocity and pitch bend.

When creating the Soundbeam, Tim Swingler kept in mind the importance of making the performer feel they can initiate something. That is, the idea of cause (the musician performing a gesture) and result (a pleasing musical sound) is central to the development of the Soundbeam.

One virtuosic performer of the Soundbeam is Ari Kinarthy of Victoria, British Columbia.[4] The Soundbeam is the premier AMTI as it appears the most in the Music Therapy literature (Magee 2006) and its current iteration costs roughly $4500 CAD. This is in contrast to a Kinect, which costs under $200 CAD second-hand with the computer adapter.

[4] YouTube video: https://www.youtube.com/watch?v=wggj7Kd7q2U .

The Magic Flute

Figure 3: Magic Flute (housemate.ie/magic-flute)

The Magic Flute[5] is a breath pressure sensor that also triggers MIDI notes. Inspired by a slide flute and the Yamaha WX5, it is the brainchild of Ruud van der Wel and David Whalen, who first envisioned the instrument in January 2006. In half a year, after their instrument proposal was rejected by many universities, they had a prototype built by Brian Dillon from Unique Perspectives. The prototype was a breath sensor with a gyroscope that had 8 tone scales and a MIDI out.

The Magic Flute is mounted on a swivelling camera stand, and the performer moves it by holding the mouthpiece and moving their head up or down. The vertical position of the flute determines its pitch while the breath strength determines note

[5] YouTube video: https://www.youtube.com/watch?v=C4EulBoILwo.

amplitude. The unit plugs into a ‘blue box’ which in turn plugs into a synthesizer via MIDI cable.

The catalyst for change in the Magic Flute was Ruud's work with children at the Rijndam Institute in the Netherlands. From that he added a lot of new tone scales, a transpose function, switch behaviour, and the ability to change user settings.

The making of these two instruments shows the importance of iterative development and user feedback. In the next section, these will be qualified and explained further.

Eigenharp Pico with Clamp

Figure 4: Eigenharp Pico (amazon.co.uk)

The Eigenharp Pico was first introduced in England in 2010, with the Eigenharp Alpha (2009) as its predecessor.

The designers, John Lambert (chief designer), Mark Rigamonti and Jim Chapman, deliberately chose not to imitate any other musical instrument. The idea for the Eigenharp came in 1994 when Lambert was playing in a band.

The Eigenharp was developed in two iterations, the first being for desktop. It was an adaptation of the core technology of the Alpha, which is based on the eigenkey, the only moving part on the Eigenharp. . It contains 16 eigenkeys and a breath sensor. The key is read every 500 microseconds, and this data rate is preserved throughout the system. A more detailed description of the eigenkey can be obtained on the Eigenharp website (see www.eigenlabs.com).

The Eigenharp is driven directly by a PC via USB 2.0, and there is no signal processing inside the unit itself.

The Eigenharp could be useful for people with disabilities because it requires only a light touch to be activated (the movement of the width of one cell) and is small and can be mounted on a clamp.

BioControl Systems

In 1987 at Stanford, Hugh Lufstead and Benjamin Knapp began experimenting with physiological interfaces to music, and the BioMuse was born. It is a processing box that allows inputs of various sensors such as 2 EEG ports, 2 EOG ports, 3 EMG ports, and an audio input, for a total of 8 channels.

These technologies had been used previously in non-real-time applications for music, and had been used in a hospital setting, but the BioMuse was the first to offer real-time human physiology possibilities to music.

One performer and early adopter of the BioMuse is Atau Tanaka[6], who has given numerous presentations about the instrument.

The BioMuse could be helpful to persons with disabilities because the sensors can be connected to various parts of the body, and can capitalize on the various responses of the person, including skin temperature and sweat, muscle activation, and brain waves.

[6] Vimeo video: https://vimeo.com/2483259.

Yamaha WX5

Figure 5: Yamaha WX5 (usa.yamaha.com)

The Yamaha WX5 is a wind MIDI controller that plugs into a synthesizer via MIDI cable to produce sounds, and was first introduced in the late 1990’s. It was preceded by the Akai EWI, another MIDI wind controller. There were also the WX7 and WX11 which were ancestors of the WX5, developed in the late 1980’s. The WX5 is an example of an instrument that was not specifically designed to be adaptive, but came to be used that way because of its small size and light weight. It can be played one-handed, and was entered into the OHMI competition.

I-CubeX

Figure 6: I-Cube X (partly-cloudy.com/misc/#4)

The original presentation of the iCube System, with its core Digitizer[7], was September 21 at the International Symposium on Electronic Art (ISEA) 1995 in Montreal. The Digitizer converts signals from a variety of sensors to MIDI data, with "numerous tools to facilitate use of these sensors in the creation of other instruments,"[8] affording non-technical people such as artists the ability to use sensors in their work. Its predecessor was the STEIM Sensorlab.[9]

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[7] https://infusionsystems.com/catalog/info_pages.php?pages_id=232

[8] personal e-mail from Axel Mulder, June 20, 2016

[9] http://steim.org/product/discontinued-products/

The iCube system has been through a number of iterations after originally being introduced in 1995. These iterations are as follows:

- 21 September 1995: Digitizer[10]
- July 2004: miniDig[11]
- November 2004: Wi-miniDig[12]
- June 2006: microDig[13]
- June 2006: Wi-microDig v5[14]
- June 2007: Wi-microDig v6[15]
- November 2008: USB-microDig[16]

Axel Mulder is the chief designer of the iCube system, and over the years various people have helped with additional iterations, including Andrey Gleener, Thomas Sternberg, Dasz Garncarz, Rolf Wilkinson, Carlos Vela-Martinez, Benoit Bolduc, Christian Martin, Nathanaël Lécaudé, Elliot Sinyor and Johnty Wang.[17]

The system can be considered adaptive because it is highly re-configurable and can accommodate a variety of different sensors that can accommodate various disabilities.

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[10] https://infusionsystems.com/catalog/info_pages.php?pages_id=232

[11] https://infusionsystems.com/catalog/info_pages.php?pages_id=107

[12] https://infusionsystems.com/catalog/info_pages.php?pages_id=114

[13] https://infusionsystems.com/catalog/info_pages.php?pages_id=152

[14] https://infusionsystems.com/catalog/info_pages.php?pages_id=169

[15] https://infusionsystems.com/catalog/info_pages.php?pages_id=153

[16] https://infusionsystems.com/catalog/info_pages.php?pages_id=225

[17] personal e-mail from Axel Mulder, June 20, 2016

Head=Space

The Head=Space was developed in 2000 for Clarence Adoo, a professional trumpet player who was involved in a car crash in 1995, leaving him quadriplegic.

The maker of the Head=Space, Rolf Gehlhaar, who works with the British Paraorchestra in London (see www.paraorchestra.com), describes the instrument:

> Headspace consists of a device which measures vertical & horizontal displacement using phase relationship differences of two ultrasound sensors in reference to each other. Worn on the head by the player, it allows him/her to move a cursor on the desktop of a computer. Furthermore it has a small puff-switch which enabled the player to transmit a mouse click. With this device, the player is able to point & click, navigating a specially designed musical GUI that is the musical instrument HeadSpace. The affordances of this GUI are manifold, in short: choose a sound/specific pitch, sustain this sound, transform/modulate it, change its loudness. HeadSpace is a polyphonic 'instrument' that allows the player to work with two different sounds simultaneously, in short, play in a dialogue with him/herself. There are also memories that store previously used settings/transformations.[18]

The Head=Space took 8 months of iterations and testing before being released in 2000, and Adoo began playing it in 2002. The Head=Space has no direct predecessors.

Gehlhaar hopes to “level the playing field” for instrumentalists with a disability, allowing them to play fully expressive instruments whenever possible. The Head=Space, and its cousin, the gyroscope-operated HiNote, were developed in London. They are both good examples of instruments developed for people with disabilities in mind, for musicians only having head movement and breath control or having limb fatigue.

[18] Personal email.

Jamboxx

Figure 7: Jamboxx (ohmi.org.uk)

The Jamboxx is a breath sensor instrument listed on the OHMI website.

Skoog

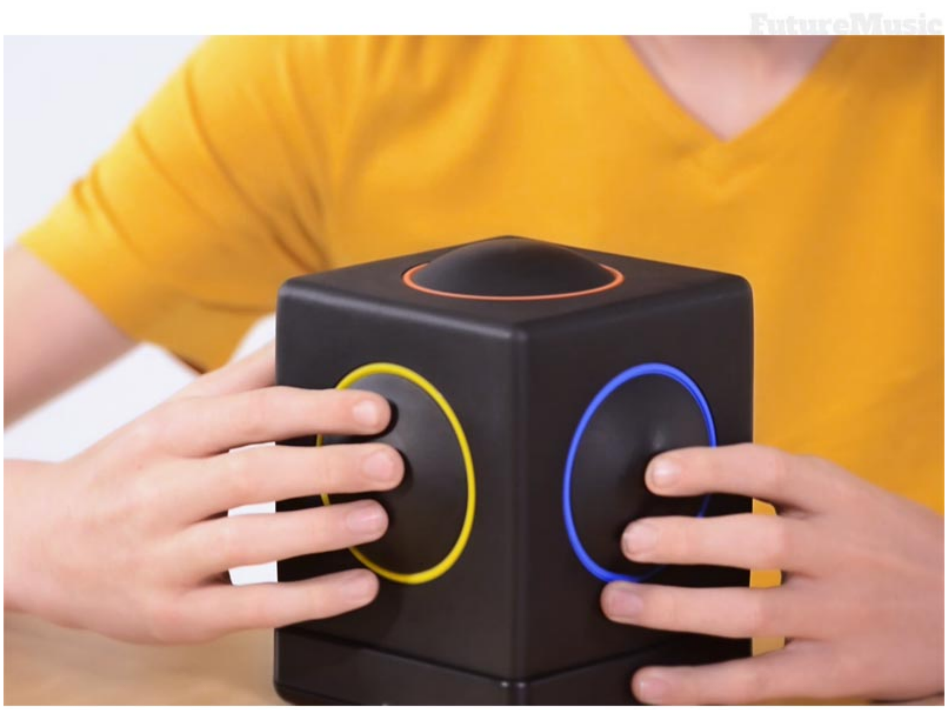

Figure 8: Skoog (futuremusic.com)

According to its website (see www.skoogmusic.com), the Skoog is "A revolutionary tactile cube that will change the way you and your family enjoy, create and learn music. Skoog is a powerful and fun music interface for iPad that opens up a world of ‘musicplay’ to everyone, including those with disabilities.”

It is a soft cube with buttons on each side that allow the user to interact with the instrument in a number of ways. It plugs into a computer via USB for sound synthesis using MIDI.

Beamz

Figure 9: Beamz (linkassistive.com)

The Beamz is a MIDI controller that plays different pre-programmed songs and sounds when one of its four beams of light is obstructed.

mi.mu gloves

Figure 10: mi.mu Gloves (ohmi.org.uk)

The mi.mu gloves are a new music instrument developed by Imogen Heap, Hannah Perner-Wilson, Thomas Mitchell, Adam Stark, Kelly Snook, Rachel Friere, Seb Madgwick and Chagall van den Berg. According to the mi.mu website (see www.mimugloves.com) , the gloves "represent a truly elegant fusion of traditional textiles with advanced motion tracking electronics and algorithms. Combined with dedicated gesture detection and mapping software, the mi.mu gloves offer a new and flexible approach to the control of music and visuals with intuitive human movement."

Kellycaster

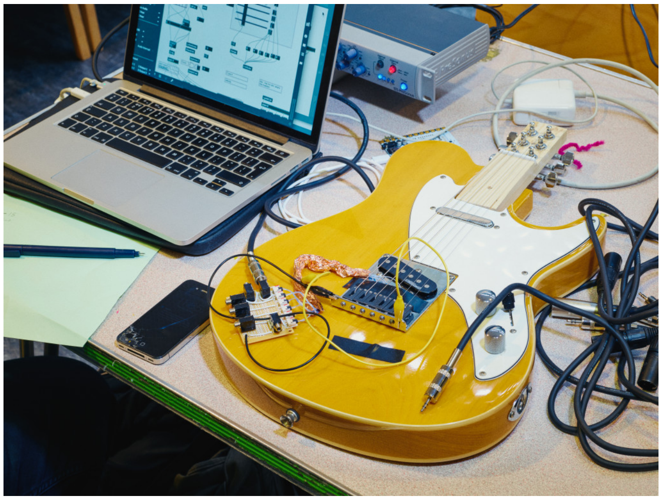

Figure 11: Kellycaster (cdm.link)

The Kellycaster[19] is a modified electric guitar named after and developed for John Kelly. More information can be found at http://www.drakemusic.org/our-work/research-development/artist-led-projects/john-kelly-the-kellycaster/.

Adaptive Use Musical Instrument (AUMI)

The AUMI prototype was created in 2 weeks in 2007, and the instrument is still being used today. It is a video-based system that allows the user to place a dot somewhere on the body of the disabled player, usually on the face, and the player to be able to move the dot around using body motion. It was designed specifically for children with disabilities, and can be used by people with extremely small voluntary movement.

The original prototype was designed and coded by Zane Van Duzen, and subsequent iterations were written by Zevin Polzin, Aaron Krajeski and Ivan Franco. The AUMI iPad app, currently available on the iTunes store, was written by Henry

[19] Youtube video: https://www.youtube.com/watch?v=BaSRAXYT1ao.

Lowengard. The AUMI is primarily used for improvisation, and its website mentions the cultural barriers of people with disabilities to playing music.[20]

MidiWing

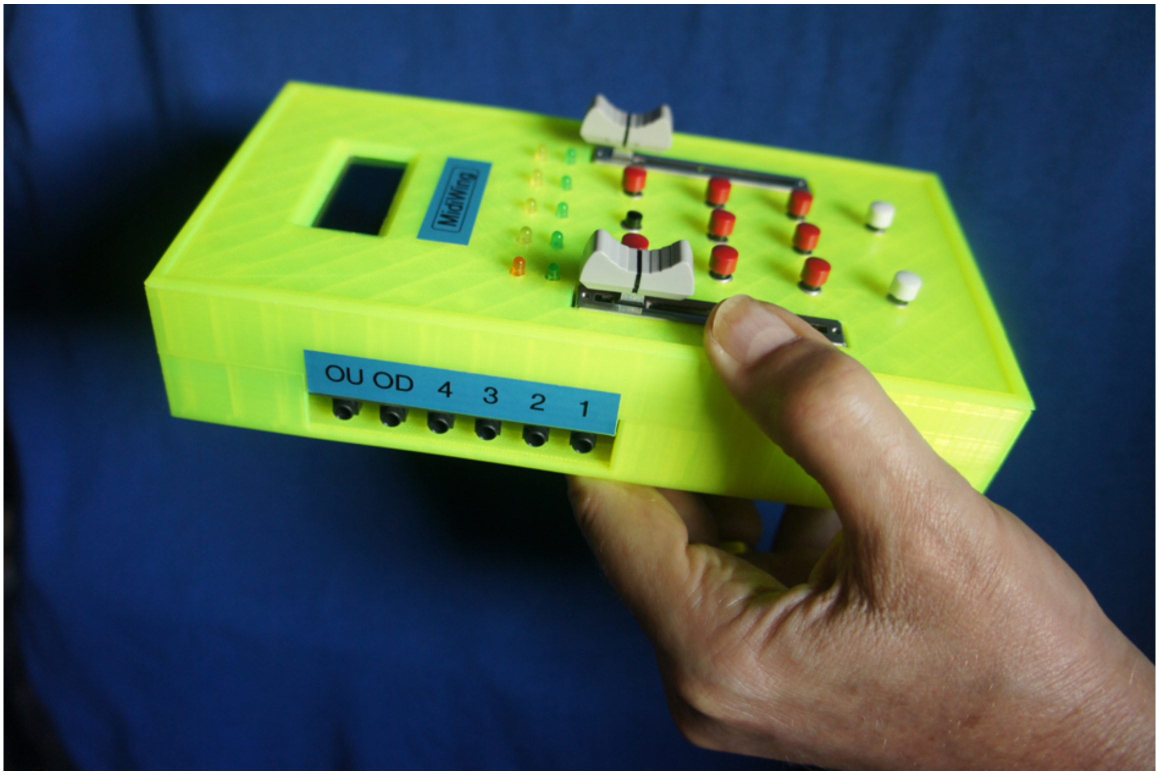

Figure 12: MidiWing (midiwing.com)

In 2004, the first iteration of the MidiWing was released, with a microprocessor that became outdated. The second version of the instrument began being developed in 2010, and was released in 2014, designed by Dan Daily and Kent Pfeifer, the latter being a micro-devices engineer at Sandia National Laboratories in Albuquerque.

Put simply, MidiWing makes it easier to take input from external controllers such as joysticks and mice, analog continuous controllers, and various switches, and to

[20] **ccc**-rpi.org/research/**aumi**/

translate them into MIDI data when plugged into the unit. According to creator Dan Daily,

It is a fully chromatic MIDI controller able to play the standard literature, but scalable to accommodate and maximize the user's capabilities. MidiWing is the first MIDI controller to make playing real music with a single line musical instrument easier by utilizing simply controlled electronics in place of complicated and difficult physical tasks. It also has modes which allow MidiWing to mimic traditional instruments which allow the MidiWing user to participate in a traditional band or orchestra class without extra effort or resources[.][21]

Daily further notes the MidiWing has "many devices in the history of electronic music which can rightly be viewed as predecessors in terms of similar concepts but MidiWing is the first instrument to make certain musical tasks easier."[22]

The instrument was designed for people with disabilities, and solves the difficulty of hooking up various devices to MIDI output. In the words of Dan Daily, "It's just easier."[23]

MidiCreator

MidiCreator was first introduced in 2001 by Immersive Media Spaces in the United Kingdom. It is a platform that takes the input of various switches and sensors and outputs them as user-controlled MIDI data.

The unit was discontinued in 2006, but there is still a resource page online (see http://www.midicreator-resources.co.uk/) that lists a number of papers that have been

[21] Personal email.

[22] Personal email.

[23] Personal email.

written about the system (see http://www.midicreator-resources.co.uk/midicreator/articles.php).

Table 2: Adaptive Music Technology Instruments

Instrument	Year Created	Creator(s)	Resources
Apollo Ensemble			http://www.apolloensemble.co.uk/
Jamboxx		Michael DiCesare	http://www.jamboxx.com/
Kellycaster		John Kelly	http://www.drakemusic.org/our-work/research-development/artist-led-projects/john-kelly-the-kellycaster/
Skoog			http://skoogmusic.com/
BioMuse	1987	Benjamin Knapp	http://www.biocontrol.com/ Knapp and Lusted 1990. Lusted and Knapp 1996.
Soundbeam	1988	Tim Swingler and Edward Williams	http://www.soundbeam.co.uk/ Swingler 1998a. Swingler 1998b. Swingler 2003.
Yamaha WX5	1990's		https://usa.yamaha.com/products/music_production/midi_controllers/wx5/index.html
E-Scape	1993	Tim Anderson	http://www.inclusivemusic.org.uk/ Anderson 1993. Anderson 1999. Anderson 2002. Anderson 2015. Anderson and Smith 1996.
MidiCreator	1994	R Kirk	http://www.midicreator-resources.co.uk/ Abbotson et al. 1994.
MIDIGrid	1994	R Kirk	http://midigrid.com/ Abbotson et al. 1994. Hunt and Kirk 1988.
I-Cube	1996	Axel Mulder	https://infusionsystems.com/catalog/info_pages.php/pages_id/117 https://en.wikipedia.org/wiki/I-CubeX Mulder 1995. Mulder 1996. Mulder 2000.
Magic Flute	2001	Ruud van der Wel and David Whalen	http://mybreathmymusic.com/en/magic-flute
Head=Space	2002	Rolf Gehlhaar	
MEDIATE	2004	Hans Timmermans	http://www.port.ac.uk/research/mediate/ Timmermans et al. 2004.
MidiWing	2004	Dan Daily	http://www.midiwing.com/

Beamz	2005 (patent filed)	Al Ingallinera	http://www.thebeamz.com/
Adaptive Use Musical Instrument (AUMI)	2007	Pauline Oliveros	http://deeplistening.org/site/adaptiveuse Oliveros et al. 2011.
Movement to Music	2007	Cynthia Tam	Tam et al. 2007.
Benemin	2008	Ben Challis	Challis and Challis 2008.
Eigenharp Pico	2010	John Lambert	http://www.eigenlabs.com/product/pico/
Eye Harp	2011	Zacharias Vamvakousis	https://theeyeharp.org/
Octonic	2011	Ben Challis	Challis 2011.
mi.mu Gloves	2013	Tom Mitchell (and others)	http://mimugloves.com/
Doozaphone	2014	Rolf Gehlhaar	
InGrid	2014	Brendan McCloskey	http://www.drakemusic.org/tags/ingrid/ Lyons and McCloskey 2014. McCloskey 2014.

