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Author	Bouzarte, Youssef(Minamizawa, Kota) 南澤, 孝太
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Master's Thesis
Academic Year 2018

Synchrovibes: Interactive Music Experience to Create Social Bonds and Promote Collaboration through Movement Synchronization

Keio University
Graduate School of Media Design

Youssef Bouzarte

A Master's Thesis
submitted to Graduate School of Media Design, Keio University
in partial fulfillment of the requirements for the degree of
MASTER of Media Design

Youssef Bouzarte

Thesis Committee:

Associate Professor Kouta Minamizawa	(Supervisor)
Professor Matthew Waldman	(Co-supervisor)
Professor Sam Furukawa	(Member)

Abstract of Master's Thesis of Academic Year 2018

Synchrovibes: Interactive Music Experience to Create Social Bonds and Promote Collaboration through Movement Synchronization

Category: Design

Summary

There is no doubt that social bonds are essential for our well-being as humans. In fact, it is one of our most fundamental needs to survive. Using Synchrovibes, we explore the relationship between social bonding and movement synchronization through music. We also investigate ways to promote collaboration and create collaborative behavior within groups.

Previous research shows that movement synchronization is directly related to social bonding. We use a multi-modal approach to music, using sound, haptics and lighting to facilitate movement synchronization with the music. With many participants synchronizing to music, they synchronize to each other and create social bonds. Through experimenting, Synchrovibes was able to achieve movement synchrony and create bonds.

Furthermore, we explore ways to promote group collaboration through movement synchronization. This is done by allowing each participants to directly contribute to her experience, and directly impact others experience as well. The results show that this design approach inspires collaborative behavior within the participants.

Keywords:

Synchronization, Movement, Social Bonding, Music, Collaboration, Haptics

Graduate School of Media Design, Keio University

Youssef Bouzarte

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Table of Contents

List of Figures

Chapter 1
Introduction

1.1 Background

It is abundantly documented that everyday well-being, psychological adjustment, physical health, individual happiness, and even longevity are all deeply influenced by the quality of relationships that we share with others. In fact, in Maslows hierarchy of needs theory, love and belonging is listed as the third most important requirement for our well-being, right after security and right before self-esteem[1] (figure 1.1). It is clear that as a species we were only able to survive this far through creating bonds, groups, and communities. Roles such as hunting, gathering, farming etc would not have been developed if we were unable to connect with others and collaborate towards a common goal, which is survival and prosperity. At that time, survival depended on food sufficiency, shelter from wildlife and catastrophes and remedies for epidemics. Nowadays, we seek relationships to combat loneliness, increase life productivity, and fulfill our sense of community belonging. As the world is becoming more and more globalized, social disconnect is becoming more apparent. Factors such as language barrier, cultural difference and different customs make it difficult for people to bond. This is not only relevant in social encounters, but also significant in the labor force. Teams are now composed of people from several parts of the world working remotely together to tackle projects. There is constant research being done to increase social well-being, and improve collaboration within teams. Similarly, we are proposing a platform to facilitate social bonding between individuals and promote collaboration. We believe that this can be the first step to trigger conversations, empathy and eventually develop relationships.

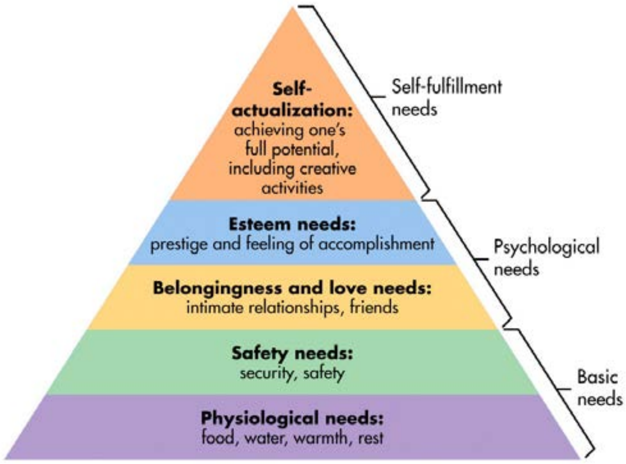

Figure 1.1: Maslow's Hierarchy or Needs

1.2 Social Bonding Requirements

In order for social bonding to take place, several requirements have to be met. The similarity attraction theory states that individuals tend to favor relationships with others who have similar attitudes and personalities[2]. This is believed to be due to the fact that as humans we anticipate that others would like us if we have similarities which reduces the fear of rejection. This tendency to risk aversion is also called the uncertainty reduction theory. This is a clear indication to our tendency to frequent environments that are within our comfort zone and that sort of assures successful social exchange. By attending social mixers or events where people share the same hobbies and interests as us, it is self assuring that bonding can easily happen.

The environment that people frequent thus play an important role in social bonding. Since bonding can happen in a verbal and nonverbal, the environment tend to favor one or the other. Music events for example make for a nonverbal bonding environment. It is true that there is a common interest between people attending the event, which is their love of music. However, what happens when everyone is concentrated on what they listen to is quite magical. Individuals tend to lose themselves and develop a sense of community with their surrounding without even engaging in any conversation. Research attributes this phenomenon to movement synchronization, which opens up another layer of social bonding that goes beyond verbal communication, but focuses more on the spiritual and emotional values.

1.3 Purpose of Thesis

Create an environment for people to develop bonds and a sense of collaboration.

There are many factors that influence human bonding. Having certain elements in this experience can help expedite the creation of bonds between people. Moreover, designing an experience that promotes collaboration can channel those newly created bonds to develop a notion of cooperation within the participants. This phenomenon can be developed through a verbal or non-verbal method. In this project the focus is on developing a non-verbal pathway to bonding. Movement synchronization has been chosen as one of the main triggers of bonding. However, the biggest challenge is to design an experience that can not only help develop the feelings of bonding but also produce a sense of collaboration between the parties. Another challenge is to achieve the goal above in as short of a time as possible and ensure that participants motivation and enjoyment has not been hindered by the content of the experience. Finally, this project aims to create a captivating experience that would allow the participants to let loose and get lost in the moment (Figure1.2). To sum it up, I will be tackling the following challenges during this thesis:

- Simplifying Synchronization between participants
- Expediting Human bonding
- Creating an immersive environment

1.4 Thesis Outline

This thesis is divided into 5 chapters. In the first chapter I describe the importance of social bonding and state the purpose of this project. Chapter 2 focuses on the related research and studies related to music and bonding, haptic technology in the context of rhythm and team collaboration. Chapter 3 describes the design process followed to create the device and develop the experience proposed. Chapter 4 serves as a time-line of all the user tests and the prototypes that preceded the

Figure 1.2: From Music to Bonding

final experience and device and the steps taken to prove the concept. Finally, Chapter 5 is the conclusion of the thesis.

Notes

1 (Byrne 1971)

2 (Byrne 1971)

Chapter 2
Related Works

2.1 Music, Synchronization and Bonding

Historical Background

Music has always been a medium to bring people together. Music and movement has existed since ancient times, and every culture had their own traditional dances that they performed on several different occasions. The indigenous Polynesian people of New Zealand, said Maori, posses one of the most recognizable traditional dance. The Haka, is a coordination of movement that the Maori performed in the times of war, both to intimidate their opponents and to motivate themselves before the battle [1] . This tradition has been carried out for ages, and it is now performed by the New Zealand Rugby team "The All Blacks" before every game they partake in. The motivation for such a choreography still holds ground nowadays, perhaps not in battle but in rugby competitions.