Table 3: Instruments from TempleTap

Instruments from TempleTap with Descriptions[24]		
Instrument	**Description**	**Links/Publications**
Dimension Beam/Body Harp	by Interactive Light emits an invisible egg-shaped infra-red light field. Motion within the light field is translated into a MIDI signal which can operate effects, keyboards, samples, lights, computers. The **Body Harp** is an octagonal array of Dimension Beam sensors that allows the entire body to create music. Music can be created with a wide selection of sounds like piano, organ, guitar, or drums. The Body Harp also comes with 24 built-in melodies. Interactive's Smart Beams have the ability to correct for electronic, temperature and other noise in the ambient environment. The company's high-speed filtering system enables powerful infra-red communications and distance sensing	

[24] All descriptions copied from http://templetap.com/ .

	technologies. Smart Beam technology includes the ability to custom design the shape of a sensing zone for a particular application. Interactive has patented its ability to create planar shaped sensing spaces. Depending on the particular application, sensing spaces can be created with other shapes such as cones or squares.	
MidiGesture	MMB Music's proportional ultrasound switch device that plays sound through the MidiCreator by detecting body movement from the simple wave of a hand to someone moving along or across the beam. Its three ranges cover between 1, 2, and 3 meters.	
MidiSensor	operates in a similar way to MidiGesture but is extremely sensitive and designed to detect even the slightest movement at a range of about six inches.	
Optivideotone	Based on the theremin, Professor Scott Hall of the Cogswell Polytechnic College has used light sensitivity in the creation of his Optivideotone, an assemblage of audio and video electronics combined to produce an object that is sculpture, musical instrument/composition tool, and projected video art exhibit in one.	http://www.oddmusic.com/gallery/om23300.html
SensorLab	created at STEIM in Amsterdam, is a small, general purpose, analog to MIDI interface for the prototyping of musical instruments and interactive control systems. This box has thirty-two channels of analog to digital conversion, two ultrasound inputs for measuring distance between sensors, over one hundred switch inputs and more.	http://steim.org/support/sensor.html
Synth A Beam	by Interactive Entertainment consists of a MIDI Interface, and photo sensor strips. Almost any directional lighting fixtures can be focused on the sensors. When beams of light are interrupted, MIDI notes are generated. The system can be used to control any equipment that responds to MIDI commands. The Synth A beam sensors are NPN photo transistors that only	https://jonkirch.com/2013/06/26/the-synth-a-beam/

	react to directional light sources and are not affected by ambient lighting.	
Eagle Eyes	developed at Boston College is a new technology that allows a person to control a computer simply by moving the eyes or head. The signals can be used to control the cursor on the screen, making this device suitable for hands-free drawing. The company claims that as the child learns to control the cursor on the computer screen, the child's capabilities and knowledge can be assessed.	http://www.bc.edu/schools/csom/eagleeyes/
Interactive Brainwave Visual Analyzer (IBVA)	The IBVA provides easy real time analysis and intricate interactive biofeedback control of brainwave conditions. The IBVA reads brainwaves in real time and allows you to use them to trigger images, sounds, other software or almost any electronically addressable device through its MIDI, serial and expansion pak features. With the network and modem features of the IBVA, brainwaves can be analysed and control equipment from anywhere in the world. The user doesn't have to be confined to a few feet of freedom. The IBVA comes standard with a lightweight wireless transmitter that works up to thirty feet away. This allows you to do just about anything while monitoring your mind state.	http://www.ibva.co.uk/
Mandala VR	The Mandala VR system by the Vivid Group uses a video camera to put the user into virtual worlds. When the user moves the virtual world responds to the user's presence. One of the first uses of the Mandala System was demonstrating how people could create music with their whole body using the system. The company these days is turning their Mandala Systems into marketable games, but they are still in touch with their musical roots, with a recent module dedicated to drumming.	http://www.mandalavr.com/
Very Nervous System (1986)	is the third generation of interactive sound installations created by David Rokeby. In these systems, video cameras, image processors, computers, synthesisers and a	http://www.davidrokeby.com/vns.html

	sound system are used to create a space in which the movements of one's body create sound and/or music. It can sense motion in a space and where that motion occurs. Output from the VNS is via a SCSI connection. Objects are provided that allow access from the MAX programming environment. It has been primarily presented as an installation in galleries but has also been installed in public outdoor spaces, and has been used in a number of performances.	

The field of AMT is ever-evolving. It is the goal here to preserve some of the most important AMT instrument knowledge, and to give credit to many of the makers of AMT instruments. The field is expanding as new technologies become ubiquitous and affordable, and this will undoubtedly lead to greater participation by people with disabilities in all aspects of music-making, from recreational playing to the concert stage. It is hoped that soon there will be no delineation between able-bodied and disabled musicians, because music technology will evolve to the point that everyone can participate fully.

Chapter 3: Recommendations

Based on the information acquired about AMTIs in Chapter 2, it is useful to glean a series of recommendations about how to proceed in developing a new musical instrument. These guidelines follow the principle of user-centred design. The rationale for this, as given by Tim Anderson in the development of his eye gaze music system for persons with severe disabilities, is as follows:

> It must be made clear that we are here talking about 'user-centred' design, not 'user-led' or 'user- driven'. There are some criticisms of 'user-led' design, for abdicating responsibility and expecting users to know what they need. Although users can well flag up problems, they may not always know the best solution. "Design is about addressing user needs, not just listening to user demands." (Kitson 2011). In user-centred design then, designers should not just listen to users' ideas, although these are important, but also observe how they work and conceive improvements to help with specific issues which are noted (Anderson 2015).

Preliminary assessment of whether the chosen hardware will respond adequately, and its limitations is required. Discuss all possible alternatives at the outset and determine a course of action. Spend ample time evaluating the hardware available prior to interfacing with the client.

Method for Future Development of Adaptive Musical Instruments

As these steps are traversed, it is important to keep in mind, “To have 'results' is especially important for a disabled student, as the working effort is far more laborious and physically tiring, so achievement and self-satisfaction are important to maintain motivation” (Anderson 2015). How the participant wants the instrument to perform should be discussed with him at every stage, and progress through these steps should be documented. This gives a sense of momentum to the process, and brings clarity to a potentially nebulous development strategy.

1. Evaluate the Technology for Reliability

It is useful to conduct as much testing as possible with the technology to be used with the person with a disability, in order to determine whether the system will meet the needs of the end user. This entails recreating as faithfully as possible the physical setup of the person with a disability. For example, with the Kinect, a fundamental difficulty is that the processing algorithm confuses the arm of the wheelchair with the arm of the participant when they move it. This results in false negatives where the sound is not triggered when the participant lifts his arm in the appropriate way.

In order to mitigate this, it is crucial to try the technology by recreating a chair setup with an appropriately long and bulbous arm. In other cases, such as with a breath pressure sensor, a measurement should be taken of the amount of breath pressure the participant is capable of producing, and the sensor chosen or calibrated appropriately. The key here is to decrease the overall amount of time troubleshooting the instrument once first contact with the participant is made. This also provides the benefit of determining a baseline for reliability of the technology used.

At this point, it is also useful to evaluate a number of input devices to decide which one may be best for the musician. An in-depth exploration of known input devices is in Chapter 2.

2. Introduce the Participant to the Technology

This is a necessary but often difficult second step. In most cases, the musician will have no or very little experience with computer music technology, and the strange hardware involved can often seem overwhelming. In a perfect world this step would be somewhere further down the list—after developing a relationship of trust with the participant as in step 7. But the need to use the technology in all subsequent steps is paramount, so the hurdle of using it must be overcome.

Depending on the participant, they might be familiar with other forms of adaptive technology. They may use an electric wheelchair or a tablet reader, for example. In these cases, it may be easier to introduce the new technology, and they will understand the learning curve in adopting something new.

The most important consideration at this early stage is to simply introduce the technology as part of a human relationship with the participant, and move on to the next step, as opposed to dwelling on it and explaining its features in detail. Let the musician discover how wonderful this new technology is for themselves, instead of explaining it before they've had a chance to experience it.

3. Determine the Participant's Range of Motion

This is a key third step and absolutely must be done as soon as possible to ensure success of the development process. Depending on the technology being used, this can be done using the instrument itself, or with another motion capture device such as the Microsoft Kinect camera. In any case, a baseline of measurements of which body parts the participant can move and how far they can move them is important.

Note that the participant must be observed closely in this step. There is a difference between being able to move in a direction, and feeling comfortable moving in a direction. This takes careful consideration, as many disabled participants will feel strained moving at all, so a threshold for what movement can be done repeatedly, versus what can barely be accomplished one time, must be determined.

The best way to determine which movements are acceptable is to know the participant and their responses. If they are verbal, you may ask them, but they may not necessarily express what they enjoy doing. Normally if there is a lot of strain on the participant's face the movement is too strenuous and should not be included in calculations.

Note that the progression of all these steps is cyclical, so a perfect result at stage two is not needed. It is better to find a few movements the performer can do well and consistently then quickly move on to step three.

4. Make Sound Quickly

Come up with a program that will allow the participant to make sound quickly to keep their interest. Normally the first three steps can be accomplished in one or two meetings. After it is determined that the participant likes the idea of the technology enough to give it a try, and they have some ability to move that can be translated into sound by the technology, it is paramount to get them making a sound a soon as possible.

One option is a simple MIDI scale that increases in pitch as the performer moves up or forward, and decreases in pitch as the performer moves down or back. This gives a quick introduction to the potential of the instrument, and gets the main goal of the exercise, to make music, into the foreground as rapidly as possible.

5. Develop a System for Activating Sounds that is Reproducible for the Performer

After some sound is made and the performer is excited about the potential of the instrument, it's time to actually create the instrument interface. That is, the performer must be able to enact a gesture, and have the system respond in a predictable way.

This is the most difficult step and the one that takes the most time to master. Playing a scale may be satisfying for some performers, but others will want a more nuanced network of possibilities. In considering how to set up the interface, the following should be decided:

How will sound be triggered? How will sound be turned on and off? How much control over the sound will the performer have, and how much of the process will be determined by the instrument? What type of music does the performer want to play? Are they open to new sound experiences?

It may be helpful at this stage to stick to tonal, Western, easily accessible sounds at first until the performer gets a better feel for the instrument.

6. Measure the Performer's Response to the System and Latency

This is a key step because it provides empirical measurements with which to document improvement. This can be as simple as playing a single drum hit and asking the performer to play a note on the instrument as soon as they hear the drum hit. The time of response between when the drum hit is played and when the sound is created on the instrument is the overall system latency (including the performer). This will hopefully decrease with time and practice, or with different scenarios such as a consistent drumbeat.

7. Evolve a Relationship with the Participant that Extends Beyond Music

This may be happening at every step but it's an essential component and must be highlighted. The relationship needed to go into the unknown and develop a new instrument is one of immense trust. Neither the researcher nor the participant knows where the process will end up, so it is important to be unified and take the journey together. Further, there are many frustrations when dealing with new musical interfaces, and these can only be overcome with mutual understanding and respect. This is true in any musical endeavour, but much more so when dealing with disability and developing something new.

8. Make Improvements Incrementally

Allow the participant to try the new prototype at each stage in development. This is a collaborative process, and the more participation from the musician, the better. One must put in enough programming work to make each session fruitful, and to keep the participant encouraged. But too much work in between sessions runs the risk of making assumptions about what the participant wants and can potentially alienate them.

9. Take Careful Notes of the Feedback of the Participant

Be sure to incorporate the participant's feedback at every stage. This relates back to step 8. But simply listening to the participant's wishes is not good enough—they must be systematically documented.

10. Evolve a Set of Exercises the Performer can do to Increase Mastery of the Instrument

This is the final step and should not be undertaken until all the others are substantially completed. However, it is important for the participant to be able to advance with the instrument. The creators of the Soundbeam place this as the forefront of instrument design: the musical device must be able to increase in difficulty as the performer progresses, and mastery of the instrument must be possible.

Time with a participant is extremely valuable, and it is important to maximize the effective use of time with them. This can be achieved by creating a clear plan for each session, with consideration to possible contingencies. The most effective sessions have a number of options prepared by the researcher for activities in the session, in case any one or number of them prove to not work with the participant. For example, two or three forms of the instrument could be brought to a session.

Chapter 4: A Case Study

One computational device that shows a lot of potential for music-making is the Microsoft Kinect camera. This device, which was initially released as version 1 in 2010, has an infrared depth sensor, an RGB camera, and a microphone that can perform speech detection. The Kinect is the first infrared depth sensor that was made available to the public with an SDK for programming. Because it can be triggered without holding, plucking, or otherwise physically touching it, which can be difficult for people with manual dexterity problems, the Kinect is a potential candidate for an adaptive musical instrument. The current release of the hardware is Kinect version 2 for Xbox One, which has an SDK also version 2.0.

A number of papers have evaluated the efficacy of the Kinect for rehabilitation applications and for persons with disabilities (Khoshelham and Elberink 2012, Chang et al. 2011, Zhang 2012, Lange et al. 2011). Some others have evaluated the Kinect for musical applications (Yoo et al. 2011, Odowichuk et al. 2011. Sentürk et al. 2012).

The biggest benefits of the Kinect for adaptive music use are its robust SDK for software development, and its touchless capabilities that do not require a participant to hold or grasp anything in order to trigger or play it. It is a hybrid video and infrared sensor, which computes limb position from its RGB camera and infrared depth sensor. It provides opportunities for large motor movements that can be seen throughout a hall in a performance situation.

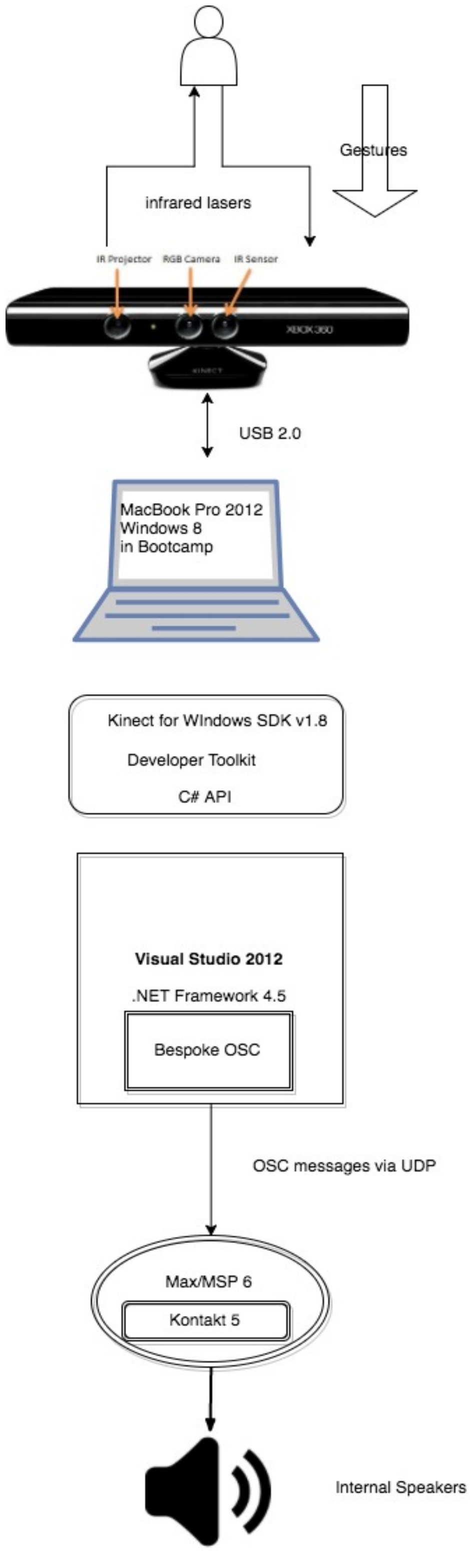

Figure 13: Overall Structure of the Kinect system[25]

[25] Kinect picture: https://www.codeproject.com/Articles/317974/KinectDepthSmoothing

Overall Structure of the System

Several software and hardware components were assembled to produce pleasing sounds with the Kinect.

Hardware

The Microsoft Kinect v1 and v2 were both tested, with respective proprietary connectors to a USB 3.0 port on a MacBook Pro (Model number A1278) running Windows 8 in Bootcamp. This is a virtual machine and may have increased processing time versus using native Windows. A Windows 8 tablet (Acer Aspire P3-171-6442) was purchased for the sole purpose of running the Kinect SDK, but it would not activate either Kinect. Perhaps it had an incompatible chipset. The list of Microsoft-tested computers for use with the Kinect v2 can be found here: https://social.msdn.microsoft.com/Forums/en-US/bb379e8b-4258-40d6-92e4-56dd95d7b0bb/confirmed-list-of-usb-30-pcie-cardslaptopsconfigurations-which-work-for-kinect-v2-during?forum=kinectv2sdk.

Microsoft Kinect SDK v1.8 and Kinect Developer Toolkit

These are the drivers for the Kinect v1 and can be downloaded here: https://www.microsoft.com/en-ca/download/details.aspx?id=40278. This link also includes detailed instructions for installation.

The joint tracking positions were calculated using the C# example provided in the Developer Toolkit Browser which comes with the Kinect SDK version 1.8. The C# API allows calls directly to track individual joints.

Microsoft Kinect SDK v2.0

This is the most recent version of the Kinect SDK, released in 2014, and is compatible with the Kinect v2 sensor. It can be downloaded here: https://developer.microsoft.com/en-us/windows/kinect/develop.

The biggest improvement of the SDK v2 is the addition of Visual Gesture Builder, which allows for the recording and tagging of gestures for the purposes of discrete or continuous gesture creation. A helpful tutorial video is available in 2 parts at https://channel9.msdn.com/Blogs/k4wdev/Custom-Gestures-End-to-End-with-Kinect-and-Visual-Gesture-Builder and https://channel9.msdn.com/Blogs/k4wdev/Custom-Gestures-End-to-End-with-Kinect-and-Visual-Gesture-Builder-part-2-.

Visual Studio 2012

This is the necessary programming environment for the Kinect SDKs v1.8 and 2.0, and can be downloaded here: https://www.visualstudio.com/.

Bespoke OSC

This free software was chosen because it was readily available online, and provided simple yet effective functionality. Its UDP sending capabilities were used to send Open Sound Control messages from the Kinect SDK to Max/MSP. The technical specifications of this package and a download are available at http://www.bespokesoftware.org/wordpress/?page_id=69.

The OSC protocol is a flexible way to send musical commands over a network, similar to MIDI but with the flexibility of allowing floats, ints, strings, and other data types. In this case, only floats (the x, y, and z positions of the left and right hands relative to the body) and strings (the first argument, by convention formatted as /lefthand/) were used. The Bespoke library was used to format the commands as OSC messages, which were sent over UDP.

Max/MSP

This visual programming language version 6 was used for all audio synthesis. It makes receipt and parsing of OSC messages trivial, and its code is capable of being altered without recompiling. This makes it exceedingly useful for working during sessions with the participant.

The patch parses OSC messages received via UDP and routes them based on body part. It then provides for manual calibration of the various relevant participant positions, and calculates zones in which the various gestures will be activated. There is also an “activator” subpatch for each gesture that ensures one chord plays until the next chord is activated.

The patch is calibrated for each participant, and can be recycled for any piece of hardware that provides x, y and z coordinates (see figure 14).

It was challenging to program with Max while keeping the session moving. The music therapist was instrumental in this. The researcher learned to bring multiple versions of the patch to each session, so that multiple options could be tried. One example of this is how the right hand activates the chord or note. A patch where the sound was produced by a measurement of the displacement of the hand from resting position in the y direction, was tried in the same session as a version where the right hand needed to move to a sufficiently high y threshold to trigger the sound. And a third was tried where the participant could displace his right hand either toward his body (in the x direction), away from his body (also in the x direction) or up in the y direction—so essentially anywhere besides resting position. These three were prepared in advance and the one that activated sound most reliably, the “RH anywhere” patch, was ultimately chosen.

It would be essential to have someone in the session who could interface with the client while Max is being programmed, because even if the programming is sped up through practice, it can never be instantaneous. Manipulating Max is a highly specialized skill, and doing so in a collaborative environment with other musicians is especially so.