In traditional cultures, music and dances expand way beyond the war perspective. In Africa for instance, rain dance rituals were an indispensable part of life. Rain being a huge concern for ancient nations that relied heavily on agriculture, it was important for everyone to come together as an effort to summon rain [2]. During the African rain dance ritual, the centerpiece were the drummers. The participants movement would follow the rhythm of the drum [3] in order to synchronize to the music. The drum beat represented a familiar sound that was simple and that people could move in-sync to. This allowed the performers to synchronize to each others movement, combining their willpower and bonding between each other in a moment of need.

These rituals are not unique to Polynesian or African cultures, and a version of the same choreographies can be found in different nations across the world. This is proof that music and dances have been a big part of ancient societies and continue to be as important today.

Music and Synchronization

The drums have been providing familiar and repetitive sound patterns that could be described as beats. These are nowadays made up of many different instruments including bass, synthesizers...etc. The beat is a regular simple sound pulse that people are able to detect easily in the music. Research has found that listening to a regular beat entertains the motor movements in our brains [4], motivating us to move more. Even babies are able to detect the beat in certain music [5] and enjoy rhythmical patterns. In an experiment done with infants and their caregiver that focused on the action of bouncing while carrying the infant [6], researchers found that the infants that were bounced while synchronizing to a musical rhythm experienced more altruistic behavior with the caregiver than others that were bounced following a random out of sync rhythm. Across countries and cultures, it seems that people tend to perceive certain beats in music [7] and tend to enjoy it more once that has been recognized.

Music and synchronization has been applied to many other different fields. Most notably in sports, where many athletes groove to beats while engaging in physical activity. In fact, runners that synchronize their pace to a certain musical rhythm reported less exertion [8] than others that did not synchronize. Moreover, in a study where exercise machines were linked to a musical output, allowing the users to create music while exercising, participants perceived physical effort to be lower [9] than the control group.

From the research above, we can declare that humans enjoy music more when they are synchronized to the beat they perceive from listening to a certain track. This is true in different stages of life and different activity settings as well.

Movement Synchronization and Bonding

Movement synchronization, especially dancing has been considered to play a big role in creating social bonds [10] and indicating coalition strength [11]. Humans tend to engage in many different social activities, and music has been one of them for a while now. What sets musical activities apart from other social affairs is the presence of a shared rhythm that people intrinsically synchronize to, allowing them to synchronize to each others' movements [12]. As a result of musical synchronization, human to human movement synchronization can influence our feelings towards the other person we are in sync with [13].

In Neurobiology, matching movements between two people lead to as sort blurring of self and other through neural pathways that stand for both action and perception[14]. During this state, a feeling of blending between self and other occurs, this is refereed to as self-other merging[15]. Oullier even argues that people tend to synchronize to each others' movement even when they are not told to do so, and that this phenomenon happens unintentionally [16]. The human preference to synchronize to others happens in many different social settings ranging from walking in sync with another person[17], tapping alongside another person[18] and dancing[19]. In a study, two participants at a time were asked to asked to rock their chairs while looking at a visual screen. No information about rhythm synchronization was provided during the experiments [20]. The conditions included a no sound state, where the people rocked their chairs without hearing any feedback from the chair. The second condition provided the sound feedback of the chairs to the participants. The last condition played a song with a bpm that matched the average rocking rhythm. The results were very surprising, The people that were rocking to the music felt like they were rocking at the same pace with each other the most (Figure 2.1). Moreover. the participants that rocked to the rhythm of the music reported that they felt connected to each other the most (Figure 2.1).

Self-reports of coupling	Agreement (%)	Correlations of coupling with	
		Partner	Music
We [partners] rocked at the same pace	55.6	.15	.30*
I changed my rocking pace because of the other person	58.7	.06	−.02
The other person changed his/her rocking pace because of me	50.0	.18	.05
I changed my rocking pace because of the music	50.0	.08	.37*
I felt connected with my partner	47.9	.07	.36*

* $p < .05$.

Figure 2.1: Percentage of Agreement With Each Statement and Correlations Between Agreement and Observed Levels of Coupling With Partner and With the Music

(Demos et al. 2012)

2.2 Music and Haptic Technology

Haptic Technology recreates the sense of touch using various mediums such as forces, vibrations...etc [21]. Haptic technology is a prominent field of research nowadays, and many researchers have tried to perfect it and use it in many different fields. In this section, we focus on the use of haptic technology to enhance music experiences and describe its' application for music learning.

Music and Haptics for entertainment

Haptic technology has been used to enhance our experiences in many different fields. Whether it is in gaming by including a vibration module inside the game controller, or Apple's 3D touch that is included in all the new versions of the iPhone. Using haptic technology to enhance musical experiences is not a surprise at all. When going to clubbing events or attending concerts, we tend to feel the power of the speakers on our bodies as if the music is touching us. This is especially true for sounds with heavy bass. Subpac for instance [22] is a product that complements the music the user is listening to and recreates the heavy impact that the bass of a huge speaker has on one's body. Other concepts focus on creating a fully immersive environment to enjoy music, with visuals and haptics. The synesthesia suit is a wearable device that gives the user vibro-tactile sensations on the entire body based on the music beat that the person is listening to [23]. The suit is used along with the PSVR to create an inclusive environment where the user feels transported to a world where music is composed of colors, sounds and touch (figure 2.2). Another approach to enhancing music sensation was done through

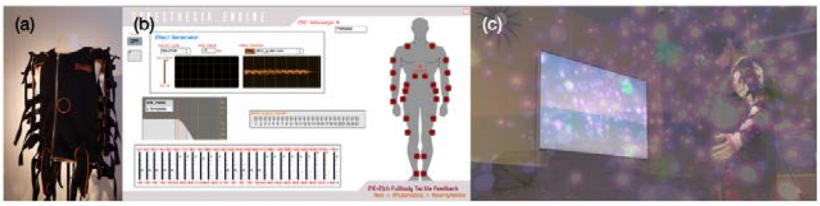

Figure 2.2: a)Synesthesia Suit, b)Synesthesia Engine, C)Demonstration

(Konishi et al. 2016)

a collaboration between the Tokyo Metropolitan University and Tokyo Institute of technology. The team created a device that transmits haptic sensation based on the music the person is listening to through a string attached to two motors. This device can be worn around the neck and can transmit the vibration to a larger area of the body [24]. The minimal design allows the users to enjoy music with haptic feedback anywhere anytime. In the media art field, Lauren Hayes, explored the integration of tactile haptic sensation in furniture to enhance musical experience. The goal of the project was to create an experience that is private and multi-sensory at the same time [25]. During ”Skin Music” the audience member is asked to lay on a piece of bespoke furniture that is composed of 6 vibration motors and 2 tactile transducers (figure 2.3). By using audio speakers as well, this work appeals to both the sense of hearing and the sense of feeling. Looking at several of works that aim to create immersion using multi-sensory models, it is clear that the use of haptic technology is prominent. Listening to music and feeling music has always happened simultaneously, whether that feeling is physical or emotional, the relationship has always existed. Haptic technology is not only used to enhance experiences, but it has also been used in music learning. In the next section, we will explore ways haptics contribute to music learning.

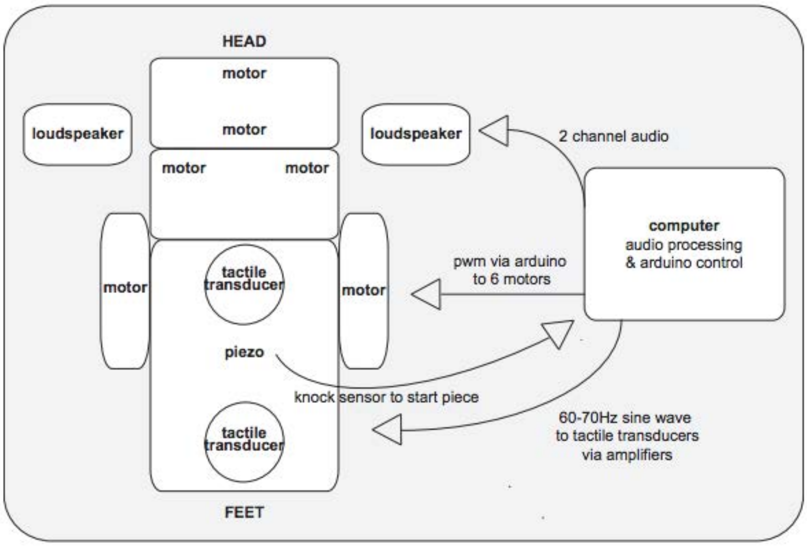

Figure 2.3: Skin Music System and device design

(Hayes 2015)

Music and Haptics for Education

Learning a musical instrument can be a very challenging task. many hours are required to learn the basic chord progression and a lot of motivation is needed to stay dedicated. Most of the people tend to give up within the first months, and never pick up the instrument anymore. This challenge has motivated a lot of researchers to come up with ways to facilitate music learning. Since the first step to learning music is being able to recognize and reproduce the rhythm, many projects explored different methods to make it easier for everyone to do so. In these different works, the use of haptic technology is very prominent. T-RHYTHM is a haptic device that provides rhythm patterns to children during solo performances and group assembly live shows [26]. This device constantly transmits the rhythm of the song, allowing the performers to concentrate on their individual parts without being confused by each other. Questionnaire results suggested that both the children (users) and the teachers agreed that their rhythm perception has been enhanced using T-RYTHM. Another project focuses on learning rhythm while playing the percussions. This instrument being highly dependent on rhythm patterns rather than notes, can be mastered as long as a certain beat pattern can be produced. In this project, a learning system has been designed to help users internalize rhythm patters. This was done using visual indications (scores), haptic indications and auditory indications as well[27].

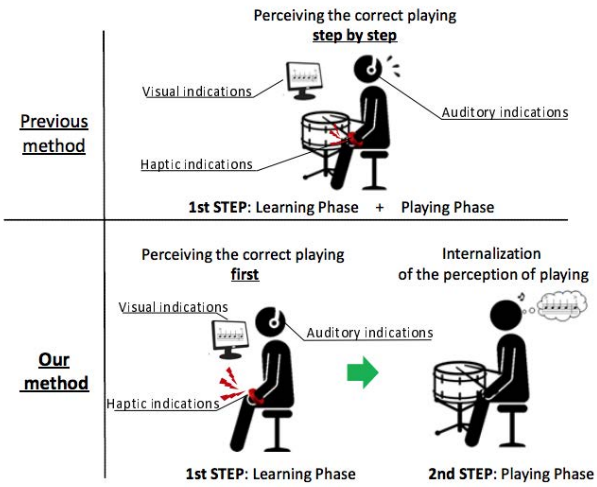

Figure 2.4: Comparison of old learning method and proposed method

(Kanke et al. 2015)

The learning process was divided into two different phases. The first phase solely focuses on internalizing the rhythm into the mind of the user through a multi-modal system. The second phase is the playing phase, where the user reproduced the rhythm they internalized. This method is unique in the way that it does not combine the use of haptics during the rhythm reproduction phase, judging that it would be distracting to do so (Figure 2.4). The results of the experiments suggest that the rhythm internalization method using haptic indications has helped users reproduce rhythms 8 minutes faster than when they simultaneously tried to learn. This is proof that multi-modal learning using sound, haptics and visuals yield to better results.

Passive Haptic Learning

Passive Haptic Learning (PHL) is a phenomenon where users can learn motor skills through haptic stimulation, even though little to no attention is dedicated to learning. Stimulation is provided by a tactile interface, and users focus their attention on another task (like completing a standardized test or playing a video game) while they passively learn [28]. Researchers from Northwestern University explored the use of passive haptic learning in piano practice. They created a haptic glove that transmits haptic sensation of every note to the designated fingers that is supposed to play it on the keyboard. The haptic actuators were placed on the knuckles of the users to ensure accuracy. The experiment consisted of a learning phase, where they use a keyboard with keys that light up. They participants spend time to learn the basic song until they reach zero error [29]. After this phase, users are asked to take a comprehension test for 30 minutes (forgetting period) where they are separated to 4 groups. The first group is taking the test without any other stimulations, where the other 3 groups are experiencing audio stimulation, vibration stimulation and audio+vibration stimulations. These 4 groups of people are then asked to play the piece of composition one more time. The results of this experiment are very surprising. the group that was receiving audio+vibration feedback seems to outperform others, while the vibration only group comes second (Figure 2.5). This is a clear indication that musical patterns can be learned passively using only haptic feedback and can be further enhanced by using sound and haptics at the same time. This research takes it even further by exploring the effect passive haptic learning can have on two hand synchronization while playing the piano. Typically, when learning a piece of music that uses both hands, piano students learn to play one hand at a time before playing with both hands

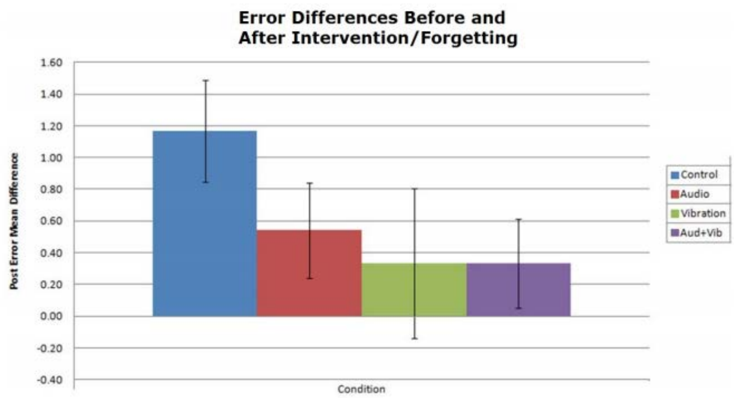

Figure 2.5: Comparison of old learning method and proposed method

(Seim et al. 2015)

simultaneously. However, music research literature believes that learning both hands together from the beginning to be more advantageous [30]. The researchers used PHL on two different groups learning a piano composition that used two limbs. The first group received haptic feedback on the left hand followed by the right hand, and the second group received feedback on both hands as if they would perform the song in real time. The results show that the two limbs synchronized condition yielded to better reproduction and less errors (figure 2.6). This is a clear indication that using haptics can even improve two limb synchronization and thus can be argued that it can improve movement synchronization as well with the help of music as an anchor. Other research that explores rhythm based learning using haptics focuses on teaching users Morse code using Google Glass. So far, haptic feedback has been applied directly on the part of the body that reproduces the rhythm, this research however investigates Passive Haptic Learning without regards to a specified place of stimulation[31]. Haptic feedback is then provided using the bone conducting actuator that the Google Glass has. The choice of Morse Code as the subject was done because it is a rhythm based skill. The language is composed of dots and dashes that are represented by short and long taps during the experiment. All the participants are given a pre-test to gauge their knowledge of Morse code, the participants are then asked to play a game as a distraction task for 20 minutes. During that time, participants are divided into two groups, one being the control group where the worn Glass repeatedly spelled certain words via audio, The other group received audio coupled with Morse code