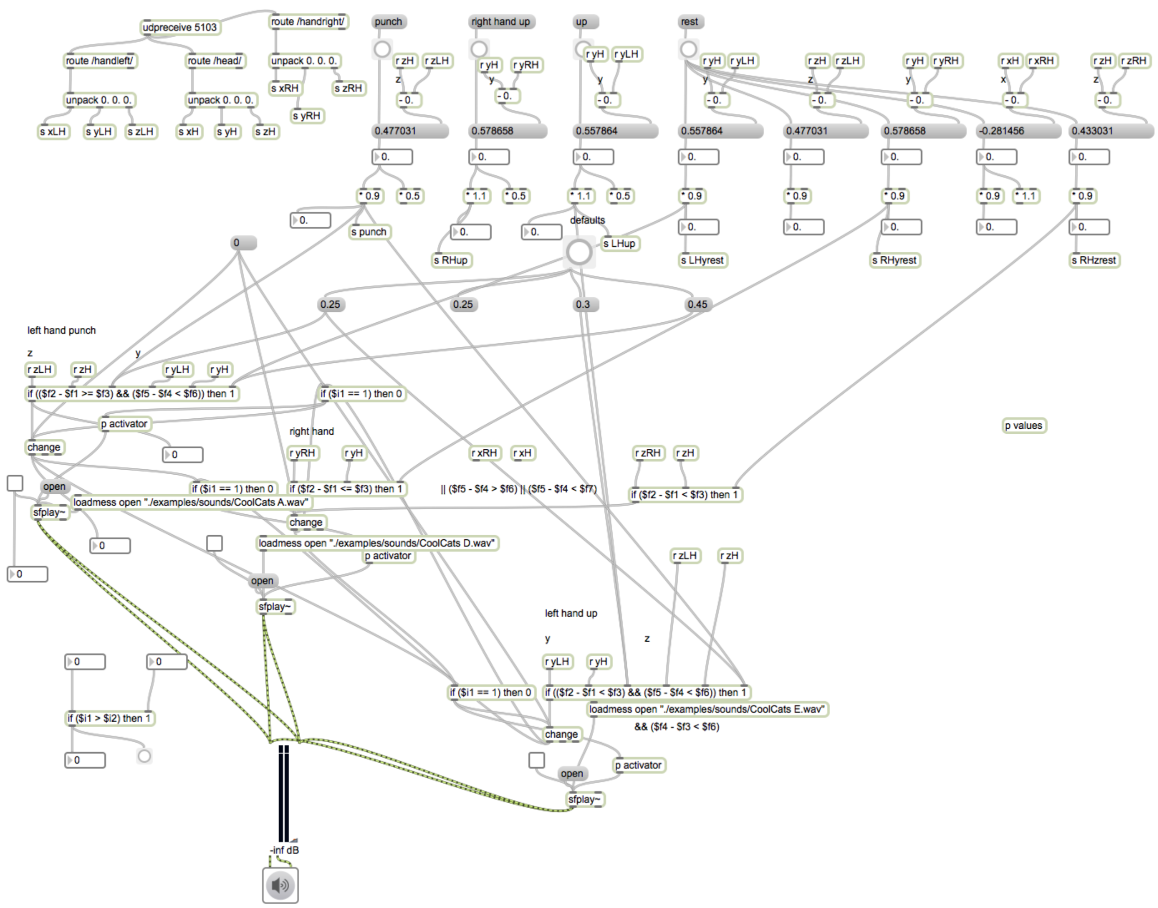

Figure 14: Sound synthesis patch

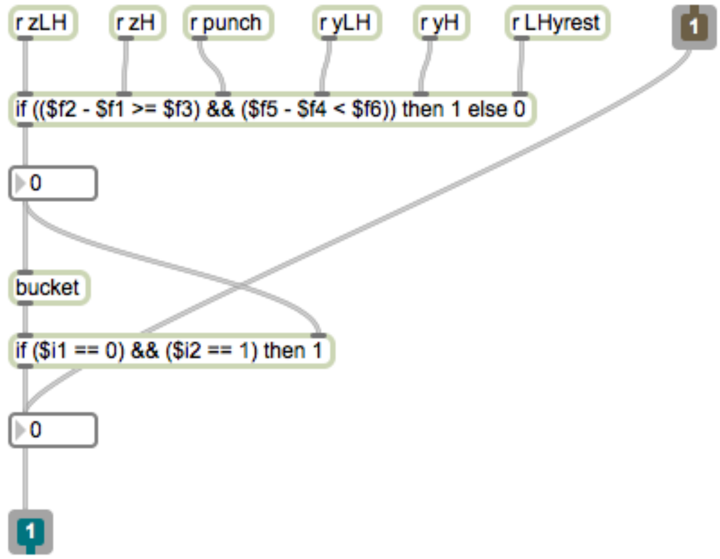

Figure 15: Left Hand Punch gesture activator subpatch

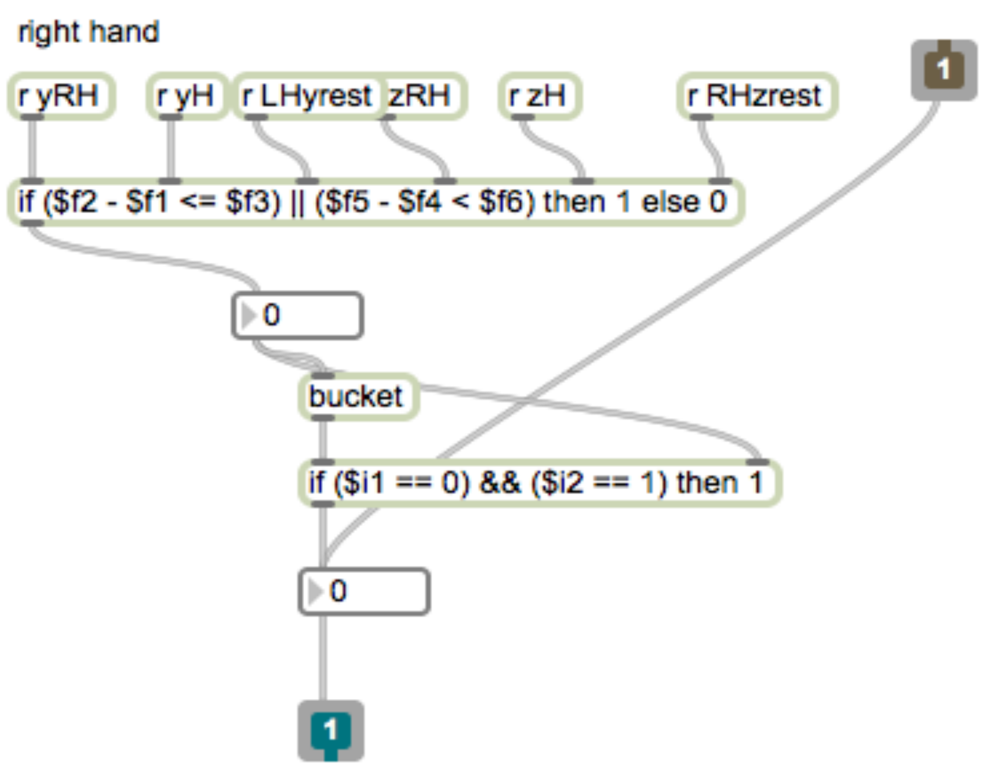

Figure 16: Right Hand Anywhere gesture activator subpatch

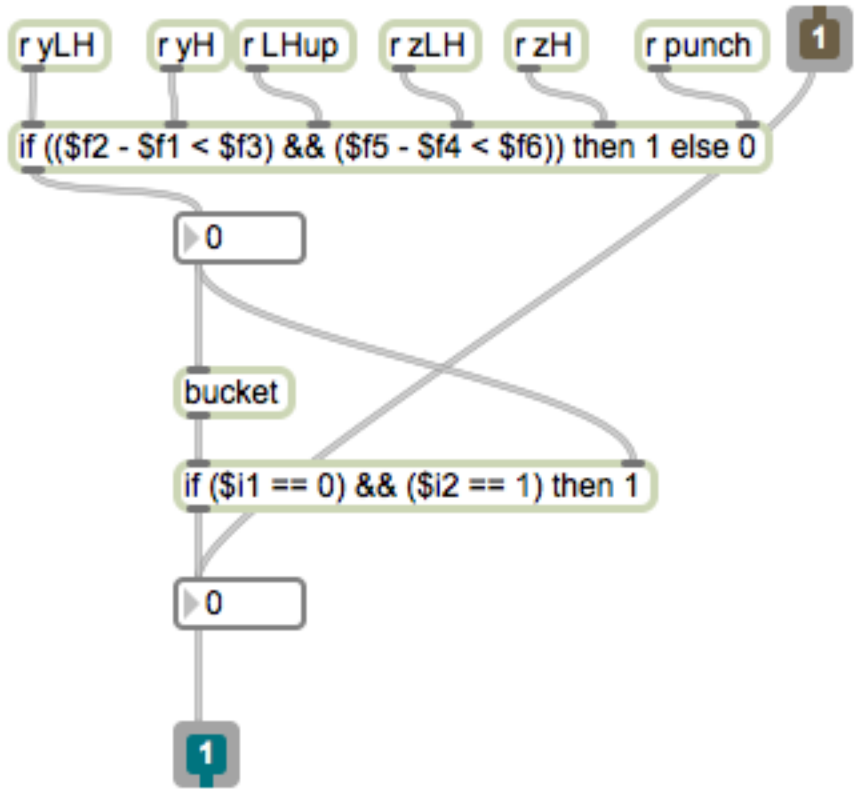

Figure 17: Left Hand Up gesture activator subpatch

Kontakt 5

This software by Native Instruments is available for both Mac and Windows. It was chosen because it interfaces easily with Max via VST, and provides high-quality, acoustically-sampled sounds that are activated through MIDI. Initially, guitar chords from freesound.org were used, but some were out of tune, and more importantly, the guitar decays quickly, and upon trying with the guitar, the participant decided he preferred a sustained sound.

Three sounds from Kontakt were selected: CoolCatsOrgan, MarkIIClassic and ChoirAh. The participant preferred the Cools Cats Organ, so this was sampled using an adapted VST example patch (see Figure), and the audio then split, layered for chords and normalized using Audacity. Because only 5 chords in total were used (I, IV and V in the keys of G, D and A) this was a quick process, but certainly this could be automated in Max if a larger number of notes/chords is used.

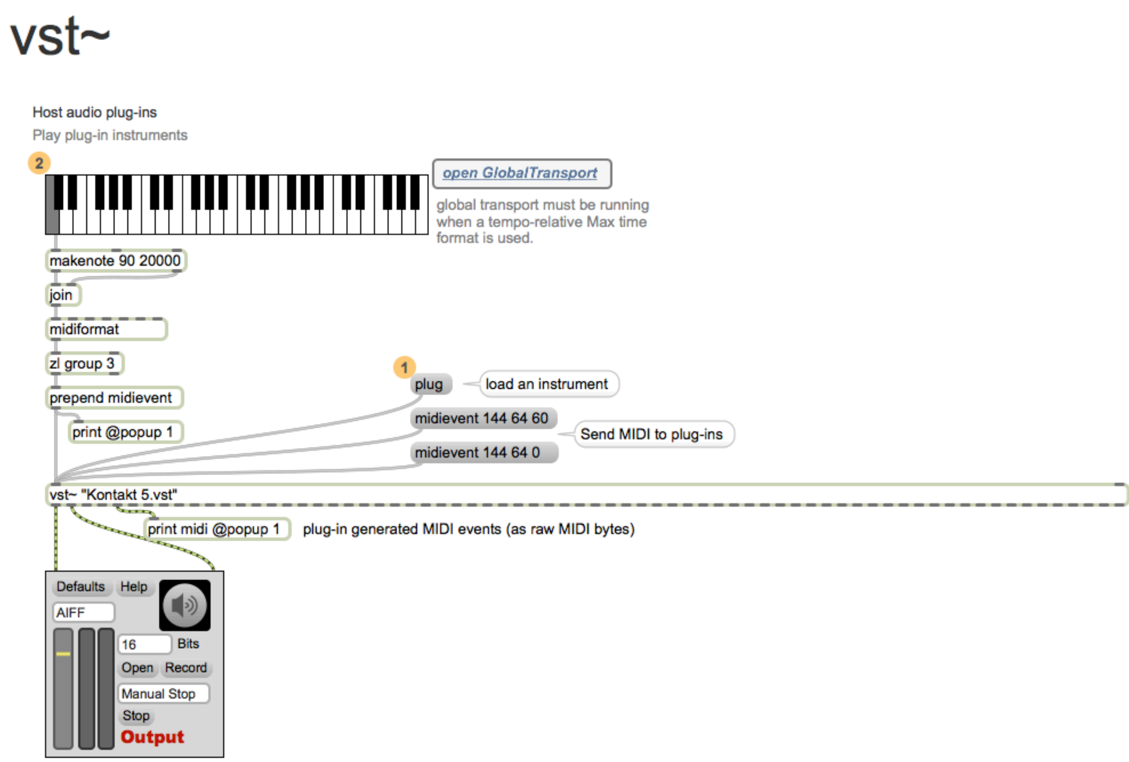

Figure 18: VST Recording Patch

Documenting the Development Process

Qualitative Research Methods

This study followed a case study method with a sample size of one. It followed user-centred design and emancipatory design principles. "A case study is an in-depth analysis of people, events, and relationships, bounded by some unifying factor."[26] A case study relies on multiple data sources including interviews, documents, reports, and observations.[27] An interview with the participant, following questions in the ethics

[26] https://researchrundowns.com/qual/qualitative-research-design/

[27] https://measuringu.com/qual-methods/

documents approved by VIHA, was conducted and recorded, interviews with other makers of adaptive music instruments including the I-Cube-X, the Soundbeam and the Magic Flute were conducted and recorded for the purpose of understanding how those instruments were developed in order to compare this to the development of the Kinect musical instrument.

Twelve sessions of approximately 1.5 hours each were undertaken with the participant at Saanich Peninsula Hospital in Victoria, BC, Canada, between January and August, 2016. In these sessions, the participant's feedback (as well as that of the music therapist, Kirsten Davis-Slamet) was documented and the necessary changes made—if possible during the session, or otherwise in between sessions. These sessions can be divided into four overlapping phases, in which specific requirements were gathered from the participant, the two Kinects were tried, and ongoing development was undertaken. It was important to make the participant as satisfied with the prototype as possible at every stage.

The music therapist was an essential part of the process, as she had a history of working with the client for three years previously. The relationship between music therapy and technology is discussed extensively in Music Technology in Therapeutic and Health Settings, edited by Wendy Magee (Baker et al. 2013). Technology should only be used to enhance the therapeutic experience, and should detract as little as possible from the heart of the session, which is to create space for the participant to express themselves with music.

To ensure that the best therapeutic practices possible were being followed, the Music Therapist was present at all of the technology sessions. Her input into how to improve the system was invaluable at each stage of the process. Also, she was able to keep the client connected to the work through music, even when the technology was not working correctly. This involved playing songs with the participant while the researcher was setting up or getting the equipment ready for use, as well as making changes to the Max patch that parsed the data for sound production.

It was a challenge to be programming the computer, changing the Max patch to accommodate requests such as different chords, while maintaining a working relationship with the participant. It was discovered that it was helpful to envision a few different possible scenarios, such as playing the chords by any displacement versus playing the chords when the hand entered a certain zone, and to have the appropriate Max patches prepared and saved separately ahead of time, to allow for minimal programming time during the session with the participant. But invariably there were requests by the participant that made it necessary to manipulate the patch in real time, which is one of the great advantages of Max when working with an end user who is not necessarily completely familiar with the language.

It was also discovered that the participant tired after a certain amount of playing the Kinect, normally around 30 minutes of continuous activity. Thus, it was important to limit the time of the sessions, and to ensure that the Music Therapist was there for most or all of the duration of the session, in order to maximize music playing time.

Phase 1: Requirements gathering

Modifications to the requirements occurred over the course of the 12 sessions, but initially it was determined that the participant had the following goals for the system:

- To make music that “rocks”

- To be able to play songs the participant likes along with a music therapist, who plays the guitar and sings
- To play songs in the keys of G, D and A, and to play I, IV and V chords in each key
- To turn off the sound using his head
- To use as much movement as possible to maintain range of motion
- To use a sustained sound such as organ that does not decay too quickly
- To play using upper body only, and limited motion in the arms and head
- Maximum control over the instrument

Additionally, it was determined that there were general technical requirements that would apply universally to anyone using the system. These were:

- Clear resting place where no sound is triggered (determined to be where participant's arms were resting on wheelchair arms)
- Lowest latency possible
- To be able to activate the chords in a way that was comfortable for the participant
- To be able to repeat gestures and achieve the same musical result every time
- To be able to hear the sounds well when playing (using the large speaker from the hospital)
- To not have unwanted sounds triggered (such as when moving through different zones to get to other zones)
- Repeatable and simple

Initially the goal was for the participant to perform with the instrument in a final concert with the music therapist, and perhaps other musicians playing traditional instruments, but the participant passed away in August of 2016, before a final concert could be performed.

The approach of using tonal chords was advantageous for numerous reasons:

- the music therapist could readily hear and understand what was being played
- the participant could have immediate and satisfying feedback when he moved appropriately
- an audience who is not necessarily familiar with computer music, such as the one at Saanich Peninsula Hospital, could appreciate what was being played
- it was straightforward to find chord samples, such as on freesound.org, to use
- they have a clear onset and release, which makes it easier to hear if something is not working with the system

In terms of listening to the client, it is key to interpret what they have to say, and not merely take it at face value. For example, in this case the performer wanted to play chords along with the music therapist. What he wanted was to play something harmonious with the chords on the guitar, not necessarily to play distinct onset chords. This presents a challenge, because the performer needs to be steered in a direction that allows for full artistic expression and maximum control of the instrument (according to Challis and Smith), while using technologies with which results are achievable.

The task in this case was to play music. This is extremely broad, and needs to be defined further through an iterative process of exploration including the music therapist and the participant. Music is a highly complex undertaking, and technical prowess of the researcher needs to match the abilities and affordances coming from the participant.

Interview results

An interview was conducted with the participant about his experiences with music and technology as well as his reactions to the Kinect on March 30, 2016, with questions as outlined in the ethics documents in appendix 1. The participant had knowledge of music technology through a recording studio he owned in Vancouver for 3 years, which had “a computer and a keyboard and a bass guitar and acoustic guitar. It had a lot of different instruments.” He expounded on his running of the recording studio: “I would record myself, what do you call, a voice track, and I would use that to put different instruments. So it would always start with the voice.” He was “very experienced” with music technology. He played bass and sang.

When the researcher first showed him the Kinect and explained to him that he could trigger sounds by moving without holding or pushing anything, “My first impression was ‘Wow.’ That’s what I said to myself was wow. Because I always wanted to continue playing music, and now I can do it with just moving an arm. Right? And then it’ll play the instrument.”

His motivation for participating in the study was “that it was music. And that motivated me.” His favourite music was “classic rock” as well as “folk rock. Lots of hard rock. Singing and acoustic guitar. Drums bass and electric guitar.” The types of bands he enjoyed listening to, for approximately 3 hours per week, included “classic bands like the Beatles, the Proclaimers, the Red Hot Chili Peppers.”

He was highly motivated to perform a final concert, which was provided for in the ethics forms, but which was never realized, partly due to the participant’s death before the study was completed, and partly due to the fact that the Kinect was deemed not reliable enough by the researcher for discrete gestures in a concert setting. For him personally, “What do I hope? To learn more about music from you.”

The Kinect was not always reliable, and when asked about technical difficulties, the participant responded, “I totally think that’s okay. I don’t mind at all. I mean it’s a brand new thing, and I realize that. So I’m enjoying myself doing that with ya.” He further added, “I’ve played in lots of bands where things went wrong, so I totally don’t try to get upset about it, I just maintain calm.” When asked directly about his experiences in the midst of an instrument that did not perform perfectly, he maintained, “No concerns. I really enjoy spending time with you and dealing with this. I love to play music!”

When asked what technology meant to him, he responded, “Well there’s lots of times you get frustrated with technology, because you don’t know what the technology is doing, as you know, so that’s the hard part about technology. Trying to figure it out.”

Phase 2: Collection and recording of motion data using the Kinect v2 for tagging

The first step in the process of development, after introducing the participant to the Kinect, was to determine which gestures the participant could perform reliably. He had somewhat limited arm and head motion, and no motion in his torso or legs. So, it was determined that the sounds should be triggered by his arms and head. Note that it was more difficult to get the Kinect v2 to track the body of the participant than the Kinect v1, and it took moving the Kinect v2 over 2 metres away from the participant to get a skeleton, then moving it closer for the tests.

We determined that the participant's left arm was more mobile than his right, and he could punch his left arm in front of his body, perpendicular to the floor, lift his left arm over his head, hold his left hand close to his left shoulder, with his arm bent, and touch his left hand to his nose. Upon further testing, it was found that the left arm tired too quickly when lifted over the head, so the other two gestures were chosen to be used.

The right hand could be lifted to right next to the shoulder, and this was the only motion that could be performed reliably, so this was chosen as a third gesture. The head could be tilted to either side, although this was extremely tiring, and it was determined that this was too potentially harmful to be used as a frequent gesture.

This phase involved recording 3D video and infrared data with the Kinect v2 using the SDK v2.0, then tagging the discrete gestures in the Visual Gesture Builder (VGB). Microsoft suggests recording gestures performed at different speeds, which was possible in a limited way but was undertaken as much as possible. At least 10 instances of each gesture were recorded and tagged. There were no prior directions from Microsoft about what is an adequate amount of instances, so improvements in gesture cataloguing methods may help in establishing a plan for recording.