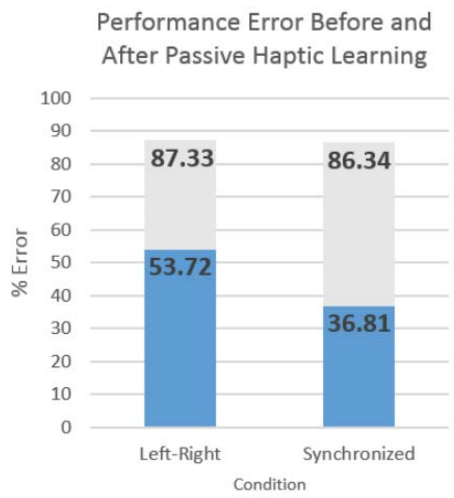

Figure 2.6: Performance error by condition. Before PHL (gray), and after PHL (blue)

(Seim et al. 2015)

through haptics. Following the distraction task, the participants are asked to take a written test for each of the words they learned in Morse, and finally write down the whole sentence. The results show drastic improvement compared to the control group (figure 2.7). In fact, users had to take two more tests, an input test and a perception test. During the input test, users were asked to input the Morse data using long and short taps on the Glass touch pad. During the perception test, the users experience Morse Code through haptic vibrations and they are asked to write down the corresponding alphabetical letters. The group that experienced passive haptic learning during the distraction phase has outperformed the control group in all of these tests.

Research in Passive haptic learning and using haptics as a means to achieve multi-modal learning is a clear indication of the importance of haptic technology in musical learning and most importantly rhythm recognition. Moreover, recently haptic technology has been integrated with sound and visuals to enhance experiences and increase immersion. The resort to the sense of feeling when it comes to musical experiences is becoming more and more popular and the sense of feeling is now closely associated with music. This is mainly due to the fact that the more we feel the music the more we enjoy it. Feeling the music also provides us with a sense of rhythm and beat recognition which further enhances our musical experience.

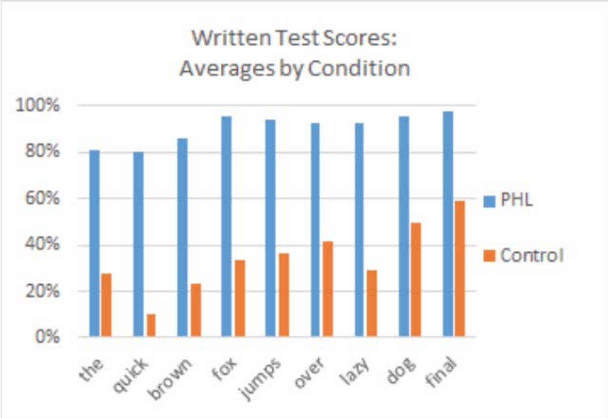

Figure 2.7: Average score by condition on each written test. Final refers to the test of the full alphabet at the end of the last session

(Seim et al. 2016)

2.3 Team Bonding and Collaboration

Collaboration is an essential element of any high performing team. It is commonly known that good team collaboration outperforms individual output and that big projects demand for team collaboration. As teams are growing bigger and cross department cooperation is becoming more prominent, it is getting harder and harder to create an environment that promotes collaboration. Complex teams are less likely to share knowledge freely, to learn from one another, to shift workloads flexibly to dissect bottlenecks, to help one another complete jobs and meet deadlines, and to share resources. Huge corporations and organizations have been spending big amounts of money in research to improve their team dynamics. In order to uncover the characteristics that define successful collaborative teams, researchers looked carefully at 55 different teams and identified those that demonstrated high collaborative behavior despite their diversity or size. Fostering significant relationships between team members is a prominent factor to successful team collaboration. The rise of work campuses that groups employees from many different departments together under the same roof tends to encourage the development of bonds between these employees. Teams that worked in companies that invested in creating social bonds between their members exhibited more collaborative behavior[32]. In other research, the concept of the bonding view of social capital starts from the premise that levels of trust between members in the network has to be strong in order to make sure that collective goals are being pursued [33]. Newel states:"developing strong team bonds provides the antecedent condition in which individual team members are more likely to at least balance the extent to which they use their social capital bridges for the public as well as the private good. Where this strong bonding does not exist, first team members are likely to feel limited normative commitment to using their social capital bridges for the public good of the project."[34] Social Capital is defined here as the network of relationship among people that live and work in a particular society, which enables the society to work better [35]. Further research explored the extent to which bonding within teams can predict the team overall performance in terms of collaboration and effectiveness. This research was survey based and involved 76 teams, 499 employees and over 48 organizations. The researchers measured bonding by assessing the network's density. In other words, if all the team members had connections with each other it would be 1 and the opposite would be 0. The findings of this research confirm that bonding positively affects team performance effectiveness. Moreover Bonding also predicts a better team identity [36].

2.4 Summary

Overall, it is clear that Music has always been closely associated with social bonding. This relationship has been mediated by movement synchronization to a base rhythm and to other people's movements. In fact, music is the best medium to facilitate movement synchronization, and that is because as humans we are more likely to recognize beats in a certain song. It has also been proved that rhythm recognition leads to musical experience enhancement. Moreover, listening to music and feeling music has always been correlated. When listening to the bass using a big speaker, our body tends to absorb the musical notes as well as internalize them through our ears. Research using haptic technology to reproduce this feeling proved that musical experience can be elevated when combining sound and haptics. This technology was also used to help beginners learn rhythm as part of instrument learning. Finally, Social bonding withing a team is seen as a prerequisite to good team collaboration. To sum up, Music and rhythm recognition through multi-modality can induce social bonding which in turn creates an environment for collaboration and instills collaborative behavior.

Notes

1 (Cunningham 2199)
2 (Welsh-Asante 1996) Page 64
3 (Welsh-Asante 1996) page 65
4 (Fujioka et al. 2012)
5 (Hannon and Johnson 2005)
6 (Cirelli et al. 2014)
7 (Hannon and Trainor 2007)
8 (Terry et al. 2012)
9 (Fritz et al. 2013)
10 (Dunbar 2004)
11 (Hagen and Bryant 2003)
12 (Merker et al. 2009)
13 (Launay et al. 2014)
14 (Overy and Molnar-Szakacs 2009)
15 (May 2011)
16 (Oullier et al. 2008)
17 (Wiltermuth and Heath 2009)
18 (Hove and Risen 2009)
19 (Reddish et al. 2013)
20 (Demos et al. 2012)
21 (Robles-De-La-Torre 2010)
22 http://subpac.com/
23 (Konishi et al. 2016)
24 (Yamazaki et al. 2017)
25 (Hayes 2015)
26 (Miura and Sugimoto 2006)
27 (Kanke et al. 2015)
28 (Huang et al. 2010)
29 (Seim et al. 2015)
30 (Rubin-Rabson 1941)
31 (Seim et al. 2016)
32 (Gratton and Erickson 2007)
33 (Leana III and Van Buren 1999)
34 (Newell et al. 2004)
35 (Oh et al. 2004)
36 (Henttonen et al. 2014)

Chapter 3
Concept

3.1 Design Overview

During the design process of Synchrovibes, various previous research has been considered. Most notably the relationship between music and bonding. It has been proved that in various traditional dances across the world, the main purpose is to bring the clan members together and create a stronger sense of belonging in crisis or in joy. Whether it is in the time of waging war in the Maori culture or praying for rain in African Cultures, synchronization between the members has always been of the highest importance. In the case of African dances in particular, synchronization was achieved by following a simple drum beat that would allow participants to synchronize to it and eventually synchronize to each others movements[1]. This mechanism has been of a great inspiration to this project. Another point of inspiration was the use of multi-modality setting and especially haptics to assist with rhythm pattern recognition and reproduction. Previous research has used sound and haptics to teach piano compositions[2], morse code[3] and even brail. in a similar manner, our system relies on a multi-modal configuration to simplify rhythm recognition. Finally, in creating social bonds and a sense of collaboration and community, we set out to develop an experience that is more enjoyable with others and that can be enhanced through collaborating with other participants. To sum up, many elements had to be considered in order to achieve the project's goal. Thanks to previous research and user studies, I was able to isolate these elements and investigate each one thoroughly. The elements this project focuses on are as follows:

- **Music and Movement:** During this section, I explore the relationship that music has with movement and how they complement each other. My interpretation of this relationship is also highlighted.
- **Simplified Synchronization** Since I focus on synchronization as a vehicle

for bonding, in this section, I will explain the approach taken to simplify rhythm synchronization in this project.

- **Bonding, Collaboration and Engagement** As the ultimate goal of this reaserch, creating social bonds between people and an environment to encourage collaboration and engagement can be challenging. To do so, many components are required. During this section these requirements are discussed.

- **Seamless Experience** The importance of a natural design in order to achieve the main goal is discussed.

3.2 Design Elements

Music and Movement

We focus on music as indicator of rhythm and movement as a vehicle to embody the rhythm. The relationship that music has with synchronization has been deeply rooted in ancient traditions and showcased in previous research. In fact a recent research using rocking chairs to synchronize movement suggests that the well-established notion that coordinating movement with another person produces positive emotions[4] May be a product of having a shared experience, in this case moving to music rather than coordinating with each others exact movement. Music also makes for an enjoyable environment where participants can reach a higher tolerance of exhaustion and be able to get immersed in the experience. Projects done with regards to music and exercise where participants created music while using exercise machines resulted in a lower perceived exertion level and a higher level of immersion[5]. Movement is a fundamental component in this concept design process because we believe it is the best way to become one with the music. However it is very important that this movement is particular to the individual. Hence the decision not to include any specific gestures that participants have to follow to synchronize, and focus on allowing them to follow the rhythm according to their desired motion. In this project bonding is created through synchronization and environment rather than coordinated movement.

Simplified Synchronization

It was important to create an experience that would simplify rhythm synchronization for the participants. I decided to follow a multi-modal system to help them perceive rhythm both through sound and also in haptics. Previous research proves that this approach leads to better rhythm recognition and when coupled with other modalities it can even lead to musical instrument learning. This was shown in several research involving piano learning[6], learning the drums[7], and even internalizing morse code [8]. Synchrovibes aim to simplify rhythm synchronization by making it easy to perceive the musical rhythm and making sure participants are aware whether or not they're in-sync. This last feature is to ensure that participants maintain synchrony and get captivated by the experience.

Bonding, Collaboration and Engagement

Previous research shows a strong correlation between social bonding and movement synchronization which can be achieved through music. Bonding is also considered as a prerequisite to collaboration. As a guitar player, I have always found joy in performing with others. The fact that I am a part of a group and being considered a core member of our performance gives me a sense of self-fulfillment. This feeling is particularly strong when I can clearly perceive my contribution to the overall act as I am playing. Inspired by these experience, I decided to put different parts of the music and different instruments in different devices. In this way, each participant actively contributes to the music being produced during the experience. One missing participant would mean that there is one missing part of the composition. This decision is a way to increase engagement and create a sense of collaboration between the participants, further strengthening the bonds that are being created. A similar approach is portrayed in Picaroon's work "Tangible Orchestra[9]".

Tangible Orchestra consists of different parts of a musical composition emitted from street poles that are triggered by proximity (figure 3.1). The more people are in the space where the poles are the more musical parts get triggered allowing them to create a complete musical work.

Figure 3.1: Tangible Orchestra Demonstration, Device lights up when activated

Seamless Experience

Since bonding happens on an emotional level, I decided to limit the amount of distractions during this experience. I believe that including all the technical component in the platform away from the participants sight can benefit greatly in achieving an immersive experience. Moreover, wearables have been voted out in case they would hinder peoples movements or affect them emotionally. It was important that all the sensors and equipment disappear inside the device and that individuals can take part and leave the experience with minimum effort.

3.3 Experience Breakdown

Synchrovibes allows users to synchronize to a base rhythm and stay in sync throughout the experience. Each device represents an instrument and will emit a basic beat pattern using that instrument once stepped on. The user would try to synchronize to the rhythm and will be able to trigger more beat layers the longer she can be in-sync. The beat layers are all prerecorded, the users however can add filters and effects by balancing their bodies on the platform. Since the experience uses 3-4 devices, all of the instruments have been programmed to play at the same basic rhythm, and complement each other. This way, all the participant are part of the same act and the experience would not be completed unless they're all in-sync. This last detail allows the users to be synchronized to the music and in turn synchronized to each others movement. By doing so, even people that met for the first time can bond with each other. The fact that the musical output strictly relies on the synchronization of all the members to the music creates a sense of common purpose, which is to create a complete musical composition and to take it through all the different transitions together as collaborators. Moreover, participation highly relies on body movement which makes for a pure physical activity. The participants have to dance or move their bodies constantly (figure 3.2). This allows the participants to embody the music they are listening to and in turn motivate each other to also dance and let loose. The fact that the experience is open and that the participants can see and hear each others' musical output results in a somewhat competitive environment that motivates them to succeed.