It seemed at first that this would work better than the Kinect v1 because it was a more advanced system with higher resolution, but upon visual inspection of the tracked skeleton in Kinect Studio (included as part of the Kinect for Windows SDK Browser v2.0), it was determined that the right hand, especially, was not being tracked accurately, with the hand point occasionally resting on the arm of the wheelchair even when the hand was lifted. This may be in part because the end of the right wheelchair arm was bulbous with the controls at that side (see Figure 19). Further, the SDK v2 always tracks the whole skeleton, while the v1.8 has an option to track only the head, shoulders and arms. This could be a potential reason why the v2 did not track as accurately the upper body, although when processing the gestures after in v2 there was a option to include only the coordinates of the upper body in the calculation.

Phase 3: Coding with Kinect v1

Coding the gestures manually by using thresholds or zones in Max/MSP proved to be more reliable, although approximately one in ten times a correct gesture would not trigger the appropriate chord. This is consistent with the articles written about the discontinuation of the Kinect by Microsoft on October 25, 2017.[28] It may be useful to record 3D motion data with the Kinect v1 for analysis with other algorithms, similar to the data recorded with v2 for use in tagging in VGB.

Three gestures were found to be discrete and repeatable by the performer. They were: left hand punch (see Figure 20), left hand up (see Figure 21) and right hand up (see Figure 22). Also, an appropriate resting position was determined to be where both arms were on the wheelchair as shown in Figure 19: Resting posture.

[28] Alternatives to the Kinect now that it is discontinued are discussed at https://pterneas.com/2017/10/25/kinect-dead/

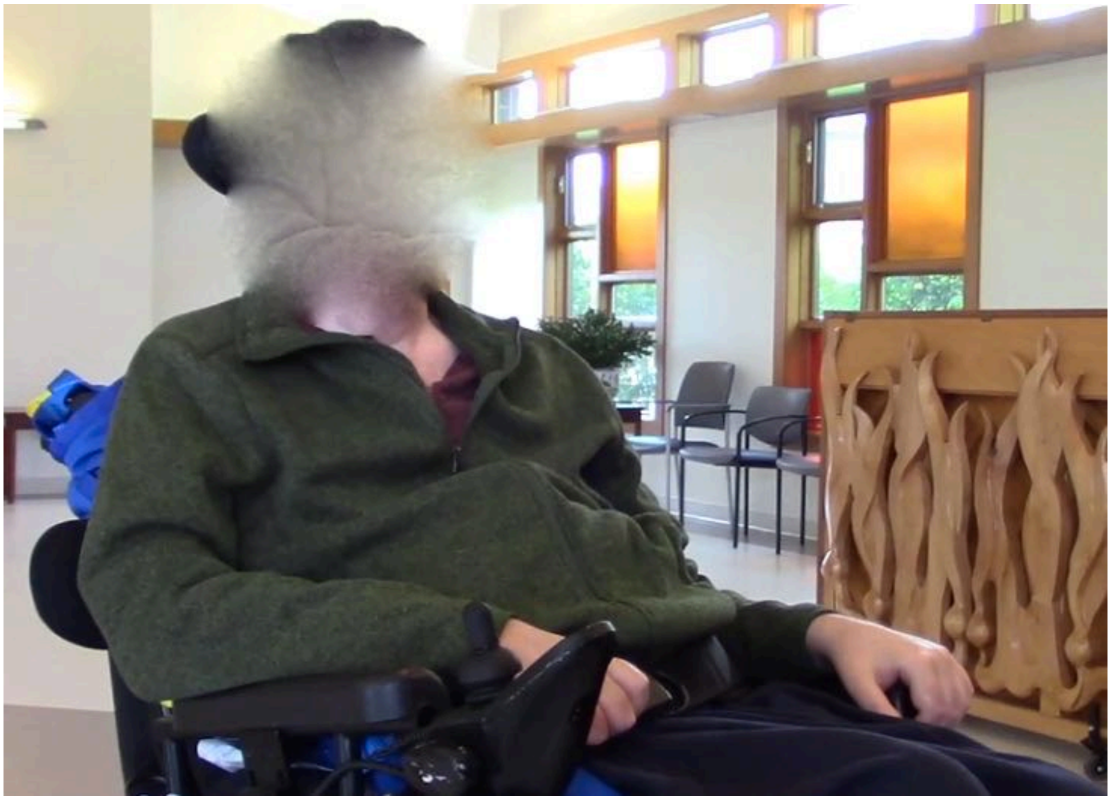

Figure 19: Resting posture

Figure 20: Left hand punch gesture

Figure 21: Left hand up gesture

Figure 22: Right hand up gesture

Phase 4: Ongoing programming and iteration with Kinect v1

This phase involved various discussions and suggestions from all involved, and was based on the user-centred design paradigm of involving the participant in all aspects of development. The possibilities discussed included:

- Using pre-recorded guitar chords versus individual bass notes versus full chords. In the end, full chords were used.
- Using a pre-programmed set of chords so that the participant would only need a single reliable motion to trigger sound such as punching the left hand forward.
- Having the left hand determine the chord to be played through

The dichotomy between control and ease of play is discussed in the literature, and we opted for a rule-based approach, somewhere in the middle of total control and no control. Thus, the participant could choose which chords to play by moving appropriately, but the volume of the chords was not changeable by the participant. We discussed making it so the volume of the chords could be changed by the speed at which the participant crossed the threshold, but decided that would be too much for the participant to control effectively, as he did not always have full control over the speed with which he moved his arm.

Evaluation

The results will be evaluated using UFE. The priority evaluation questions that arise in UFE step 7 are latency, repeatability and training time, and artistic merit questions.

Utilization-Focused Evaluation

This evaluation follows the UFE Checklist of Michael Quinn Patton (2013).The Applications to this Study column is added as comments by the thesis author, and all other text is from the cited website.[30] Note that this is a general evaluation checklist focussing on the end user, not specifically designed for AMT, and was applied after the study was completed. This could be adapted for AMT by using it as a road map for evaluation before, during and after working with the person with a disability, and by fusing it with some of the steps listed in Chapter 3. The Metaevaluation in step 17 of UFE could be especially useful in providing a road map for future studies in AMT.

Going through the steps of UFE after work with the participant was completed was exceedingly illuminating, and this research could have benefitted if more care was taken to adopt a structured approach to the research by following UFE. Step 1, the assessment of readiness, was addressed by completing the ethics application, but some of the other steps, such as Step 12, simulating findings, could have helped to identify and potentially avoid pitfalls during the development process, instead of afterward.

Table 4: U-FE Checklist

Primary Tasks	Applications to this Study
Step 1 Assess and build program and organizational readiness for utilization-focused evaluation.	
Assess the commitment of those commissioning and funding the evaluation to doing useful evaluation.	The commitment of the primary investigator to the evaluation is substantive and ongoing, as evidenced by completion of the entire VIHA ethics process, including the Operational Review, the VIHA HREB online tutorial course, and the HREB application.
Assess the evaluation context: • Review important documents and interview key stakeholders. • Conduct a baseline assessment of past evaluation use. • Find out current perceptions about evaluation.	This was primarily done as part of the ethics forms, found in Appendix 1.

[30] https://wmich.edu/sites/default/files/attachments/u350/2014/UFE_checklist_2013.pdf

When ready to engage, plan a launch workshop that will involve key stakeholders to both assess and build readiness for evaluation. • Work with key stakeholders to launch the evaluation. • Make the launch workshop an opportunity to further assess readiness for evaluation as well as enhance readiness.	A meeting with the Music Therapist was undertaken at the beginning of January 2016 to discuss how best to proceed and who would take notes related to data collection. It was decided that the primary investigator would take most of the notes.
Introduce the standards for evaluation as the framework within which the evaluation will be conducted. (Joint Committee, 2010)	This was done with the participant by reading the consent form to him and asking him to sign it. See Appendix 1, Consent Form.
Based on the initial experience working with key stakeholders, assess what needs to be done next to further enhance readiness, build capacity, and move the evaluation forward.	The plan for executing the study was outlined in Appendix 1, Protocol, specifically Section 3: Study Objectives/Purpose.
Step 2 Assess and enhance evaluator readiness and competence to undertake a utilization-focused evaluation.	
Assess the evaluator's essential competencies: 1. Professional practice knowledge 2. Systematic inquiry skills 3. Situational analysis skills 4. Project management skills 5. Reflective practice competence 6. Interpersonal competence 7. Cultural competence	See Appendix 1, Protocol, Section 2: Background and Rationale for the evaluator's competencies.
Assess the match between the evaluator's commitment and the likely challenges of the situation.	Potential pitfalls and challenges were not adequately examined at the inception of this evaluation, although risks to the participant were noted as part of the Consent Form, Appendix 1.
Assess the match between the evaluator's substantive knowledge and what will be needed in the evaluation.	The ideal development and evaluation paradigm for an adaptive musical instrument is outlined in Chapter 3: Recommendations. This comes as a result of conducting the evaluation and discovering what was missing.
Adapt the evaluation as the process unfolds.	The development/evaluation was adapted based on the technical requirements as well as the participant's feedback.
Assess whether a single evaluator or a team is needed and the combination of competencies that will be needed in a team approach.	A single evaluator, the Thesis author, was employed to comply with the requirements of this thesis. The Music Therapist and the participant provided much useful evaluation data, so this evaluation was collaborative in nature, although one person published the results.
Assure that the evaluators are prepared to have their effectiveness judged by the use of the evaluation by primary intended users.	The evaluator was prepared to be assessed by the participant and Music Therapist, although this could have been made more explicit at the onset of the evaluation.
Step 3 Identify, organize, and engage primary intended users.	
Find and involve primary intended users who are • interested • knowledgeable • open • connected to an important stakeholder constituencies	See Inclusion and Exclusion Criteria in Section 4: Study Population of the Protocol in Appendix 1.

• credible • teachable • committed and available for interaction throughout the evaluation process	
Explain the role of primary intended users throughout the evaluation process.	The participant's role is to provide both direction in what is required for the instrument, as well as feedback about the design and the process.
Organize primary intended users into a working group for decision-making and involvement.	There is only one primary intended user in this study; the instrument is built custom for him.
Involve intended users throughout all steps of the U-FE process.	In accordance with user-centred design principles, the user was involved in all stages of the process.
Monitor ongoing availability, interest, and participation of primary intended users to keep the process energized and anticipate turnover of primary intended users.	This was accomplished by obtaining verbal consent at the beginning of each session.
Orient any new intended users added to the evaluation working group along the way.	Only one user was present throughout the evaluation.
Step 4 Conduct situation analysis with primary intended users	
Examine the program's prior experiences with evaluation and other factors that are important to understand the situation and context. (See Exhibits 4.1, 4.4, and 4.5, Patton, 2012)	The instrument is new and has never been previously evaluated. See SWOT Analysis (immediately following this table) for details on this step.
Identify factors that may support and facilitate use. (Force field analysis, Exhibits 4.2 and 4.3, Patton, 2012)	
Look for possible barriers or resistance to use. (Force field analysis, Exhibits 4.2 & 4.3)	
Determine resources available for evaluation.	
Identify any upcoming decisions, deadlines, or time lines that the evaluation should meet to be useful.	
Assess leadership support for and openness to the evaluation.	
Understand the political context for the evaluation and calculate how political factors may affect use.	
Assess how the evaluator's relationship to the program (internal v. external) might affect use" (See Exhibit 4.6, Patton, 2012))	
Determine the appropriate evaluation team composition to ensure needed expertise, credibility, and cultural competence.	The evaluation team for the purposes of this study is the thesis author.
Attend to both • tasks that must be completed • relationship dynamics that support getting tasks done.	
Analyze risks related to • ideas • implementation • evidence. (See Exhibit 4.8, Patton, 2012)	This point was not completed.
Continue assessing the evaluation knowledge, commitment, and experiences of primary intended users.	

Steps 1 to 4 interim outcomes check and complex systems interconnections review. Overall situation analysis: • How good is the match between the evaluation team's capacity, the organization's readiness and evaluation needs, and the primary intended users' readiness to move forward with the evaluation?	
Step 5 Identify primary intended uses by establishing the evaluation's priority purposes.	
Review alternative purposes with primary intended users. • Consider how evaluation could contribute to program improvement. • Consider how summative evaluation judgments could contribute to making major decisions about the program. • Consider accountability uses • Consider monitoring uses • Consider developmental uses • Consider how evaluation could contribute by generating knowledge.	
Prioritize the evaluation's purpose.	
Step 6 Consider and build in process uses if appropriate.	
Review alternative process uses with primary intended users. • Consider how evaluative thinking might be infused into the organization culture as part of doing the evaluation. • Consider how the way in which the evaluation is conducted and who is involved can enhance shared understandings. • Consider possibilities for using evaluation processes to support and reinforce the program intervention. • Consider potential instrumentation effects and reactivity as process uses to be made explicit and enhanced. • Consider how the evaluation might be conducted in ways that increase skills, knowledge, confidence, self-determination, and a sense of ownership among those involved in the evaluation, included the program's staff and intended beneficiaries. • Consider how evaluation could contribute to program and organizational development.	This step was not completed.
Review concerns, cautions, controversies, costs, and potential positive and negative effects of making process use a priority in the evaluation.	

Examine the relationship and interconnections between potential process uses and findings use (Step 5).	
Prioritize any intended process uses of the evaluation and plan for their incorporation into the design and conduct of the evaluation.	
Step 7 Focus priority evaluation questions.	
Apply criteria for good utilization-focused evaluation questions: • Questions can be answered sufficiently well to inform understanding and support action. • Questions can be answered in a timely manner and at reasonable cost. • Data can be brought to bear on the questions, that is, they aren't primarily philosophical, religious, or moral questions. • The answer is not predetermined by the phrasing or framing of the question. • The primary intended users want the question answered; they have identified it as important and can say why. • The answer is actionable; intended users can indicate how they would use the answer to the question for future decision-making and action.	The priority evaluation questions for this study are latency, repeatability and training time, and artistic merit. These were determined in consultation with VIHA ethics, and with my supervisors. See the appropriate sections below in the Evaluation section for more details and answers to these questions.
Listen carefully to the priority concerns of primary intended users to help them identify important questions.	The end user was consulted at every stage of the development process, and his requirements and concerns informed development.
Connect priority questions to the intended purpose and uses of the evaluation to assure that they match.	The purpose of the evaluation is to determine the effectiveness of the Kinect as an instrument for a person with a disability. The questions devised support this purpose.
Offer a menu of focus options (see Menu 7.1, Patton, 2012, pp. 182-187).	
Step 8 Check that fundamental areas for evaluation inquiry are being adequately addressed.	
Consider options for implementation evaluation that address the question, "What happens in the program?" • Effort and input evaluation • Process evaluation • Component evaluation • Treatment specification and intervention • dosage	This point was not completed as part of the evaluation.
Consider options for outcomes evaluation to answer these questions: • What results from the program? • How are participants changed, if at all, as a result of program participation? • To what extent are the program's goals achieved? • What unanticipated outcomes occur?	See interview results under Chapter 4, Documenting the Development Process, Qualitative Research Methods.

• To what extent are participants' needs met by the program?	
Determine the importance and relative priority of the attribution issue: To what extent can outcomes be attributed to the program intervention?	This point was not completed.
Step 9 Determine what intervention model or theory of change is being evaluated.	
Determine if logic modeling or theory of change work will provide an important and useful framework for the evaluation.	A logic model was not used for this evaluation.[31]
Consider options for conceptualizing a program or intervention—or different elements of a program or change initiative: • a linear logic model • a map of systems relationships • a complex adaptive system	Not applicable.
Appropriately match the evaluation design and measurement approach to how the program or intervention is conceptualized, understanding that linear logic models, systems maps, and complex nonlinear conceptualizations of interventions have both conceptual and methodological implications.	Not applicable.
Step 10 Negotiate appropriate methods to generate credible findings and support intended use by intended users.	
Select methods to answer users' priority questions so that the results obtained will be credible to primary intended users.	Questions about the process were solicited at the Consent Form stage, but while feedback about the instrument was solicited and encouraged throughout development, questions from the user per se were not.
Assure that the proposed methods and measurements are • Appropriate • Practical • Cost-effective • Ethical	The appropriateness, practicality and ethicality of the methods used to collect data were verified by completing the ethics process with VIHA and UVic. The cost-effectiveness was dependent both on the researcher and the Operational Review assessment as part of the ethics review process.
Assure that the results obtained from the chosen methods will be able to be used as intended.	See Appendix 1, Protocol, Section 8: Analysis.
Negotiate trade-offs between design and methods ideals and what can actually be implemented given inevitable constraints of resources and time.	This point is very important and was not adequately considered by the researcher. A more rigid, detailed schedule with specific goals for each session, while malleable, should have been established.
Identify and attend to threats to data quality, credibility, and utility.	See SWOT Analysis directly following this table.
Adapt methods in response to changing conditions as the evaluation unfolds, dealing with the emergent dynamics of actual fieldwork.	
Step 11 Make sure intended users understand potential controversies about methods and their implications.	

[31] https://ctb.ku.edu/en/table-of-contents/overview/models-for-community-health-and-development/logic-model-development/main

Select methods appropriate to the questions being asked.	See Appendix 1, Protocol, Section 9: Data Collection and Data Management.
Discuss with intended users relevant methods debates that affect the methods choices in a particular evaluation, if appropriate and helpful to support decision making about methods. Issues to consider include: • Quantitative versus Qualitative data • The Gold Standard Debate (experimental versus non-experimental designs) • Randomization versus naturally occurring and purpose sampling approaches • Internal versus external validity as a design priority • Generalizations versus context-sensitive extrapolations • Pragmatism versus methodological purity	These were not discussed with the intended user (participant).
Step 12 Simulate use of findings.	
Fabricate findings based on the proposed design and measures of implementation and outcomes.	This step was not completed.
Guide primary intended users in interpreting the potential (fabricated) findings.	Not applicable.
Interpret the simulation experience to determine if any design changes, revisions, or additions to the data collection would likely increase utility.	Not applicable.
As a final step before data collection, have primary intended users make an explicit decision to proceed with the evaluation given likely costs and expected uses.	Not applicable.
Step 13 Gather data with ongoing attention to use.	
Effectively manage data collection to ensure data quality and evaluation credibility.	See Appendix 1, Protocol, Section 9: Data Collection and Management.
Effectively implement any agreed-on participatory approaches to data collection that build capacity and support process uses.	
Keep primary intended users informed about how things are going in data collection.	The participant should have been made more aware of how the process of data collection was going. Technical difficulties with the instrument meant that the focus was often on programming as opposed to direct evaluation. See Weaknesses Section of SWOT analysis.
Offer appropriate feedback to those providing data, for example: • Let interviewees know that their responses are helpful. • Provide program staff and leadership with a debrief of site visits and evaluation observations.	The participant was made aware of the usefulness of their feedback and expertise throughout the process. A debrief email with the Music Therapist at the conclusion of each session would have been a useful tool, but was not undertaken.
Report emergent and interim findings to primary intended users to keep them interested and engaged: • Avoid surprises through early alerts about results.	The progress of the study was apparent by the technical progress of the instrument, as it corresponded with the needs of the participant.

• Match the nature and frequency of interim reports to the purpose, timeline of the evaluation and duration of data collection.	
Watch for and deal with turnover in primary intended users: • Bring replacement key stakeholders up-to-date quickly. • Connect new intended users with those involved all along the way. • Facilitate understanding, engagement and buy-in among any new primary intended users.	One great advantage of this study was that there was no turnover of the primary intended user.
Step 14 Organize and present the data for use by primary intended users.	
Organize data to be understandable and relevant to primary intended users: • Organize the findings to answer priority questions. • Keep presentations simple and understandable. • Provide balance. • Be clear about definitions. • Make comparisons carefully and appropriately. • Decide what is significant. • Be sure that major claims are supported by rigorous evidence. • Distinguish facts from opinion.	See results of the primary evaluation questions in the corresponding sections under Evaluation.
Actively involve users in interpreting findings: • Triangulate evaluation findings with research findings. • Consider and compare alternative interpretations and explanations.	This was not possible because the participant passed away before his feedback on the evaluation could be sought.
Actively involve users in making evaluative judgments: • Be clear about the values that undergird judgments.	Clearer questions about the values of the participant could have been included in the interview portion, as well as deductions about his values and judgements based on observation.
Actively involve users in generating recommendations, if appropriate and expected: • Distinguish different kinds of recommendations. • Discuss the costs, benefits, and challenges of implementing recommendations. • Focus on actions within the control of intended users and those they can influence.	See (in this Chapter) Documenting the Development Process, Phase 1: Requirements Gathering.
Examine the findings and their implications from various perspectives.	
Step 15 Prepare an evaluation report to facilitate use and disseminate significant findings to expand influence.	
Determine what kinds of reporting formats, styles, and venues are appropriate: • Consider both formal written reports and less formal oral reports.	The evaluation report for this study consists of the Evaluation section, as well as Recommendations in Chapter 3.

• Adapt different report approaches for different audiences and uses. • Focus the report on answering priority questions and providing the evidence for those answers. • Be prepared to help users maintain balance and deal with "negative" findings.	
Deliver reports in time to affect important decisions.	This evaluation was completed after the Kinect was discontinued and is no longer commercially available, although it is relevant to the development of future adaptive music technology instruments.
Decide if the findings merit wider dissemination: • Consider both formal and informal pathways for dissemination. • Be alert to unanticipated pathways of influence that emerge as use and dissemination processes unfold.	See Appendix 1, Protocol, Section 10: Publication of results.
Step 16 Follow up with primary intended users to facilitate and enhance use.	
Plan for follow-up. Develop a follow-up plan with primary intended users.	This step was not completed.
Budget for follow-up.	
Proactively pursue utilization: • Adapt findings for different audiences. • Keep findings in front of those who can use them. • Watch for emergent opportunities to reinforce the relevance of findings. • Deal with resistance. • Watch for and guard against misuse.	
Look for opportunities to add to the evaluation. • Opportunities may arise to add data to answer emergent or previously unanswered questions. • Longer term follow-up of program participants may become more valued and important to see if short-term outcomes are maintained over time. • Designing an evaluation for the next stage of the program may emerge as an opportunity.	
Step 17 Metaevaluation of use: Be accountable, learn, and improve.	
Determine the metaevaluator and the primary intended users for the metaevaluation.	This step was not completed.
Determine the primary purpose and uses of the metaevaluation.	
Determine the primary standards and criteria to be applied in the metaevaluation: • Joint Committee Standards (www.jcsee.org) • International standards for development evaluation (www.oecd.org/dac/ evaluationofdevelopmentprogrammes/)	

Budget time and resources for the metaevaluation.	
Follow the steps for conducting a utilization-focused evaluation in conducting the utilization-focused metaevaluation.	
Engage in systematic reflective practice about the evaluation, its processes and uses, with primary intended users.	
Engage in personal reflective practice to support ongoing professional development: • Reflect on what went well, and not so well, throughout the evaluation. • Assess your essential competencies and skills as an evaluator. • Use what you learn to improve your practice and increase use	

SWOT Analysis

Strengths

This thesis focussed on the development and evaluation cycle with the Kinect camera with one participant, which provided a specific use case. It provides an in-depth analysis of how this camera can be used for music-making with persons with a disability. Its greatest strength is that it is unique.

Weaknesses

This study had a sample size of one. Two additional participants were vetted, but they were not selected for the study because they had movement limited so that the Kinect could not render a skeleton when they were sitting in a wheelchair. I may have been advantageous to recruit at least one additional participant for the purpose of comparing the two development processes using the same hardware, but it was exceedingly difficult to find another participant that met the inclusion and exclusion criteria included in the ethics protocol in Appendix 1.

Further, since a preliminary study of the Kinect and its strengths and weaknesses was not undertaken before the participant was recruited (see Recommendations in

Chapter 3), there was no guarantee that the hardware would perform as promised by Microsoft.[32] It was found to be not possible to reliably activate chords, so with the lack of dependability, it was perhaps not wise to involve a second participant, given the potential frustration with the system.

Another weakness is that a more detailed account of the time usage in each session with the participant was not kept. It would be valuable to know exactly how much time was spent troubleshooting and programming, versus how much time was spent by the participant playing the instrument with the music therapist, to get a sense of the pace and effectiveness of each session, but only the feedback and feelings of the participant were documented.

Questions from the participant were not encouraged and documented actively enough. In the development of these types of instruments, questions from the participant could prove a useful tool to solicit more feedback.

The sound quality of the videos taken of the participant playing the instrument with the music therapist is not as good as it could have been. It was difficult to hear the Kinect instrument because the output was from the Mac's internal speakers (although the sound was normalized to produce maximum sound output). A solution could have been to bring an external speaker to the hospital to Bluetooth to the computer to increase overall volume, because it is important for both the players and the audience to hear clearly what is being played.

The attempt was made to put the participant at the centre of the development process at every step by including him as much as possible through conducting many

[32] https://msdn.microsoft.com/en-us/library/hh855347.aspx

sessions. His feedback was documented after each session, and this was used to inform the next session. However, a more structured way of approaching the development process is required, including documenting any changes in the participant's mood or movement abilities over the course of a session and between sessions, and iteratively gathering requirements for the purposes of programming the instrument. The usefulness of this type of research needs to be proven more methodically.

A focus in this study was an end concert in which the performer would demonstrate the instrument. However, the concert never happened, and the process of developing the instrument was found to be intensely valuable and exceedingly complex in itself.

Opportunities

This thesis also illustrates various pitfalls of this type of development. See Chapter 3 for recommendations for how to avoid these pitfalls.

Threats

There are numerous threats that fall into the domains of data quality, credibility and utility as outlined in UFE.

Latency

The latency of the overall system of the Xbox Kinect version 1, plugged into a computer via USB 2.0, including internal processing, from movement onset to sound production, is roughly 120 milliseconds according to Odowichuk et al (2011). In order to measure the overall latency of a system with a player with a physical disability, the Kinect SDK version 1.8 was used.

The test involved playing a drum sound by clicking a mouse on a 'bang' message in Max/MSP, which prompted the player to ‘strum’ a guitar chord by lifting his left hand as quickly as possible afterward to trigger a guitar chord sound in Max/MSP. A threshold object determined if the position of the left hand was more than a certain distance away from its location in the previous frame, and if the threshold was met, the guitar strum sound played.

The goal of the test was to teach a person with a physical disability how to play a touchless instrument, which is not intuitive, and to measure the overall latency of reaction time and the system. With minimal training and practice, the overall latency of the system for a person a mobility disability for a test of 10 trials, was on average 1365ms. The lowest latency was 868ms, while the highest was 1770ms (see Figure 23). In contrast, for a person with no physical disability, the average latency for 10 samples was 857ms, with times as low as 530ms and as high as 1425ms. So the difference in reaction time between the able-bodied person and the person with a mobility disability was on average about 330ms.

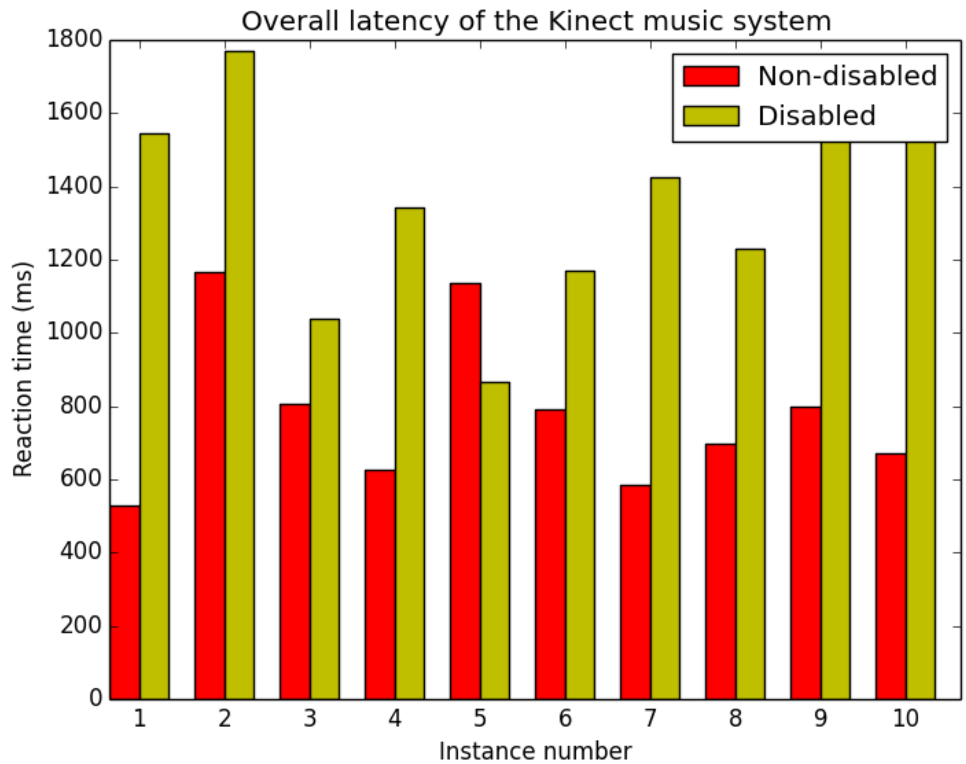

Figure 23: Latency times for the Kinect with disabled and non-disabled users

An interesting development occurred when the triggering drum sound was repeated at two second intervals. This gave the able-player the opportunity to compensate for the system latency, in order to play the guitar sound at a closer interval to the drum sound. In this case, the deviation between the drum sound and the guitar strum was much lower. Because the player could anticipate the onset of the drum, some of the guitar samples occurred slightly before the drum, so the interval ranges from approximately -200 to +400ms. However, these are outliers, and the average of the absolute value of the deviation between drum and guitar was under 150ms, with times as low as 30ms. This shows that with training the system could be played fairly precisely.

More improvement could be possible with increased practice and increased exposure to the instrument. As with any musical instrument, there is a steep learning curve, which can only be overcome with increased practice opportunities.

Certainly the current amount of latency is much too high for concert performance, and is the product of the system latency (120ms) plus the hearing latency (40ms) plus the arm movement latency plus any cognitive challenges the performer may have, but anecdotally this system has proven enjoyable for the participant in a Music Therapy situation.

Repeatability and Training Time

In order to measure repeatability and training time, a new variation of the system was developed. Instead of the sound being triggered by the left hand “strumming” upward, the Max/MSP patch was changed so that the sound was triggered when either hand crossed a threshold. The Kinect SDK returns x-, y- and z-coordinates for each joint of the body, with the x-coordinate representing the distance out from the body, parallel to the floor and perpendicular to the Kinect, the y-coordinate representing the vertical distance, parallel to the body and perpendicular to the Kinect, and the z-coordinate parallel to the infrared streaming of the Kinect, so that moving the hand forward facing the Kinect decreases the z parameter. Each of these coordinate planes is perpendicular to each other.

The left hand played the E minor chord when it was held out sideways perpendicular to the body, after crossing a pre-determined threshold in the x-dimension, while the right hand played an A major chord when held out from the body in the x-dimension, and a B chord when held up in the y-dimension.

The biggest difficulty was teaching the participant to move his hand directly up to activate the B chord, without moving it out to activate the A chord unwittingly. Also, sometimes the A chord would not sound right away when the participant extended his arm. This could be due to a limitation of the hardware and software, such as that the arm of the participant's wheelchair was occasionally being detected instead of his own arm. More testing, including using the visualization of the joint tracking available in the Kinect SDK, needs to be done to isolate the cause of this deficiency.

A test was developed where the participant was asked to play common chord progressions using the chords of E minor, A and B. There three were chosen because many common songs can be played using them. The participant was asked to play various progressions in his own time, without skipping any chords or otherwise making any errors. In all cases of these basic progressions, the participant was able to play them on the first or second try, after a practice and training time of 30 minutes. Table 5 shows the progressions used and the number of attempts required for the disabled participant to play them successfully.

Table 5: Disabled User

Number in series	Chord progression	No. of attempts
1	EmABEm	2
2	ABEm	1
3	BAEm	2
4	EmAEm	1
5	EmBEm	1

Because the disabled participant was already familiar with the Kinect, as the author had already spent 5 sessions with him troubleshooting and developing a system, and the participant already had extensive musical training, it was deemed necessary to recruit a second participant to try the test. The second participant, who had no formal musical training, was given basic instructions about where in space each chord was located, but these instructions and the training time were limited to 5 minutes total. The number of repetitions to achieve a successful progression as well as the time taken to achieve each chord progression were measured. Also, more elaborate chord progressions were used. Table 6 shows the results of the more detailed experiment performed on the non-disabled user.

Table 6: Non-disabled user

Number in order	Progression	Number of attempts	Time to success (minutes)
1	EmABEm	12	8:06
2	ABA	2	0:47
3	BAEm	2	0:45
4	EmAEm	3	1:30
5	EmBEm	3	0:35
6	EmAEmABEm	5	2:23
7	EmABEmBEm	1	0:44

Artistic Merit

In the Vancouver Island Health Authority (VIHA) ethics application which was approved, several questions to evaluate the artistic merit of the instrument were included. The relevant questions (given that there was not a final performance with an audience) are listed here with answers:

What degree of control does the participant have over the instrument? The participant had mastery of the three gestures that would activate chords in the instrument, and the correct chord was activated when the participant performed the correct gesture. No sound was triggered in the final iteration of the instrument when the participant was at rest. However, the correct gesture sometimes produced no sound at all. This occurred for approximately 1 in 10 chords, which is unacceptable in an artistic context.

Are they able to repeat the same action and have the same sound come out every time? No, the participant could, for example, punch his left hand toward the Kinect, and even though the gesture was performed correctly, the corresponding chord would not activate.

Do sounds come out when the participant makes no action? No, in the final iteration there was never a sound produced when the participant was at rest. T

Did the performance take a number of hours to rehearse and put together? Yes, twelve sessions of approximately 1.5 hours each were conducted with the participant and the music therapist. This amounts to 18 hours of direct contact with the instrument by the participant, which was extensive enough to determine that the instrument was not entirely reliable. This does not count the extensive experience and practice time of the music therapist, who played with the participant, and the hours spent by the researcher troubleshooting the instrument.

Is there an appropriate balance of silence and sound, and does this balance change over the course of the performance? The participant wanted a chord to be held until the next chord was played, even if this hand was no longer in the zone of the gesture. This meant that the only silence while playing the instrument was at the beginning and end of a song. The use of a head gesture was tested to stop the sound, primarily for the end of the performance but also for emphasis throughout a song, but it could not be reliably implemented by the time of the participant's death.

Being able to stop a sound is just as important as being able to start it, and while one chord did stop when the next was initiated with the appropriate gesture, there was no way to initiate silence during or at the end of a song by the participant.

Are all of the performers and the participant fully engaged the whole time? It was clear through observation of the participant that performing the three gestures repeatedly was taxing, especially over the course of a whole song, and most especially when the correct gesture did not always produce the expected result. This brought the participant out of the flow of the performance, as evidenced by him glancing at the researcher when a chord did not activate.

Is there a variety of articulations possible with the instrument? The possibility of this was discussed with the participant and music therapist. Due to the latency of chord onset, it was determined that the chords should be held continuously until the next chord was played.

If the participant moves more quickly, does the sound differ compared to if she moves slowly? The velocity of the gesture, could have been linked to the volume of the chord, like a piano, so that a faster performance of the gesture would trigger a louder sound, but this was determined to be a poor choice because the participant might inadvertently trigger a loud or quiet chord if the speed of the gesture was not entirely in his control. So it was a design choice to have only one volume of sound. With the Kinect V2, the gestures were recorded and tagged at various speeds, to teach the system that velocity should be ignored. With the Kinect V1, only the threshold of the zones of each gesture was used to trigger the sound, and no other parameters were gathered from the participant.

Was the participant able to develop fluency with the instrument? As demonstrated by the training time, the participant was able to understand how to trigger sound quickly. He had moments of enjoying playing the chords. It took a considerable amount of trial and error to settle on three gestures he could play reliably without fatiguing before the end of the song. But by the end of our sessions together the participant had proficiency at the three gestures, and this remained relatively consistent over the final session.

Does the performer seem to move effortlessly as they play the instrument? Any movement was difficult for the participant, and playing the instrument was not effortless. The payoff was not there when he performed a gesture and the chord did not activate. Further, we planned to amplify the sound from the laptop with a speaker from the hospital, but were not able to accomplish this before the participant died. So, it was difficult to hear what he was playing while he performed songs with the music therapist. This detail made it again frustrating for the participant.

In summary, the instrument was not able to perform even a basic artistic function of playing the correct chords at the correct time. Please see Chapter 3 for a method of development that would avoid the pitfall of not having basic functionality even when much time and effort is put into the development of an instrument. The Kinect for persons with disabilities is not reliable enough to provide artistic enjoyment and expression when used for discrete gestures, and the technology should have been evaluated before the person with a disability was involved, as performance of gestures by said person is inherently more taxing than for an able-bodied person.

Chapter 5: Conclusions and Future Work

The field of AMT has developed alongside computer music. Especially since the advent of MIDI, which allowed for simple communication between hardware and software, the field has grown substantially. It is hoped that with a set of parameters with which to approach developing an instrument, more researchers will take on this rewarding task.

In the words of David Whalen, the maker of the Jamboxx and the Magic Flute, "If you have a disability of any kind, the point is that with the resources we have today, there might be a solution for you. New technology and computers are opening many doors for us."

There are a number of computer-based devices available to aid persons with disabilities in playing music. One of the most promising for future developments is the Microsoft Kinect. In its current form, the latency is very large and may be mitigated by keeping a steady beat and adapting accordingly. This thesis provides a baseline for future improvements by measuring the latency of the current Kinect system, as well as training time and repeatability. It is hoped that with this information, future improvements can be made and documented.

Development of new musical instruments is an extremely complex task in the field of Human-Computer Interaction. There are many factors that make an instrument effective, and the physical interface with the performer is of primary importance. Thus, it is natural that the techniques employed in the development of these instruments could be used to develop other useful interfaces for the disabled. One recent example of this is a team that used the Jamboxx, an adaptive musical instrument, as a controller for a robot that allows a disabled person more control over their surroundings. Many of the systems described in Chapter 2 also include visual cues, and this could be incorporated in the development of future instruments. A comprehensive system for classification of adaptive music technology instruments could be developed.

The Kinect, while having many advantages for persons with disabilities, may not be the best interface in every situation. It does have an easy-to-use SDK that is still available for download as of the writing of this thesis, and due to its portability it could continue to be used, especially in spatial artistic installations. There are a number of newer touchless depth sensors and body trackers that may replace the Kinect. The author predicts the Kinect will be quickly outpaced by newer technologies, making it essentially obsolete for artistic purposes.

Thus other input devices may be explored such as breath pressure sensors, eye trackers, and even handheld devices as indicated by the needs of the participant. In performances with the Kinect, including at ICMC 2015, it is normally used as a continuous instrument.

The Kinect may be best for continuous gestures, monitoring the progress of a movement over time. This should be harnessed when designing a musical interface with the technology.

As written by Matossian and Gehlhaar (2015), “We believe that working under constraints and requirements such as the ones that are imposed by disability will lead to new paradigms. The history of inventions has shown several times that ideas developed for disabled people became essential tools in the everyday life of the able bodied. In the 21st Century we are witnessing significant progress in the development of new interfaces for musical expression. Perhaps working with people with disabilities can catalyse the emergence of new ideas for musicians and artists in general.”

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Appendices

Appendix 1: Ethics Documents

Human Research Ethics Board Application

Research and Capacity Building
Memorial Pavilion – Kenning Wing – Royal Jubilee Hospital – 1952 Bay Street
Victoria, BC V8R 1J8

Health Research Ethics Board (HREB)
Application Form

There are two streams of review and approval for research at VIHA that flow concurrently. BOTH must be satisfied before the research can commence:

1. **Research Ethics Review and Approval:** All studies must be reviewed and approved by the Health Research Ethics Board. This is a completely separate process from Operational Review.
2. **Operational Review and Approval:** All studies must have approval to conduct research at Island Health from the Director of each impacted department, facility, service or support at Island Health. This is a completely separate process from Research Ethics review. Included in operational review and approval may be the requirement for contracts and other agreements, and assessment by the department of Information Stewardship, Access & Privacy.

Once both approvals are obtained, a final Institutional Approval Certificate (which will include the date of Research Ethics approval) will be provided by the Research and Capacity Building Department.

The Operational Review application form is available online at: http://www.viha.ca/rnd/operational_review
To find out more about Operational Review and approval at Island Health, see the FAQ online at:
http://www.viha.ca/rnd/operational_review

This application must be accompanied by a protocol or study proposal. If the answer to a question in the application is in the protocol, please just insert "please refer to protocol page ____". If there is a discrepancy between the information in the application and protocol, the application will be used for research ethics purposes.
Please click on HREB PROTOCOL TEMPLATE to access.
Incomplete submissions will not be accepted.
The HREB application form is designed to be filled out electronically.
Hand written applications will not be accepted.

How to complete and submit your proposal for review by the REB:

1. Please select FILE and SAVE AS a name that reflects the content: e.g. HREB Application_PI Name_version no._date.docx
2. Use tab keys to move from one *text box* to another. Use the mouse to click boxes, e.g. ☒Yes ☐ No
3. Please ensure the form is FULLY complete. Blanks result in delays as we will need to confirm if any information is missing, or if it was left blank because it was 'not applicable'.
4. All signatures may be attached electronically. File types that are accepted include .jpg, .jpeg, .wmf, .png, .bmp, and .tif. If you have any questions, please contact our office. A typewritten name is not considered a signature. If an original signature is used, please submit a scanned version of the original signature in the appropriate section and attach with the application.
5. Please submit the application by email to researchethics@viha.ca with all the required documents. Paper copies are no longer required. Documents to include::
    a. Signed (electronic signature is acceptable) and completed HREB Submission form
    b. Study protocol
    c. Data collection instruments, including questionnaires, surveys and interview scripts
    d. Letters of support from collaborating organizations, if applicable
    e. All informed consent forms, assent forms
    f. All recruitment materials (flyers, posters, introductory letters, telephone scripts, email scripts)
    g. Any other participant handouts
    h. The Primary Investigator's Curriculum Vitae and certificate of TCPS2 completion (if not already on file)
    i. Certificates/letters of approval from other REBs (if available/applicable)
    j. Scientific/peer review reports (if available/applicable)

1 Full Project Title

Protocol Version: Adaptive Music Technology Using the Kinect Protocol Version Date: May 21, 2015
Project Nickname or Acronym (if applicable): N/A

2 Principal Investigator Contact Information

PI: the leader of a research team who is responsible for the conduct of the research, and the actions of any member of the research team.