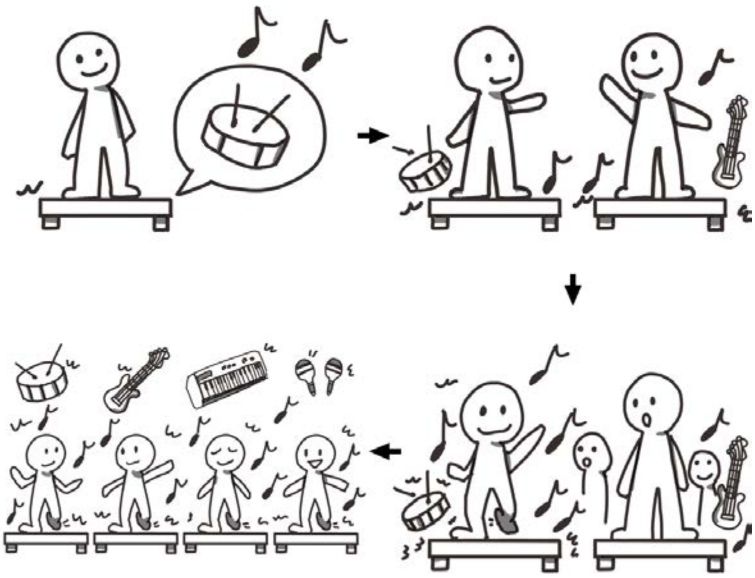

Figure 3.2: Synchrovibes Step by Step experience

3.4 System Overview

The system is composed of several devices that are controlled using one computer. Each device is equipped by a set of actuators, sensors and LEDs. The computer serves as output to music into each device, and each device outputs sensor data into the computer. In order to explain each part more clearly, I will split each component used in the system design in a different section.

Sensors

Each Synchrovibe device is equipped with four bar shaped load cell sensors that have a load capacity of 136KG combined (figure 3.3). Every sensor is attached to a respective leg of the platform used at the device. These sensor are able to detect the change of the weight of the person standing on the device. The four sensors are attached to 4 load cell amplifiers which are in turn connected to one Arduino Uno. In this case the change of weight is considered movement. If the change of the weight is happening at the same interval as the rhythm, then the system considers that the user is in-sync. The fact that each one of these sensor collects data independently allows users to add filters and effect to the music just by balancing their posture on the board.

The data tracked by these sensors is sent to arduino which communicates with Max for live through Serial Port. This data is gathered by Max for Live, funneled through an algorithm and made to use.

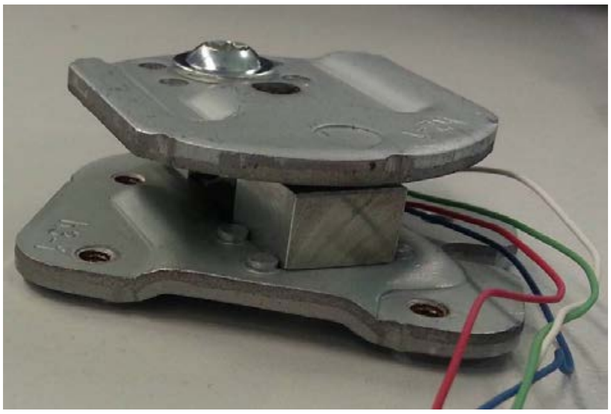

Figure 3.3: Bar Shape Load Cell Sensor

Haptics

Each device is equipped with a tactile transducer. (ClarkSynthesis TST239 Silver Transducer) to create the haptic feedback and produce the sound for the music at the same time. This transducer is placed under the platform in order to provide the feedback to the feet of the user (Figure 3.4). Each transducer is attached to a respective amplifier which is in turn hooked up to an audio interface. This allows the software used (Ableton Live 10) to route each part of the music to the respective Synchrovibe device. These transducers are able are able to provide a high quality tactile haptic feedback as well as good quality sound.

Figure 3.4: Placement of Transducer

Lighting

The devices are embedded with LED lights that react to the music beat. The body of the platform has been hollowed, planted with LED strips and then covered with Sanded acrylic. This design decision allows the LEDs to light up on a larger surface and cover the hollowed area with color (Figure 3.5). The lights only turn on once the users is on top of the platform, and the colors change based on each different beat being produced.

Each LED strip is attached to an Arduino Uno that communicates with the software using serial port. Every time a different note has been hit, Abelton notifies Max for Live which notifies Arduino and colors change.

Software System

In this experience 3 different software are being used, Arduino software, Abelton Live 10 and Max for Live.

- **Arduino Software:** Two different patches are being used. The first one gathers the sensor data that is being sent to the Arduino Uno from the

Figure 3.5: Placement of LED lights

Load Cell Amplifiers. The second patch is a customized NeoPixel Library program that takes values from Max for Live and sends them to the LED lights.

- **Abelton Live 10 :** Abelton Live is used for Content making of the music in MIDI format and also to output the music to the devices through the Audio Interface. This software sends MIDI data to Max for Live which in turn communicates with Arduino to change the LED colors. Live also assures that all the tracks are playing at the same rhythm and enables collaboration between users.
- **Max for Live :** Max is the software that does the heavy lifting during Synchrovibes. It is composed of 4 different patches. An activation patch, a synchronization patch, lighting Control patch and and effect control patch.
  1. *Activation Patch:* This program receives data from the Load Cell sensors through Arduino and detect whether the user is on the platform or not. Based on this information, it communicates with Abelton Live to activate or deactivate the music.
  2. *Synchronization Patch:* The synchronization patch receives information from the Load Cell sensors through Arduino, Calculates the rate

of change of the value and compares it to the rhythm of the music. If it judges that the rate of change is aligned with the rhythm, it will then control Abelton Live to activate more layers of the music and vice versa.

3. *Lighting Control Patch* The lighting control patch receives MIDI data from Abelton Live based on the notes being played in each music layer. This data is then converted to RGB based on work by Langfeld that attributed colors to different notes[10]. The RGB data is then sent to the LED lights through the arduino Controller. These color patterns are also inspired by Tokyo based Artist Nor in his work "Hereing"[11].
4. *Effect Control Patch:* This patch detects the balance of the user and the pressure that she is putting on top of the platform. This data is then sent to Abelton Live which converts it to different audio effects such as reverb or echo.

The software system flow chart is as follows (Figure 3.6)

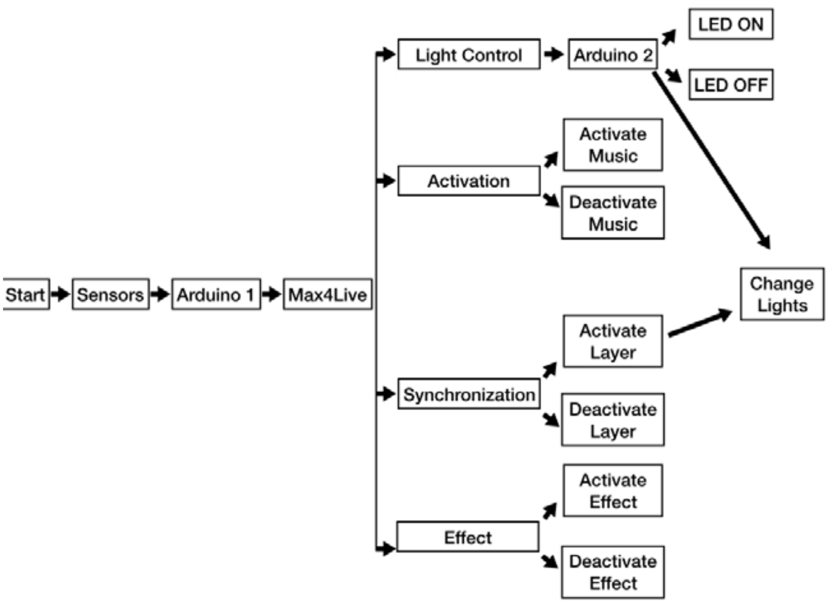

Figure 3.6: Software System Configuration Flow Chart per Device

The overall overview of the whole system using 4 different devices is showcased in figure 3.6. It show the combination of the hardware part included in the design of the system as well as the connections that each one of the devices has with each other.