Title: **Masters Student** First Name: **Kimberlee** Last Name: **Graham-Knight**

Type of Primary Affiliation: External Research - NO Affiliation Organization: **University of Victoria**

Secondary Affiliation Organization (if applicable): Click here to enter text

3 Primary Contact

☒ Principal Investigator is the Primary Contact (skip to next question)

OR

Please indicate if the Primary Contact is to receive REB correspondence:

☐ In addition to the PI OR ☐ Instead of the PI

Title: Click here to enter text First Name: Click here to enter text Last Name: Click here to enter text

Organization: Click here to enter text Address: Click here to enter text

City: Click here to enter text Province: Click here to enter text Postal Code: Click here to enter text

Phone: Click here to enter text Fax: Click here to enter text Email: Click here to enter text

4 Other Study Team Personnel ***(please attach list as Appendix if more room is required. Enter all other study team personnel names and the role they have in the study, such as Research Assistant, Research Coordinator, Statistician, Data Manager, Co-Investigator, etc.)***

Please be advised that you will require a member of your research team to be affiliated with Island Health

Name	Organization/Affiliation and Role	Research Role for this Project
Kirsten Davis Slamet	**VIHA/Music therapist**	**Music therapy**
Click here to enter text	Click here to enter text	Click here to enter text
Click here to enter text	Click here to enter text	Click here to enter text
Click here to enter text	Click here to enter text	Click here to enter text
Click here to enter text	Click here to enter text	Click here to enter text
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Click here to enter text	Click here to enter text	Click here to enter text
Click here to enter text	Click here to enter text	Click here to enter text
Click here to enter text	Click here to enter text	Click here to enter text

5 Is this submission part of an academic program? ☒ Yes ☐ No

If **Yes** selected:

Name of Academic Institution: **University of Victoria**

Name of Academic Supervisor: **Peter Driessen**

Name of Academic Program: **INTD Masters in Music and Computer Science**

Please ensure Academic Supervisor signs the Signatures of Attestation page. Applications will not be processed without this signature. ☐Completed

6 Other REB Approvals

Will this study be submitted to another REB? ☒ Yes ☐ No ☐ N/A

If **Yes**, name of the REB: **UVic HREB**

6.1 If Yes, please indicate the status:
☐Pending Approval ☐ Approved ☒ Not submitted yet ☐ Not approved

6.2 Is this study multi-jurisdictional? For more information see www.bcethics.ca ☐ Yes ☐ No

If **Yes,** name of the REB(s): **UVic HREB**

6.3 Are other approvals required e.g. school board approval, community agency approval? ☐ Yes ☒ No ☐ N/A

If **Yes,** please provide details (e.g. enclose letters of support and include them in the List of Attachments):
Click here to enter text

6.4 To your knowledge, has this research been approved by other relevant bodies, such as community groups, school districts, etc.? ☐ Yes ☐ No ☒ N/A

If **Yes,** please provide details (e.g. enclose letters of support and include them in the List of Attachments):

Click here to enter text

The Island Health HREB reserves the right to contact an external REB (e.g. another BC Health Authority's REB) for consultation pertaining to the review if required.

7 When is the estimated start date for the research? Note: A study may not begin until Institutional Approval has been granted. *READ MORE*

Estimated Start Date: **01-Sep-2015** Estimated Completion Date: **30-Apr-2016**

7.1 Are there any time sensitivities (e.g. funding or student deadline)? ☒ Yes ☐ No

Please be aware that the ethical review processes may take upwards of 4 weeks to complete.
If you have any known time constraints that the Research Ethics Office should be aware of, please state them here (e.g. you need to start by a certain date because you have limited time to complete the study for your academic program)

If **Yes** selected, please explain: **My program ends in April 2016, so it is imperative that I begin research as soon as possible.**

8 Project Funding

☐Confirmed ☐ Pending (if pending, please attach explanation) ☒ Unfunded

8.1 Please indicate type of funding:

☐ Industry Sponsored Name of Sponsor: Click here to enter text
☒ In kind contribution from Island Health (e.g. space, equipment, or other institutional resources)
☐ Privately Supported
☐ Academic Institution Grant ☐Federal Grant ☐Provincial Grant
☐Foundation Grant ☐Association Grant ☐ US Federal Grant
☐ Other (please explain): Click here to enter text

8.2 If grant funding is indicated, please provide the name of the grant funding agency: Click here to enter text

Please attach a study budget if applicable and list as an Appendix.

Please ensure REB fees are included in the budget. Schedule of Fees

9 Commercial Purposes

9.1 Do you anticipate that this research will be used for commercial purposes, such as the development of a commercially available, or marketable, product or process? ☐ Yes ☒ No

If yes, please explain how the data will be used for a commercial purpose:
Click here to enter text
If yes, indicate if and how participants will benefit from commercialization:
Click here to enter text

10 Peer Review Scientific

☒ Yes ☐ No

Reviews are encouraged for all studies. If none were completed, please explain. Scientific reviews completed by granting agencies or graduate supervisory committee reviews are sufficient proof of scientific review.

10.1 Has this research undergone scientific peer review?

If **Yes**, name of organization(s): **Graduate supervisory committee**

If **No**, please describe why this research has not undergone scientific/methodological peer review: Click here to enter text

11 Main Category of Research Project

(check all that apply)

☐ Retrospective Chart Reviews
☐ Registry (e.g. disease, product, health services)
☐ Observational Study
☐ Interviews/Focus Groups
☐ Survey (On-line Survey/Paper/Telephone)
☒ Other (please explain): **Individual research sessions with participants providing range of motion.**

12 Principal Investigator Research Experience

Please attach a signed and dated CV for the Principal Investigator

12.1 Have you taken the Tri-Council Policy Statement – Second Edition (TCPS-2) online tutorial? ☒ Yes ☐ No

12.2 Have you previously provided a copy of your Certificate of Completion? ☐ Yes ☒ No

If **No,** please attach a copy of your Certificate of Completion.

12.3 Due to the nature of the proposed research and the characteristics of the participants, are there special training requirements or qualifications required of the PI and/or study team? ☒ Yes ☐ No

If **Yes** selected, please describe: **The researchers involved require musical training to participate.**

13 Conflict of Interest

Conflict of interest (COI) may arise from a researcher`s dual or multiple roles. It may not be possible to eliminate all COI. Researchers must identify, minimize and manage their individual COI in a manner that is satisfactory to the REB.

13.1 Are you or any of the research team members in a perceived, actual or potential conflict of interest in regard to this research project (e.g. in relation to participants, partners in research, private interests, research funders, intellectual property and/or potential commercialization of the output of the research)? ☐ Yes ☒ No

If **Yes** selected, please identify how this conflict of interest will be mitigated for each affected team member*:*
Click here to enter text

14 Power Over or Undue Influence

Research participation must be voluntary. If the researcher is in a pre-existing power-over relationship with potential participants, potential participants may not feel entirely free to refuse to participate (e.g. if the researcher is also their physician, caregiver, or employer for example). Conversely, potential participants may also perceive positive inducements for their participation (e.g. gaining advantages or earning favour with the researcher who is also their teacher for example)
The REB recommends that consenting of participants is conducted by someone on the research team other than anyone who is in a power over situation. Please refer to TCPS2

14.1 Is the PI or any of the research team members or Island Health employee in a perceived, actual or potential power over relationship essential for the conduct of this research project (e.g. the PI or research team member is the supervisor of any potential participants and is also performing consent)? ☐ Yes ☒ No

If **Yes** selected, please describe how this situation will be mitigated for each affected team member*:*

Click here to enter text

14.2 Have you assessed whether there is the potential for impact/harm on secondary parties implicated in the research findings? ☐ Yes ☒ No

If **Yes** selected, please describe how this situation will be mitigated for each affected team member*:*
Click here to enter text

15 Recruitment of Research Participants and Target Populations

15.1 Please indicate the number of local participants that are planned for recruitment: **1-5**

15.2 Do you plan to exclude any potential participant populations? ☐ Yes ☒ No
If YES, please justify: Click here to enter text

16 Recruitment Process

Please see attached protocol page: Click here to enter text
OR
Please check all that apply. If recruiting from different populations, please specify details for each population in this section.

16.1 Permission to Contact program ☐ Yes ☒ No
If Yes, please indicate: ☐ Island Health PTC OR ☐ Other
If No, please describe how potential participant names are accessed and prescreened, and by whom: **Kirsten Davis Slamet is familiar with the inpatient population of the hospital, and may approach prospective patients to participate.**

16.2 Face to Face recruitment ☒ Yes ☐ No
Please describe the context/setting and specify who approaches the prospective participants:
Kirsten Davis Slamet will approach all prospective participants. She will ask them if they are interested in participating, and will give them my contact information if they want to participate, so I can give them the consent form and answer any questions. Kirsten will approach the potential participants in-hospital.

16.3 Telephone ☐ Yes ☒ No
Please specify who calls the prospective participants: Click here to enter text

16.4 Email or Letter ☒ Yes ☐ No
Please specify who sends the email or letter to the prospective participants: **Kimberlee Graham-Knight**

16.5 Public Advertisements (radio, television, newspaper) ☐ Yes ☒ No

16.6 Posters/flyers ☐ Yes ☒ No

16.7 Social media ☒ Yes ☐ No

16.8 Study website ☐ Yes ☒ No

16.9 Other: Please describe: Click here to enter text ☐ Yes ☐ No

Copies of any recruitment tools used (such as advertisements) must be enclosed with this application.

16.10 Are you planning to recruit from any vulnerable populations (e.g. children, cognitively impaired people, prisoners, socioeconomically disadvantaged, individuals unable to provide consent, etc.)? ☐ Yes ☒ No ☐ N/A

If **Yes**, please provide more detail if the process is not fully described in the protocol: s**ee protocol**

16.11 Are you planning to specifically recruit from any First Nations, Inuit or Metis populations? ☐ Yes ☒ No ☐ N/A

16.12 Will Indigenous identity or membership in an Indigenous community be used as a variable for the purposes of analysis? ☐ Yes ☒ No ☐ N/A

16.13 If **Yes** selected for 16.11 or 16.12, have you initiated or do you intend to initiate an engagement process with the Indigenous collective, community or communities for this study? ☐ Yes ☐ No ☒ N/A

If **Yes** selected please describe the process that you have followed or will follow with respect to community engagement. Include any documentation of consultations (*i.e. formal research agreement, letter of approval, email communications, etc*.) and the role or position of those consulted, including their names if appropriate: ☒ N/A

Click here to enter text

If **No** selected, briefly describe why community engagement will not be sought and how you can conduct a study that respects Indigenous communities and participants in the absence of community engagement. ☒ N/A
Click here to enter text

17 Risks and Potential Impact of Participation

17.1 Identify any ways in which taking part in this research may be an inconvenience to participants, including the demands on their time, travel and child care costs, etc.: **This research is an inconvenience to participants because of the time demands, and may result in some fatigue from performing musical motions repeatedly.**

17.2 Is there potential for impact/harm on secondary parties implicated in the research findings? If so, please explain: **The participant may become fatigued over the course of a session as he or she needs to repeat various gestures.** ☒ Yes ☐ No ☐ N/A

17.3 Indicate if this research could pose any of the following risks of harm for participants:

Real or Potential Risks of Harm	Likely	Possibly	Unlikely
i. Embarrassment during participation in the research	☐	☐	☒
ii. Fatigue or stress	☐	☒	☐
iii. Other emotional or psychological discomfort	☐	☒	☐
iv. Social risks, such as stigmatization, loss of status, privacy and/or reputation	☐	☐	☒
v. Physical risks, such as falls	☐	☐	☒
vi. Economic risk (e.g. job security, job loss)	☐	☐	☒
vii. Any other harms (e.g. risk to community, family or the participant, incidental findings)	☐	☐	☒

17.4 Explain how you plan to mitigate these risks: **The risk of fatigue from performing musical gestures will be mitigated by telling the participant they are encouraged to only perform gestures that are comfortable for them. The participant will be encouraged to stop or modify the gestures if there is any discomfort whatsoever, and to continue at a subsequent session.**

17.5 In consideration of the potential risks and vulnerability of participants and based on the TCPS-2 definition, do you believe this study to be a minimal risk study? *OPEN GUIDANCE* ☒ Minimal ☐ Above Minimal

Please provide any explanation that could guide the Board in their assessment: **This study does not pose any major risks to researchers or to participants, based on the TCPS-2 definition.**

17.6 Are there any potential risks to researchers and their study team members (e.g. injury, emotional distress, etc.)? ☐ Yes ☒ No

If **Yes** selected, please explain how you will mitigate the risk(s): **N/A**

17.7 How will you respond if harm occurs to participants, researchers, or study team members? (e.g. what is your plan?) **If the participant becomes fatigued, I will stop the session immediately and reschedule for a time at least 2 weeks in the future.**

18 Benefits

18.1 Describe any potential or known benefits related to participating in this research (check all that apply)

☒ Benefit to the participants (please explain): **The participants will receive the opportunity to produce interesting music, which can be beneficial on many levels. The research will also allow for a certain degree of physical activity, albeit entirely in a stationary place, which is also beneficial. It could also be beneficial for the participants to feel they are contributing to knowledge and helping others with disabilities.**

☒ Benefit to society (please explain): **This research provides enormous benefits to society. It produces and shows art from a marginalized group that deserves to have its voices heard in the music world, and gives a greater opportunity to many people for self-expression. The research will culminate in a public music performance, which will likewise provide enrichment for the public.**

☒ Benefit to the state of knowledge (please explain): **It is paramount that groups that are marginalized find a voice in the arts, and indeed the arts are often the best place for this to happen. This research will provide a framework for developing electronic musical instruments for people with disabilities, and will allow for more researchers and musicians with disabilities to work together in future. This advances the state of knowledge because it provides a pool of resources for researchers to draw on when approaching a similar task in the future.**

19 Compensation

19.1 Will participants be compensated for taking part in this research (i.e., out of pocket reimbursement for parking, travel, gifts of money or items, food or drink, lunch, etc.)? ☐ Yes ☒ No ☐ N/A

If **Yes** selected, please explain: **N/A**

If **Yes** selected, please ensure this is described in the Informed Consent Form (if applicable).

***Please note**: For PIs based at Island Health, if the funds for the research are held at Island Health the current financial policies do not include a mechanism to directly compensate participants. Please contact Dawn Waterhouse at dawn.waterhouse@viha.ca for more information.*

20 Obtaining Informed Consent

20.1 Is an alteration to informed consent requirements being requested due to minimal risk and in accordance with TCPS2 (2014) Article 3.7A? ☐ Yes ☒ No

Please provide rationale: **N/A**

20.2 Is an alteration to informed consent requirements being requested based on secondary use in accordance with TCPS2 (2014) Article 5.5? ☐ Yes ☒ No

Please provide rationale: **N/A**

20.3 Will participants be fully informed of everything that will be required of them prior to the start of the research? ☒ Yes ☐ No

If **No** selected, please provide a justification and describe your plans to debrief participants at the end of the study: **N/A**

20.4 Please identify each participant group and then select the consent processes to be used for each:

Options for Consent	Disabled musicians	Identify Group 2 (if applicable)	Identify Group 3 (if applicable)	Identify Group 4 (if applicable)
Initial verbal explanation of study information and signed consent form	☒	☐	☐	☐
Letter of information and signed consent form	☐	☐	☐	☐
Letter of information and verbal consent*(explain below)	☒	☐	☐	☐
Implied consent (through anonymous, mailback or web-based questionnaires or surveys)	☐	☐	☐	☐
Other Click here to enter text	☐	☐	☐	☐
Other Click here to enter text	☐	☐	☐	☐
Other Click here to enter text	☐	☐	☐	☐

*Please explain why written consent is not possible and how verbal consent will be documented: **I have checked both signed consent and verbal consent, as some people may have fine motor impairments that make it impossible for them to sign the form.**

20.5 For each group please describe the sequential steps that will be followed in the process of obtaining informed consent, and who will perform each step:

☐ Same for all participant groups

OR

1. **The process of working with the Kinect will be explained in full. This involves explaining how the technology works (using infrared light that detects body positions) and how the participant will interact with it (the infrared light will bounce off the participant's body and the Kinect will determine the angle of refraction). The Kinect will be pointed at the participant and will analyze their data at all times. This will occur at the first meeting.**
2. **The time commitment will be explained. The research will involve multiple sessions, culminating in a musical performance in April 2016. This means that a large time commitment is required of each participant. A plan will be developed at the second meeting for the ongoing research. This will be explained at the first meeting.**
3. **The nature of the research will be explained. The research could potentially benefit many persons with disabilities. This needs to be explained to the participant to justify the large time commitment. This will be explained at the first meeting.**
4. **The participant will be provided with the written consent form at the first meeting, possibly after I emailed it to them previously. The consent form will be collected at the first meeting before any research is undertaken.**

After initial written consent is obtained, I will obtain ongoing consent at the beginning of each session verbally, by asking the participant if they wish to continue with the study, as well as if they feel well enough on the day to proceed with the session. If the participant does not feel well that day, I will postpone the session for a later time. I will also have the participant initial and date the consent form for each session to show ongoing consent.

20.6 Does this study require *ongoing* consent of participants? ☒ Yes ☐ No ☐ N/A

Ongoing consent may be required for research conducted over more than one session (eg. two interviews) or over a period of time ranging from hours to years. Arrangement must be made to confirm that participants continue to consent to participate, such as periodic reminders to participants, or having participants initial the signed consent form on a subsequent research activity, or multiple consent forms. Please refer to TCPS2 (2014) Article 3.3.

If **Yes** selected, please describe in 20.5 above.

20.7 What provisions are planned for participants, or those consenting on their behalf, to have special assistance during the consent process (e.g. languages other than English)?

☒ Special assistance is not anticipated

or

☐ Describe: **N/A**

21 Participants Lacking Capacity to Consent: Additional Considerations ☒ N/A

21.1 Adults lacking capacity to consent (check all that apply):

☐ Legal authorized representative consent will be obtained

☐ Participant assent will be obtained

☐ Participant assent will not be obtained. Explain why not: Click here to enter text

☐ Consent will be obtained if capacity is regained

21.2 How will children or youth provide consent? (check all that apply):

☐ Parent/guardian consent will be obtained

☐ Child consent/assent will not be obtained. Explain why not: Click here to enter text

☐ Child/youth assent will be obtained, and parental consent will be obtained

☐ Consent of child/youth will be obtained when the child or youth has the capacity

Please describe: Click here to enter text

22 Participants Right to Withdraw from Study

Participants are under no obligation to participate or continue to participate in a study. Refusal or withdrawal will not impact their ongoing care or services. Consent will be required to confirm data use and this must be in the consent form.

22.1 Describe what participants will be told about their right to withdraw (e.g. what is stated in the Informed Consent Form): **There is no compensation involved, so this does not figure into the participant's right to withdraw. Each participant will be told that the study is completely voluntary and they are welcome to withdraw at anytime if they no longer wish to proceed with the study. They can withdraw by verbally saying that they withdraw at any session with me, the researcher, or in a phone call to me, or in writing in email. They can also choose to withdraw by notifying any of the support staff that may be working with us at any time. Openness will be encouraged at all times, and the participant will not be made to feel pressured about staying in the study.**

22.2 Please indicate how data will be used upon withdrawal:

☒ It will not be used in the analysis

☐ It is logistically impossible to remove participant data i.e. part of a focus group

☐ It will be used in the analysis if the participant agrees

22.3 If applicable, describe how agreement to use participant data will be obtained if they withdraw:

☐ This is described in the Informed Consent Form

Or

☒ other, please describe: **If the participant chooses to withdraw, their data will not be used and will be destroyed.**

22.4 If participants withdraw prematurely, will their compensation (if any) be prorated to the time that they withdraw? ☐ Yes ☐ No ☒ N/A

If **No** selected, please explain: **N/A**

23 Confidentiality of Participants

Confidentiality *means the protection of the person's identity and the protection, access, control and security of his or her data and personal information during the recruitment, data collection, reporting of findings, dissemination of data (if relevant) and after the study is completed (e.g. storage). The ethical duty of confidentiality refers to the obligation of an individual or organization to safeguard entrusted information. The ethical duty of confidentiality includes obligations to protect information from unauthorized access, use, disclosure, modification, loss or theft.*

Anonymity *means that no one, including the principal investigator, is able to associate responses or other data with individual participants.*

23.1 Will the participants be anonymous in the data gathering phase of research? ☐ Yes ☒ No ☐ N/A

23.2 Will the participants be anonymous in the dissemination of results (be sure to consider use of video, photos)? ☐ Yes ☒ No ☐ Possibly

If anonymity will not be protected and you plan to identify all participants with their data, provide the rationale below.

The participant will be videoed in order to provide data for gesture recognition to be used in the final concert. Video is the only way to obtain the necessary data, and it would degrade the quality of the video to blur out the face or otherwise alter the data format. Also, it is not in the interests of the study to protect anonymity, as the participants will be performing in a concert at the end of the study period.

23.3 Are there any limits to protecting the confidentiality of participants?

☐ No, confidentiality of participants and their data will be completely protected

☒ Yes, there are some limits to the researcher's ability to protect the confidentiality of participants (Check relevant boxes in 23.4 below.)

23.4 Please indicate any limits to the researcher's ability to protect the confidentiality of participants:

If there is more than one participant group, please be explicit: **There is only one participant group: the disabled musicians.**

☐ Limits due to the nature of group activities *(e.g. focus groups)*

☐ Limits due to context: The nature or size of the sample from which participants are drawn makes it possible to identify individual participants *(e.g. rare medical conditions)*

☐ Limits due to participation: *(e.g. a workplace study involves study activities that will occur where employees are working)*

☐ Limits due to legal or professional requirements for reporting *(e.g. suspected child abuse)*

☐ Limits due to legislation *(e.g. the US Patriot Act when there will be data storage in the United States)*

☒ Other: **The participants will be performing in a concert at the end of the study.**

23.5 If there are limits to confidentiality, describe how you will address them (e.g. use of pseudonyms, conduct research away from the workplace, describe limits in the consent form etc.)

There is no expectation of confidentiality and this will be made clear in the consent forms.

24 Privacy, Confidentiality and Security of Study Data

Please include as an appendix a data flow diagram or description. See HERE for example.

Data Sources

24.1 Please select the data collection techniques that will be used:

☒ interview ☐ survey ☐ group activity

☐ test data ☒ biometric data ☐ fMRI data ☐ chart review

☒ other, please describe: **Use of the Microsoft Kinect 3D camera to capture motion data.**

If interview, survey or group activity selected, please describe the location, length and frequency of the interaction: **The interview portion will take place at each weekly session on an informal basis, to ascertain how the participant is feeling about the study and the performance of the instrument. The interview portion of each session should not exceed 10 minutes.**

24.2 Will information be *collected directly* from study participants (e.g. pre-screening questions, focus group activities or interviews/surveys)? ☒ Yes ☐ No

If **Yes,** please select who will collect it (select all that apply):

☒ A member of the Study Team (who is not an Island Health employee, physician or fellow)

☐ An Island Health Employee (who is also a member of the Study Team)

☐ An Island Health Employee (who is not a member of the Study Team)

☐ Other (please describe): Click here to enter text

If more than one team member will collect data, please explain who has responsibility for which elements of the data collection activity: Click here to enter text

24.3 Are you collecting information from study participants' *Island Health record(s)*? ☐ Yes ☒ No

If **Yes**, please select who will collect it from the study participants' Island Health record(s) (select all that apply):

☐ A member of the Study Team (who is not an Island Health employee)

☐ An Island Health Employee (who is also a member of the Study Team)

☐ An Island Health Employee (who is not a member of the Study Team)

☐ Other (please describe): Click here to enter text

If more than one team member will collect data from Island Health records, please explain who has responsibility for which elements of the data collection activity: Click here to enter text

24.4 Will the research activity be recorded? ☒ Yes ☐ No

If **Yes**, please select all that apply:

☒ Video ☒Audio ☒ Photographs

If **Yes,** please explain how confidential participant information will be protected and ensure this explanation forms part of the informed consent: **None of the information recorded will be confidential, and much of it will be shared with the media to advertise for the final concert.**

Linkage of the Study Data with Other Data

24.5 Will study participants' information be *linked* with any other non-Island Health sources of data about the same participant (e.g. government or other health authority records, private physician records, registries, etc.)? ☐ Yes ☒ No

How Study Participants are Identified

FIPPA allows for the use of limited amounts of Personally Identifiable Information only in situations where de-identified (coded) or anonymized information cannot reasonably be used to achieve the study objectives.

24.6 What type of data will be collected? (select all that apply):

☒ Directly Identifiable (please provide rationale): **The study requires video footage captured by the Kinect to analyze body movements in 3D. So because the data collected is video of the participant, he or she will be directly identifiable. Also, the final performance will require the participants to play music publically on a stage, so no anonymity is possible.**

☐ Indirectly-Identifiable (please provide rationale): Click here to enter text

☐ De-Identified (Coded)

☐ Anonymized

☐ Anonymous

☐ Aggregate

24.7 If the study is using **de-identified (coded) or anonymized data**, at what point and by whom is it de-identified or anonymized? (*select all that apply*):

☒ N/A, data is fully or indirectly identifiable

☐ Prior to leaving Island Health, by an Island Health employee, physician or fellow (who is also a member of the study team employee)

☐ Prior to leaving Island Health, by an Island Health employee (who is not a member of the study team)

☐ After leaving Island Health by a member of the Study Team

☐ Prior to or after leaving Island Health by a third party (e.g. service provider or sponsor), please describe: **N/A**

☐ Other (please describe): **N/A**

If more than one team member will de-identify or anonymize the data, please explain who has responsibility for which elements of that activity: **N/A**

24.8 If the study is using **de-identified (coded) or anonymized data**, is a Study Code List that links the study participant to a study code/ID being kept? ☐ Yes ☐ No

If **Yes**, please answer the following:

Who is keeping the list? **N/A**

Where is the list being kept? **N/A**

How long is the list being kept? **N/A**

What safeguards are in place to protect the list? **N/A**

Data Security, Storage and Transmission

24.9 Will electronic or paper study data be stored or managed at Island Health (e.g. in a database, on an Island Health computer, in a paper file, file share, SharePoint site, etc.)? ☐ Yes ☒ No

If **Yes**, please describe: **N/A**

24.10 Will data be entered into an *external* (non-Island Health controlled) system (e.g. into an electronic data capture system, into a web form etc.)? ☐ Yes ☒ No

If **Yes**, provide the following:

A description of the system (including trade name if available): **N/A**

Who will be entering data into it: **N/A**

The contact information (name, email and phone number) of a contact who can answer technical questions: (*if necessary*): **N/A**

24.11 Will any of the tools used to collect or transmit data in this study be linked to an Island Health information system to extract information? ☐ Yes ☒ No

If **Yes**, please explain: **N/A**

24.12 Will you be transmitting or transporting paper data? ☐ Yes ☒ No

If **Yes**, please describe how security will be maintained: **N/A**

Use of Electronic / Mobile Devices

24.13 Will this study require that any non-standard/non-Island Health issued devices be connected to Island Health's network? ☐ Yes ☒ No

If **Yes**, please describe: **N/A**

If **Yes**, who will be using the device?

☐ The study participant

☐ A member of the Study Team (who is not an Island Health employee)

☐ An Island Health Employee (who is also a member of the Study Team)

☐ An Island Health Employee (who is not a member of the study team)

☐ Other (please explain): Click here to enter text

24.14 Will this study require that any software be installed on an Island Health computer (e.g. a program that is installed on an Island Health computer to analyze/manipulate data)? ☐ Yes ☒ No

If **Yes**, please name the software and explain its purpose? **N/A**

24.15 Will any information from Island Health's records be stored or transported on any removable storage (e.g. CD/DVD, USB Drive, etc.) or mobile devices (e.g. tablet, iPad, laptop, smart phone, camera, etc.)? ☐ Yes ☒ No

If **Yes**, please describe: **N/A**

24.16 If **Yes**, will the removable storage or mobile device be *encrypted* to the advanced encryption 256 Bit standard? ☐ Yes ☐ No ☐ Don't Know *(please contact researchethics@viha.ca for assistance)*

If **No**, please explain why not: **N/A**

Transmission, Access or Storage of Data Outside of Canada

24.17 Will any information be sent to, accessed from, or stored outside of Canada? ☐ Yes ☒ No

If **Yes**, please answer the following:

What Information will be sent to, accessed from, or stored outside of Canada? **N/A**

For what purpose will it be sent to, accessed from, or stored outside of Canada? **N/A**

How will it be sent to or accessed from outside of Canada? **N/A**

Where will it be sent to or accessed from? **N/A**

24.18 Are you obtaining consent in a manner that complies with this section in the guidance (click here to view) for data being sent to, accessed from or stored outside of Canada? ☐ Yes ☐ No

If **No**, why not? **N/A**

Destruction and Disposal of Data

24.19 How long will you retain the data after the study is closed? **5 years**

A minimum of five (5) years retention from the date of official study closure is recommended for minimal risk studies.

24.20 How will the data be destroyed at the end of the retention period? **Deleted from laptop**

24.21 Who will be responsible for ordering the destruction of the data? **Primary researcher**

Future Use of Data

24.22 Will any study data be used for future research related to this project? ☐ Yes ☒ No ☐ Possibly

If **Yes or Possibly**, is this explained in the consent form? ☐ Yes ☐ No

If **No**, please describe how you will obtain participant permission: Click here to enter text

If **Yes**, will the data be anonymized? ☐ Yes ☐ No

If **Not**, please explain: Click here to enter text

24.23 Will any study data be used for future research unrelated to this project? ☐ Yes ☒ No ☐ Possibly

If **Yes or Possibly**, is this explained in the consent form? ☐ Yes ☐ No

If **No**, please describe how you will obtain participant permission: Click here to enter text

If **Yes**, will the data be anonymized? ☐ Yes ☐ No

If **No**, please explain: Click here to enter text

25 Dissemination of Results

For more information on developing effective dissemination strategies, please contact Vancouver Island Health Authority, Research and Capacity Building office at 250 370 8340.

25.1 Please provide initial indication of how you plan to disseminate results. Please select all that apply:

- ☒ Journal publication
- ☒ Other type of publication/ educational materials
- ☒ Presentation
- ☐ Book development
- ☐ Clinical practice guidelines
- ☐ Educational outreach and strategies
- ☒ Educational materials
- ☒ Other (Please provide description): Master's thesis
- ☐ Computerized decision support tools
- ☐ Media campaign/social media
- ☐ Infographics and data visualization
- ☐ Policy brief
- ☐ Audit and feedback
- ☐ Community of practice/networks
- ☐ Interactive workshops

25.2 Are there any plans to provide a report of the results back to participants? ☒ Yes ☐ No

If **yes**, please describe how the results will be reported back to participants: **The participants will have an active role in the whole process including final concert.**

If **no**, please justify: Click here to enter text

26 Signatures of Attestation

Principal Investigator Signature

By signing below you:

- Attest that you are the Principal Investigator who is accountable for the conduct of this study.
- Attest that the information provided in this form is accurate and up to date.
- Agree to abide by:
  - The Tri-Council Policy Statement Ethical Conduct for Research Involving Humans 2nd Edition (TCPS-2)
  - The study protocol
  - The informed consent form
  - Island Health policies and procedures pertaining to the conduct research, including:
    - 25.2 Free and Informed Consent in Research
    - 25.3 Research Integrity Policy
    - 705 Research Finance Policy
  - The decisions, conduct guidelines and reporting requirements of Island Health's Health Research Ethics Board (HREB)
    - http://www.viha.ca/rnd/research_ethics/forms_page.htm
- Acknowledge that Island Health may conduct an audit of this study.

Kimberlee Graham-Knight

Name of PI

01-Jan-2015

Signature

Date

As a research-focused organization, Island Health provides periodic reports on research conducted under the jurisdiction of its Research Ethics Boards. Please advise whether you consent to the external release of high level study information, including but not limited to your name, the title of the study, and the location. Island Health will not release any confidential or sensitive information pertaining to your research.

☒Yes ☐ No

Academic Supervisor Signature (If **Yes** selected in Question 5.)

By signing below you are:

- Attesting that you are the Academic Supervisor for the Principal Investigator of this study (as listed on page 1).
- Attesting that you have reviewed and support this submission as part of the Principal Investigator's course of study.

Name	Position	Signature	Date Signed
Peter Driessen	Professor		

Co-investigator or Island Health Site Liaison Signature(s)

By signing below you agree:

- To abide by:
  - The Tri-Council Policy Statement Ethical Conduct for Research Involving Humans 2nd Edition (TCPS-2)
  - The study protocol
  - The informed consent form
  - Island Health policies and procedures pertaining to the conduct of research
    - 25.2 Free and Informed Consent in Research
    - 25.3 Research Integrity Policy
    - 705 Research Finance Policy
  - The decisions, conduct guidelines and reporting requirements of Island Health's Health Research Ethics Board (HREB)

- http://www.viha.ca/rnd/research_ethics/forms_page.htm

- Provide a PI who is external to Island Health with the information required to ensure they are aware of and abide by the requirements set out above.

Name	Signature	Date
Kirsten Davis Slamet		17-Jun-2015
Click here to enter text.		01-Jan-2015
Click here to enter text		01-Jan-2015

If additional space for Co-investigator or Site Liaison signatures is required, please attach a separate page.

Protocol

Adaptive Music Technology using the Kinect

Principal Investigator/ and Co-Investigators *Kimberlee Graham-Knight, BMus, Kirsten Davis Slamet, BMT, MTA*

Institutions: *University of Victoria, Vancouver Island Health Authority*

Protocol version number/version date: April 11, 2016, Version 7

1. **Protocol Synopsis**

This study fuses fields of Music Therapy, Music, and Computer Science to create new musical instruments for participants who cannot play traditional musical instruments due to lack of manual dexterity. The new instruments developed use the Microsoft Kinect camera, a three-dimensional motion capture device, to harness the player's every movement and turn it into sound. A sampling of individuals with a variety of movement impediments, who are still capable of large motor movements, is required to show the potential of the Kinect. The protocol revolves around getting a person who is not otherwise able to play music, to perform on a concert stage with other performers. It also encompasses the process of developing the instrument, and the participants' various reactions to the process. This performance will prove that people with disabilities can play interesting music of note, and can equally participate in the creative process.

2. **Background & Rationale:**

The research question is an artistic one: what kind of artistic performance can be achieved using participants who cannot play traditional instruments, employing the Microsoft Kinect camera, and what is the process to achieve that performance? This is an extremely important question, because until now these people could not play music at all, or used to play music but lost their ability to do so, and society is missing out on the artistic expression of these individuals. To my knowledge, nobody else has used the Kinect camera to help disabled individuals to date, so there is a gap in the research.

The field of computer music is rapidly expanding as technology makes more and more means of musical expression possible. Recently, the field of human-computer music interface (HCMI) has made great strides, and computers can be used in real-time as new musical instruments. As a musician, a pianist since the age of three, I am greatly interested in the artistic possibilities of this emerging medium. Specifically, I have intimate knowledge of the emotional, physical and metaphysical ways an instrument can help define and express one's place in the world, and I want to fuse these with learnings about modern technology to develop a new atmosphere for creation. Moreover, I have evolved a set of parameters with which to judge instrumental technique and musical merit. All of this, coupled with my passion for helping persons with disabilities, inspires the creation of a three-dimensional, movement-based musical instrument especially designed for people with physical disabilities.

Human-Computer Musical Interface (HCMI) began in the 1960's, with composers such as Alvin Lucier generating musical iterations from body feedback, specifically electrical impulses on the outside of the skull, notably in Music for Solo Performer, 1965.[1] This has evolved to include sensors on various muscles and nerves, and most recently, to a camera that detects movement in order to produce music.

The current literature focuses on how to evaluate the merits of HCMI—specifically, "for the field of [Digital Musical Interface] design, a much broader definition of the term 'evaluation' than that typically used in human-computer interaction (HCI) is required to reflect the fact that there are a number of stakeholders involved in the design and evaluation of DMIs." [2] The main stakeholders for my research are the participant, the composer, and me, the programmer. I need to make something that has an "ability to support diversity in musical style and performance." [3] Further, my instrument needs to "support the acquisition of skill and thereby the engagement of skilled performers over a long period of time."[4] It is essential to engage the participant as she acquires proficiency over the long-term.

At the Music Intelligence and Sound Technology lab (MISTIC) at the University of Victoria, a lab is developing a camera-body interface so that it can be made widely accessible to composers and musicians. Specifically, the need is for a formalized system of categorization of movements and their links to musical gestures. I propose research centred around perfecting the interface so that it operates without time lags, and documenting all possible movements that can be detected by the system. Further, I want to develop a set of musical parameters that can be manipulated by these gestures, for the production and performance of new musical works. Then, I want to record these works.

An excellent example of the type of performance I want to achieve is the British Paraorchestra, which first performed internationally at TEDx Brussels in 2011. Using digital and acoustic instruments entirely controlled by people with disabilities, this video illustrates the possibilities of melding traditional and new instruments in a way that is easily accessible to the listener.

As a music graduate, I have a substantial foundation in music production and music theory, and my proposed course of study will capitalize on this while giving me the technical foundation necessary. I will take Computer Science and Music courses, which will provide theoretical and practical knowledge in systems design, signal processing, computer music generation and sound recording.

1 Alvin Lucier, "Music for Solo Performer," © 1982, 1965, by Lovely Music, vinyl.
2 Sile O'Modhrain, "A Framework for the Evaluation of Digital Musical Instruments," Computer Music Journal 35, no. 1, (2011): 28.
3 S. Jorda, "Digital Instruments and Players: Part II: Diversity, Freedom and Control," Proceedings of the International Computer Music Conference, San Francisco, California (2004): International Computer Music Association: 206-210.
4 D. Wessell and M. Wright, "Problems and Prospects for Intimate Musical Control of Computers," Proceedings of the International Conference on New Interfaces for Musical Expression (NIME), New York: Association for Computing Machinery (2001): 1-4.

3. **Study Objectives(s)/Purpose:**

The goals of this study, in order, are as follows: to develop a musical instrument to be played by people with disabilities in a concert performance; to evaluate the efficacy of the Kinect camera in achieving such a performance; to develop a system that can be used to develop new musical instruments for people with disabilities.

The primary objective of this study is twofold: to develop a musical instrument that can be played by a person with motor impairments who still has large motor movements in a concert performance on a stage, and; to document the process of development of the musical instrument and the reactions of the participant to every stage in the process. The goal is the performance along with the observation of the participant, and all other objectives derive from that. Phrased as a question, the primary objective could be written, What caliber of musical performance is achievable with a person with a physical disability and the Microsoft Kinect camera, and what process can be used to achieve that performance? The goal is on the artistic result of the performance, not so much on the technical considerations of the camera, although this certainly plays into it. This primary objective is multi-faceted and requires many underpinnings to be successful. These will be discussed in more detail in the secondary objectives.

The secondary objectives support the primary objective. First, there must be an evaluation of the efficacy of the Kinect in achieving a musical performance. As a question, What is the usefulness of the Kinect camera in achieving a high-quality musical performance? Can it rise to the job, or is it inadequate to achieve something truly artistic? This is a highly subjective outcome, and a rubric must be developed for evaluation of this metric. I have included a set of questions that will help to determine the artistic merit of the music being made with the Kinect (see Appendix 1).

Another secondary objective is to develop a system that can be used to develop new musical instruments for people with disabilities. This involves a network of steps used to interact with the disabled performer and find out what kind of motion they can perform reliably. It also involves how to introduce the technology and get the person to interact with it naturally, how to document the process, how to keep the subject motivated throughout the study, and how to develop a set of exercises for the subject to use to develop mastery of the instrument. Put as a question, this secondary objective could be: What are the steps required to develop a new musical instrument for a disabled performer?

4. Study Population

The population of the study will be roughly 1-5 participants who have some mobility difficulties but are capable of moving enough to be tracked by the Kinect camera. For example, one participant could not be able to move their fingers well, but could still move their arm. This is a deliberately broad definition, and the development of the study will largely depend on what participants are recruited. If someone in a wheelchair is recruited, the study must account for that. If someone who has almost complete mobility but who can still not play an instrument is recruited, the development of the instrument for that person will look significantly different. Most likely the participants will self-identify as having a disability, in order to be properly recruited, but this is not a hard and fast requirement.

Inclusion Criteria

a. Persons with motor function impairment but still able to move to some degree.
b. Adults between the age of 19-85
c. Cognitively intact and able to consent independently
d. Agrees to performance in a public concert
e. Willing to be videotaped and have photos taken
f. Willing to commit to weekly training sessions over an extended period of time
g. Understands and can speak English and/or French
h. Excellent hearing abilities

Exclusion Criteria

a. Unable to hear well
b. Children
c. Able-bodied
d. Not cognitively able to consent

5. **Recruitment**

The participants will primarily be recruited by Kirsten Davis Slamet and the other music therapists she knows in the hospital, both at Saanich Peninsula Hospital and Aberdeen Hospital. The music therapists will read the protocol and informed consent forms, and will determine from this whether there are people in their practice who may be eligible to participate. Then, they will approach the participants in person, as they see these participants in person frequently as part of their music therapy sessions. If the participant is interested in taking part in the study, the music therapist will forward their information to me via email (with no last name of the participant) and I will phone the participant to schedule a time for them to fill out the informed consent form. Then, once the form is filled out, the study will proceed as designed.