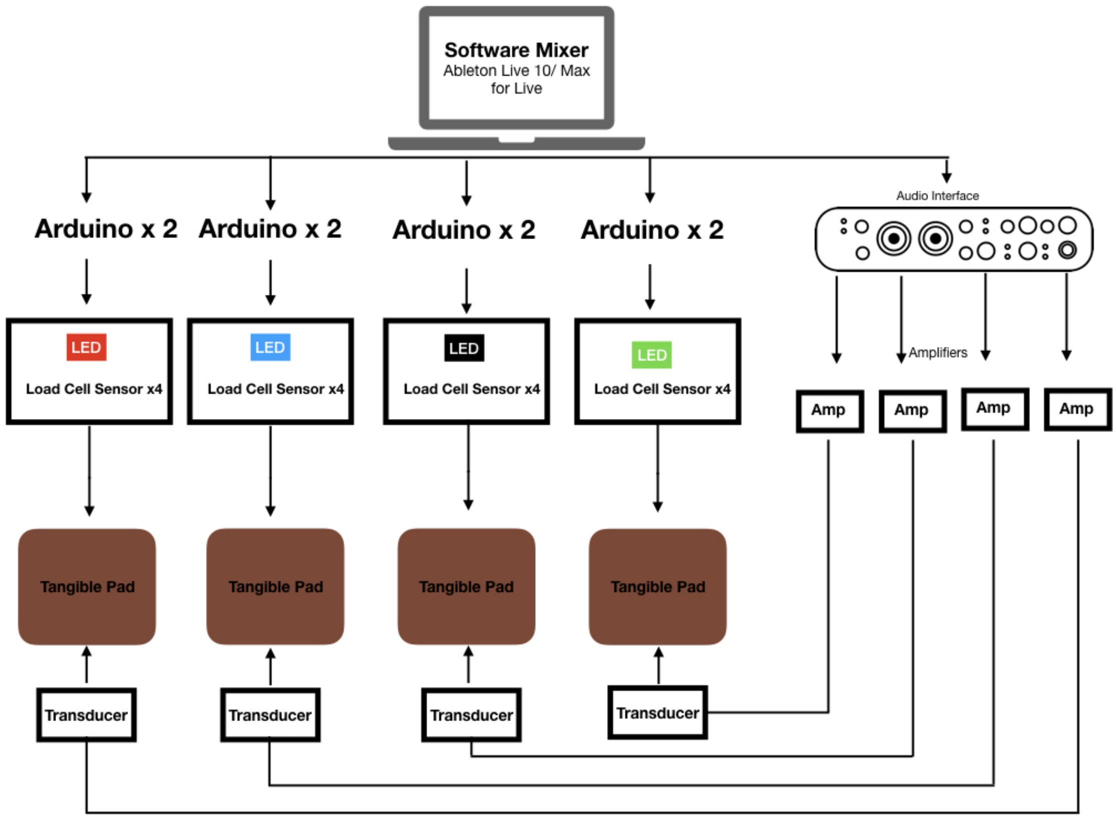

Figure 3.7: Overview of the system including 4 different devices

3.5 Product Design

The shape of the product was inspired by the drum-pad buttons on a MIDI controller. The fact that you can store different beat patterns and parts of the song in different buttons has influenced my design process. Similarly, the Synchrovibes platforms are shape in squares and "store" different parts of a song that are triggered with the person's movement. The shape is also inspired by tiles on a floor. When people dance, they usually do that on a wood dance floor because it provides the best medium for smooth movement and it conducts vibrations produced by the speakers. Following this basis, the device is made out of wood and equipped with a tactile transducer placed at the bottom of the device. The final size of each device is 60cm x 60cm. This surface ensures freedom of movement and allows users to concentrate on the music without being distracted by the risk of falling off the platform.

I decided to embed the LED lights inside the structure and attach each sensor directly to the leg of the device in order to have a standalone device that could be used outdoors as well as indoors. Moreover, having all the parts included in the structure allows users to take part in the experience and exit it in the most convenient way possible.

3.6 Interaction Design

In order to achieve the desired interaction, several components had to be included. Some of these components play a crucial role in the interaction design process and the users engagement. These components are as follows:

- **The Element of Surprise:** During Synchrovibes, the platforms are idle until the person steps on them, then they immediately react. Music, lights and haptics are instantly activated upon engagement and deactivated once the person is off the platform. This direct fast response makes up for an important element of surprise that helps captivate the users and engage their sense of curiosity about the experience.

- **Distinct Layers:** Once users synchronize to the rhythm of the first track for a certain amount of time, the second layer of that instrument is triggered. It is very important for this layer to be easily discerned from the base track and so are all the other layers. This is an indication for the participant that she is in Sync with the music and it also provides a sense of music creation. Adding subtle changes that only people familiar with music making can recognize.

- **Multiple Layers/Different Times:** It is important to have multiple layers of music representing each platform during Synchrovibes. These layers keep the users looking forward to the different variation of the song while also motivating them to stay synchronized and keep moving (Figure 3.8). The challenge here is to make sure not to give away all the layers within the first minute and also to make sure the music does not get overcrowded and become noise. This was achieved by having different layers activate at different times. For example, if the first layer activates after 10 seconds of synchronization, the next one will get activated after 30 seconds...etc. These intervals are decided based on the type of content and number or available layers.

- **Creating Music:** In order to create an environment that inspired collaboration, it is important that each person contributes to the making of the music being produced. This can be challenging if layer 2 of the drums does not fit with layer 4 of bass. I had to keep in mind that not everyone can synchronize at the same time, consequently all the different instrumental layers had to complement each other regardless of the speed of synchronization of everyone. At the same time, activating other layers was based on achieving the same pace of synchronization in the middle of the experience. These layers all played at the same BPM of 120 at quarter note delay to ensure that the rhythm being played is the same across instruments and across layers too.

Figure 3.8: Multiple Music Layers on Ableton Live

Notes

1 (Welsh-Asante 1996)
2 (Seim et al. 2015)
3 (Seim et al. 2016)
4 (Demos et al. 2012)
5 (Henttonen et al. 2014)
6 (Seim et al. 2015)
7 (Kanke et al. 2015)
8 (Seim et al. 2016)
9 http://www.picaroon.eu/tangibleorchestra.html
10 (Langfeld 1915)
11 https://nor.tokyo/herering/

Chapter 4
Implementation

In order to identify the elements needed to achieve this experience, several prototypes have been created. Through various user studies and field testing, many observations and feedback has helped me refine Synchrovibes. The prototyping time line consists of 3 product and experience iterations and the final product. Each one of these iterations has been tested in the field with more than 40 people of different ages, cultures and backgrounds. The experience has also been tested in events with different lengths, from 1 to 5 days. These tests also took part in 3 different countries and including 2 continents. The events that each one of Synchrovibes iterations took place are: **Keio Media Design Forum, Dubai International Film Festival, SXSW Education Playground and Embodied Media Project Open Lab.** In this chapter, I will be describing each iteration and field test. I will also provide the feedback and observation in each part accompanied with the design decisions that they inspired.