6. **Study Design & Procedures**

The study will consist of three phases that rotate as needed. The first phase will be data collection. This involves video taping in a systematic way the various movements of the participant. This phase is the foundation of the whole study and must be done as soon as possible. The participant will be asked to perform various gestures, from moving a single arm to movements that need both arms and maybe even the head.

Then, after all of the possible motions (that are comfortable for the performer) are documented and videotaped in multiple (at least three instances per movement), I will tag all of the motions according to which ones are the same. This tagging, along with the videotaping, will be done using the Microsoft Kinect Software Development Kit (SDK), a computer program that has graphic tagging built-in.

The third part of the study is the one that requires the most feedback from the participant and the most reiterations. It involves taking the tagged information and translating each motion into a sound that can be reproduced each time by the performer. So for example, when the performer swipes his left hand to the right, a snare drum sound will play. This requires ongoing contact with the performer and many sessions to iterate through all of the possible gestures and sounds, which will be the most time-consuming part.

Assessments for this study will be performed on an informal basis. The performer will try a new instrument system I have produced for him, and provide his feedback in a session with him. For example, he may say the sound is too difficult to activate, and needs to be triggered in another way, and I will adjust the instrument accordingly. These sessions will take place during normal music therapy sessions, and so will not require any additional time of the participant.

The study will begin on January 15 once I receive ethics clearance and will continue until August 30. It will consist of weekly meetings with participants where we recap what happened in the previous week and try out the new technology I have programmed for them in the past week. This time will also allow for any feedback from the participant about what he did and didn't like about how I have the music-making set up for him. Every month there will be a mini-performance where the participant gets time to play with the instrument and find out if he likes how it is responding.

This study is unique in that it requires a concert to be completed at its conclusion, and this concert in large part will determine the validity of the study. The dress rehearsal and final concert will be the most taxing part of the study for the participant in all likelihood. One participant with the Kinect will be used per piece, and participants may also perform their original work or arrangements of others' work.

There will be other possibilities for performance as well including at a hospital and in the community.

A sample study session with the participant will include 10 minutes to set up the Kinect technology, and another 15 minutes to calibrate the Kinect for use. Normally the camera and the computer will be ready to play for the performer in about 20 minutes total. Then, I will explain the changes I made to the system since the previous session, and have the performer try out the changes. This can take upwards of a half hour, depending on the number of changes made. Throughout this process, I will make changes to the coding as needed to facilitate music-making, in line with the feedback the performer gives me.

The main coding language used for this study will be Max/MSP, which is a visual language that allows for real-time sound synthesis. That is, I can change the setup of the code whenever I like without waiting for the program to compile first, in response to the feedback I am given.

After the trial session, the performer may choose to play and/or sing a few pieces with the music therapist. This will allow the performer to enjoy the instrument and remain motivated in the study.

The study will be kept on track by weekly work by me after the sessions with the participant end. In this weekly work, I will document everything I do as well as my goals for the week and whether of not I achieved them. This documentation will be key in the process, as it will be the only record that I am getting closer to my goals.

7. Statistical Considerations

This study will involve approximately one to five participants, because this is a number that can be managed easily in a concert setting and can be visited individually and have instruments prepared for them.

8. Analysis

The artistic merit of the performance will be judged primarily by the audience, but also by me using the questions in Appendix 1. This is extremely subjective and difficult to do, but I will do my best as it is important for this study. I have attached an Appendix 2, which is the qualitative interview protocol for various stages in the study. It will be important to monitor the participants at every stage to ensure they are still enjoying the work and finding it rewarding. It is desirable to ask open-ended questions of the participant that allow for maximum feedback and data to be obtained. Therefore I have structured a number of open-ended questions, which will be used in conjunction with follow-up questions to glean more information.

The data will be analyzed by myself, and coded to extract relevant themes. The goal here will be to determine how the process of creating the instrument was for the participant, and what if anything can be improved in the process for subsequent researchers. All of the interviews will be taken as a whole and looked at to extract codes, then each interview will be looked at line-by-line to determine what was missed in the initial pass. Please see Appendix 2 for a list of interview questions for the participant.

In the event that the participant withdraws before the final concert, I will attempt to obtain their consent to use the qualitative interview data I have obtained from them for the purposes of my research. The video of them for the purposes of motion analysis will be destroyed. The goal in this case will be to ascertain what went wrong in the study or with the participant that made them not want to commit to a final concert.

It is also conceivable that the participants may find it too onerous to go all the way to UVic for a performance. In this case, a performance will be scheduled at the hospital in a suitable venue in order to show off the skills acquired by the participant with the Kinect. Again, the goal of this study is twofold: to engage the participant in a music-making process using the Kinect, and to show a performance to other people who may be interested in this form of musical expression. The best solutions to these two goals will be sought in the study.

The method of analyzing the qualitative interview data will be to code for various themes by reading through the transcripts of the interviews. A first pass through all the transcripts will give a general overview of the major themes involved, then a line-by-line analysis will provide a more in-depth study of the data. Then after I have coded all the data, I will organize it into themes and report on it in my thesis.

9.Data Collection and Data Management

The data to be collected will be primarily video of the participants performing various motions, which can be analyzed and turned into triggers for musical gestures. The source of the video will be sessions with the participants performing various gestures and having them recorded directly into the camera. The other kind of data to be collected will be the informal feedback of the participant during each music-making session. This feedback will be taken as notes of what the performer prefers and doesn't prefer.

The initial video data will be collected primarily at the beginning of the study. Depending on how the mobility of the participant changes, or how his feelings about what he enjoys doing change, additional video gathering may be required at subsequent steps in the process. This will be determined on the basis of ongoing consultations with the participant, whose feedback will also be collected as data. So the video will be collected primarily in the first five weekly sessions, with subsequent video to be collected as needed, and the feedback will be collected at every music-making session as the performer provides feedback. The video is the baseline measurement, and the following feedback is the follow-up measurement, which will happen on an ongoing basis. I plan to conduct sessions every week as needed in the study for roughly 1.5 hours each time.

The most important parameter for obtaining informed consent in this case is to explain to the participant exactly what the technology is and how it works, without going into too much technical detail, and to ask whether the person is comfortable with the technology and how they will be asked to interact with it. This is a lot of information for a person on initial interview, but is required so there are as few surprises as possible later. After the explanation of the technology, the following will be explained to the participant: 1. This study requires the participant to perform on a concert stage at the end of the instrument development. This means that the performer should be willing to work with other musicians to perform pieces with the Kinect. 2. The performer is allowed to withdraw at any time. At that point, the data collected from the person, namely video of their movements, will be destroyed, however some of the experience that came from working with them will not necessarily be able to be destroyed. It is important that the musician understand this is a collaborative process, working closely with me, and those experiences cannot be destroyed by the click of a mouse. 3. The performer is responsible for ensuring they never do anything uncomfortable, namely movements that may cause fatigue. This is an essential aspect of the consent process, as the performer must understand that the goal is never to make them uncomfortable in any way.

Confidentiality and privacy will not be protected in this study, and no representation that confidentiality and privacy will be protected will be made to the participant. The goal here is to perform on a concert stage with other musicians, and this means confidentiality should not be sought. Putting on a concert requires pictures to be taken and circulated of the performers on posters, flyers, and in the media including online, so the participants should not expect to remain anonymous, and quite the opposite, should expect to become more well-known as a result of this study. However, details of the individual music-making sessions will remain confidential, as is the custom for any concert.

Because the program with the Kinect version 2.0 (the Software Development Kit) extracts information from the video in order to determine what is a "gesture" (this will be done with manual tagging done by me), the video must be stored on the (password-protected) Bootcamp side of the MacBook Pro. The program needs to use the video of the participant to extract relevant information, so that when the participant performs a gesture, the machine recognizes it. No names or other identifying information will be stored with the video, but the participant will be identifiable by face. This will be explained clearly to the participant, and if they are not willing to be videoed, another version of the Kinect (version 1.0) may be used that does not require video. However, this old version of the Kinect does not allow for gesture recognition.

I have purchased a Kingston DT4000 (32GB) for storage of data. The interview data will never be stored on the Mac or Windows side. The encrypted USB, along with the UVic cloud, will be the only place where identifying information about the participant is stored for the duration of the study. If the participant consents, pictures will be taken of them for the purposes of publishing in papers as well as a video of the final concert.

Quality assurance and verification of the video data will be done by visual inspection. Is the performer looking square at the camera and is his body square to the camera? Are there glitches in the video, or is it smooth throughout? Does the data allow for proper tagging (clear delineations between gestures)? Does video have high-resolution and good contrast? All of these considerations make it easier for the Kinect to detect the motions of the participants.

Another facet of data that will be collected is the reactions of participants to various sessions of trying out the Kinect. This data will again be stored on the encrypted USB drive for analysis later, or on a UVic cloud server behind the UVic firewall. UVic maintains 1GB of storage space per student, and this will be used to back-up the information on the encrypted USB key. The confidentiality of data will be maintained at all times, and this will be paramount in how data is collected and stored.

In summary, the following types of data will be obtained:

a. Video of the participant for the purposes of motion analysis. This, by necessity, will be stored on the password-protected Windows 8 side of my MacBook Pro.
b. Qualitative interview responses. These will be stored on an encrypted USB and in the UVic cloud.
c. Notes about the Kinect technology system. These are not sensitive and will be stored on the hard drive of my laptop, as well as backed up to the UVic cloud.
d. Names and identification numbers of participants. These will be kept on the encrypted USB and in the UVic cloud.
e. Video of participants performing with the Kinect, which will be disseminated to people directly by me, not using any of the Internet services such as YouTube or Facebook.

I understand that having video data stored on a (password-protected) MacBook is not ideal in any study. However, this is essential to the conduct of the study, and I hope you will consider that I have taken all of the possible steps to protect data.

10.Publication of Results

The study will be primarily conducted by Kimberlee Graham-Knight, with support from Kirsten Davis Slamet and members of Kimberlee's supervisory team, Dr. Peter Driessen, Dr. Andrew Schloss and Dr George Tzanetakis. Depending on the input of my supervisors, they will be acknowledged as required. Also, numerous publications in Music Therapy journals will be sought, and these will be spearheaded by Kirsten Davis Slamet, so she will be the primary name on those publications.

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Consent Form

University of Victoria

island health

Participant Consent Form

Adaptive Music Technology Using the Kinect

You are invited to participate in a study entitled Adaptive Music Technology Using the Kinect that is being conducted by me, Kimberlee Graham-Knight.

I, Kimberlee Graham-Knight, am a Masters Student in the departments of Music and Computer Science at the University of Victoria and you may contact me if you have further questions by phoning (250) 858-8591 or by emailing kimberleegk@gmail.com.

As a Graduate student, I am required to conduct research as part of the requirements for a degree in Master of Arts. It is being conducted under the supervision of Peter Driessen. You may contact my supervisor at peter@ece.uvic.ca.

Purpose and Objectives
The purpose of this research project is to help people like you who cannot otherwise play music due to mobility difficulties, to play music using the Microsoft Xbox Kinect. Many people may be musically inclined, but may not have the manual dexterity to play a traditional musical instrument. This study will attempt to remedy that by providing opportunities to people who cannot play a traditional instrument, but who have some limb mobility, to use the Kinect to make music. The objective of this research is to develop a new musical instrument, and for the participant to play it in a concert setting.. This will allow for artistic expression, and will prove that the Kinect and the disabled participant can be effective in attaining this artistic expression.

Importance of this Research
Research of this type is important because until now the opportunities for music-making for persons with mobility impairments have been somewhat limited, and this research attempts to bridge that gap. It will provide an opportunity for a new kind of musical expression using the Kinect camera, which is commercially available, and a laptop with special software installed. This research will open up profound artistic expression to people who have large motor movement abilities only.

Participants Selection
You are being asked to participate in this study because you exhibited interest in making music, and have some fine motor impairments that make it difficult to play a traditional instrument. You are also able to give your consent willingly, and are willing to perform in a final concert with the Kinect camera. You are a patient at Sannich Peninsula Hospital or Aberdeen Hospital.

What is Involved
If you consent to voluntarily participate in this research, your participation will include meeting with me on a weekly basis for under an hour over a period of 6 months to develop and troubleshoot the instrument. It will involve moving in ways that are comfortable for you and having this motion captured by the Kinect camera. It will also involve performing with the Kinect in a final public concert, for which there will be at least one rehearsal

The Kinect sends infrared signals and captures the angles these form on your body in order to measure how you are moving. This program is very powerful at determining your body position, and it's a robust SDK (software development kit). The process will involve taking video of you performing various "gestures," then using the software to tag these gestures so that when you move that way, it will result in music (that we decide on together). The process will be iterative, with you trying out a new program that I adapt for you each time and providing feedback.

The following kinds of data will be collected from you: answers to Interview Questions of which notes are taken typed on a computer (such as, What is your previous experience with music and/or technology? What do you hope to get out of this experience?); video to be used for the purposes of gesture tagging; photos will be taken for dissemination in concert publicity and papers about the research to be presented at conferences; and video of various performances of pieces will be used for dissemination.

Written notes and observations of the research will be taken as required throughout the study.

Video tapes and photos will be taken of you interacting with the instrument or talking about it with your permission to be disseminated in various papers about the research, to publicize the concert, to give more information about the research to the public, and in the thesis of the primary investigator, Kimberlee Graham-Knight.

Inconvenience
Participation in this study may cause some inconvenience to you, including use of your time and energy while performing with the Kinect.

Risks
There are some potential risks to you by participating in this research and they include fatigue while playing the Kinect and some need for recovery time afterward. To prevent or to deal with these risks the following steps will be taken: I will ensure sessions are a manageable length (under 1 hour altogether) and have sufficient recovery time between them. Another potential risk is that the final public concert may be emotionally taxing. To mitigate this I will ensure you have sufficient practice with the instrument beforehand, and that you know the process of the concert before you perform.

Benefits
The potential benefits of your participation in this research include: You will receive the opportunity to produce interesting music, which can be beneficial on many levels. The research will also allow for a certain degree of physical activity, albeit entirely in a stationary place, which is also beneficial. It could also be beneficial for the participants to feel they are contributing to knowledge and helping others with disabilities.
This research provides numerous benefits to society. It produces and shows art from a group that deserves to have its voices heard in the music world, and gives a greater opportunity to many people for self-expression. The research will culminate in a public music performance, which will likewise provide enrichment for the public.
It is paramount that groups that cannot play traditional musical instruments find a voice in the arts, and indeed the arts are often the best place for this to happen. This research will provide a framework for developing electronic musical instruments for people with disabilities, and will allow for more researchers and musicians with disabilities to work together in future. This advances the state of knowledge because it provides a pool of resources for researchers to draw on when approaching a similar task in the future.

Voluntary Participation
Your participation in this research must be completely voluntary. If you do decide to participate, you may withdraw at any time without any consequences or any explanation. If you do withdraw I will ask for your consent to use the video and pictures of you I have collected, as well as the observational and interview notes I have made. If you consent I will continue to use these in my study, and if you do not I will destroy them.

On-going Consent

To make sure that you continue to consent to participate in this research, I will orally verify with you at the beginning of each session that you still wish to participate.

Anonymity
Data will be collected about the process of developing the musical instrument, and this will be documented anonymously. There will be no identifying data recorded anywhere in the study, and your reactions and emotions will be kept in strict confidence. However, there will be video and pictures captured of you that may be used for promotional purposes (if you consent) and you will be asked before any pictures are released. Some of the video will remain private for the purposes of programming the Kinect. It will be made clear to you before each form of video and pictures is collected what it will be used for—either to program the Kinect, or for promotional purposes for the concert and in academic papers (including Kimberlee's thesis). Your anonymity and confidentiality will be broken during the final concert, which is part of the research activity.

Confidentiality
Your confidentiality will be protected wherever possible. For example, any reactions that you do not want to be documented in the study (even without your name attached) will not be documented without your consent. Likewise, video collected of you for the purposes of programming the Kinect will not be disseminated.

Dissemination of Results
It is anticipated that the results of this study will be shared with others in the following ways: thesis, academic published articles, presentations at scholarly meetings.

Disposal of Data
Data from this study will be disposed of five years after the completion of the study by destroying it from the encrypted USB stick on which it was recorded.

Contacts
Individuals that may be contacted regarding this study include the researcher, or any of the researcher's supervisors including Peter Driessen at peter@ece.uvic.ca, Andrew Schloss at aschloss@uvic.ca, or George Tzanetakis at gtzan@uvic.ca.

In addition, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Office at the University of Victoria (250-472-4545 or ethics@uvic.ca). Island Health's Health Research Ethics Board (HREB) may be contacted at (250) 370-8620 or researchethics@viha.ca.

By consenting to participate in this study, you do not waive your legal right to recourse about any research-related harm that may occur during the study.

Your signature below indicates that you understand the above conditions of participation in this study, that you have had the opportunity to have your questions answered by the researchers, and that you consent to participate in this research project.

______________________	______________________	____________
Name of Participant	*Signature*	*Date*
______________________	______________________	____________
Name of Researcher	*Signature*	*Date*

Visually Recorded Images/Data Participant to provide initials, *only if you consent*:

- Photos may be taken of me for: Analysis _______ Dissemination* ________
- Videos may be taken of me for: Analysis _______ Dissemination* _________

*Even if no names are used, you may be recognizable if visual images are shown in the results.

PLEASE SELECT STATEMENT only if you consent:

I consent to be identified by name / credited in the results of the study: ______________ (Participant to provide initials)

A copy of this consent will be left with you, and a copy will be taken by the researcher.

Telephone Script for Contacting Participants

Telephone Script for Contacting Potential Participants

Hello prospective participant. My name is Kimberlee Graham-Knight and I am a Master's student in Music and Computer Science at the University of Victoria. I got your number from Kirsten Davis Slamet, a music therapist with Island Health. I am conducting a study about using the Kinect camera for music, and I wonder if you might be interested. It would involve moving in ways you are comfortable with and having that motion tracked by the camera, in order to make sounds that you and I find pleasing. Your participation is completely voluntary, and will not affect the level of care you receive at Vancouver Island Health.

If you choose to participate, what is involved is a final concert that will take place at the University of Victoria, and smaller concerts that will take place at Saanich Peninsula Hospital. I am phoning you to ask if you would like to look at an Informed Consent Form for the study.

If you like, I can send you the consent form, which contains many more details about the study and may answer some of your questions. Do you want to give me your email so I can send the form?

Thanks so much for taking the time to talk to me. Have a great day.

Version 2, January 4, 2016

Email Script for Contacting Participants

Email script for contacting participants

Hello prospective participant,

This is a note to ask if you would like to participate in a music study. The study will be conducted by Kimberlee Graham-Knight, a Master's student in Music and Computer Science at the University of Victoria, and Kirsten Davis Slamet, a Music therapist at Saanich Peninsula Hospital. We would love if you would become a part of our team and help us conduct research, and your participation is completely voluntary and will not affect the quality of care you receive at Island Health (either way you decide).

We're looking for people who have some mobility difficulties but who can still move a little bit, and we think you would be an ideal candidate. The study involves using the Microsoft Kinect camera, a 3D motion capture device, to track movements of the participant and turn them into music. The Kinect sends infrared light and detects how it is reflected off the participant's body, then does some processing to detect the body's position and how it is moving.

What is involved in participating is attending weekly sessions with Kimberlee and Kirsten for 6 months, where we try out the device and any improvements made since the previous week. Then, after a few months, participants will perform in a final concert where they show off the instrument and the musical skills they have learned. There will be opportunities to perform at the hospital, at the University of Victoria, and in the community.

If you choose to participate, I will send you an email with the consent form, then I will meet with you in-person to ensure it is signed.

If you have any questions, you may contact Kimberlee Graham-Knight at kimberleegk@gmail.com or 250-858-8591. Please do not send any personally-identifiable information about you via email, but simply a phone number where I can reach you. We hope you will be in touch and that you will want to participate in this exciting study.

Sincerely,
Kimberlee Graham-Knight, BMus

Version 4, January 4, 2016

Appendix 2: Instructions for getting code running

The schematic of the overall system, as well as the software required to achieve the results described in this thesis, can be found in Chapter 4. In Visual Studio, the following dependencies must be added:

- From Bespoke_OSC: Bespoke.Common, Bespoke.Common.OSC, Transmitter
- From Microsoft: Microsoft.Kinect.Toolkit

The majority of the code used was found on a forum for Kinect, and can be found here: https://social.msdn.microsoft.com/Forums/en-US/631aff06-cb4c-42ff-84ee-d895c94c5da4/how-to-get-x-y-z-coordinates-of-joints-in-kinectexplorer-from-sdk-20?forum=kinectsdk

This was adapted to use Bespoke_OSC, which also has example code for how to use the OSC Transmitter.

The code needs to be built before it is run. Ensure the Kinect drivers are installed or the Kinect will not be detected.