4.1 Field-Test 1

Prototype 1

Product

The first prototype that was created consists of three different platforms, 45cm x 45cm each. These platforms were equipped with a Vt7 Vibro-trasducers from Acouve Laboratory, along with regular sound speakers both placed under the platform. This prototype used a pressure sensor attached to one of the legs to detect if the person is on the platform or not. It also used an accelerometer sensor attached to the bottom of the plate to detect the movement of the user (Figure 4.1).


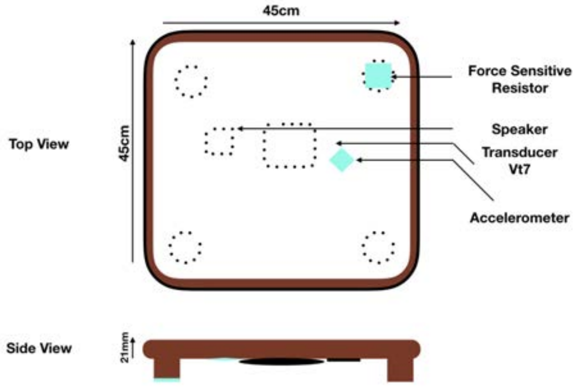

Figure 4.1: Synchrovibes: Prototype 1 at Keio Media Design Forum (left) Hardware Design (right)

Experience

Each one of the devices was assigned to an instrument and had a combined set of layers that would play at the beginning. It was divided into Drums, Bass and Synthesizer. The song would become complete by simply having 3 people on top of each platform respectively. Movement, however, would trigger different effects according to platform. Moving on top of the device designated to the drums would trigger a MIDI effect that can repeat a certain beat in time. The other two devices had a reverb and an echo effect assigned to them respectively. Here movement was not aligned with rhythm and any random jumping or dancing would trigger the effects. The main purpose here was to motivate people to enjoy the music through movement regardless of synchronization.

Setting and Participants

This field test took place at Keio University, Keio Media Design annual forum. It was held in the month of November and spanned over the weekend. The majority of the participants were families with their kids. Within the two day event, we had more than a 100 people come to the event and the demonstration was very popular. Kids that did not know each other joined in the experience and parents alongside their kids jumped and danced together (Figure 4.2).

Figure 4.2: Left: Group of kids during experience. Right: Family during experience

Feedback and Observations

The most prominent feedback that I kept getting over and over from the participants is that the haptic feedback acted like a pushing force for them to continue moving and aligning their movement to the hits under the platform. This feedback later on helped shape the experience greatly. Another useful feedback was that families felt happy they could engage in a physical fun activity with their kids. They also expressed that it is a good way for kids that do not know each other to have fun together. The mid-age participants (Mostly University Students) said that they enjoyed the fact that they can contribute to the completion of the song. On the other hand, many participants reported that they were unable to recognize the variation in music once the effect has been activated. In fact, the only apparent variation was the drums because the beat pattern changed using the MIDI effect.

I noticed that the element of surprise was a big factor in the success of this demonstration. Many people were surprised that the music would start and stop based on whether they are on top of the platform or not. Many people were also interested in "feeling" what different instruments felt like. I also realized that this experience was very short. Even though there was one kid that did not leave until he was dragged away by his mom, most people spent about 2-3 minutes on average. Finally, since I did not account for kids during my initial design process, I deduced that children also enjoy physical activity related to music, such as jumping and dancing.

Future Work

Thanks to this first field test I decided to modify certain aspect of the experience to address some issues. I also used some of the positive observations and feedback as inspiration for my next iteration. The following steps were on my to-do list:

- **Change in music:** additional audio effects are hard to recognize. However Drum Beat repetition was a success
- **Aligning movements with haptics:** The fact that people tried to align their movement to the hit that they felt under them provided me with an opportunity to explore this relationship more in-depth.
- **Length of Experience:** The experience has to be more engaging to captivate the users longer.

4.2 Field-Test 2

Prototype 2

Product

The design of the device went through several changes compared to the first prototype. During the first field test, the vibro-transducers failed to produce haptic feedback for synthesizers that were not very edgy. In order to solve this problem Vt7 transducers were replaced by ClarkSynthesis TST239 Silver Transducers. The transducers also provided high fidelity sound, so the addition of regular speakers was unnecessary. Inspired by the past interaction that users had with haptics, tracking users' exact movement on top of the platform became necessary. In order to do this, the accelerometer sensors have been replaced with Piezo sensors. The platforms were also hollowed on the side and LED lights were added in order to increase immersion and engagement (Figure 4.3).

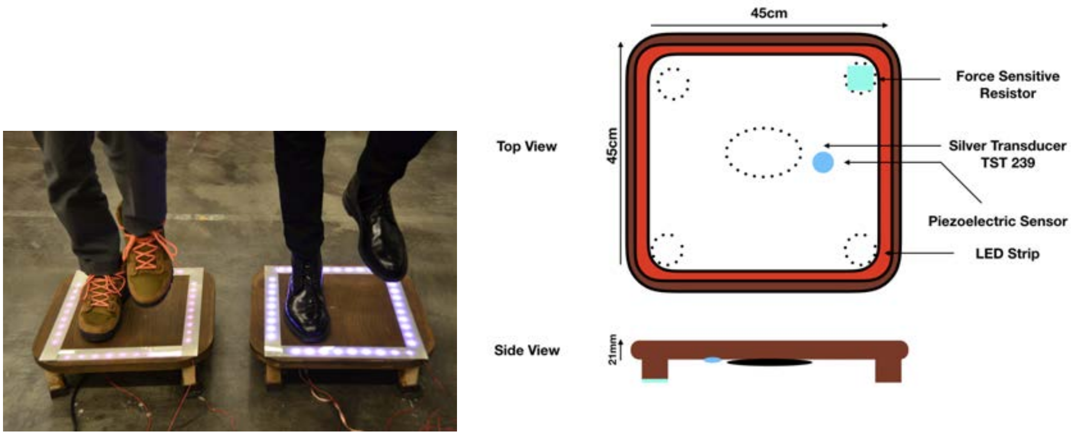

Figure 4.3: Prototype 2 Product Design (left) Hardware Design (right)

Experience

The experience underwent various adjustments. Inspired by the Drum beat repetition MIDI effect, I decided to make the music change based on layers of music rather than audio effects. Once the participant starts moving on top of the platform, more music layers will get activated. This movement was also further defined. Using the Piezo sensor I was able to identify knocks on the platform top from the people's feet motion. I compared the rate of the change in the sensor reading with the rhythm of the song. The music layers will only be activated if the above is correct and maintain over a certain period of time. The LED lights installed also changed colors based on the rhythm of the song thus providing another rhythm indicator and offering more immersion. Each devices included a total of 3 variations including the base sound upon activation.

Setting and Participants

This field test took place at the Dubai International Film Festival. DIFF had an interactive exhibition area that was part of their entertainment and technology theme and we were invited to showcase some of our work from the Embodied Media Project. The participants were mainly ranging between high-school students and adults with few children. I was able to demonstrate this work to group of teenagers and adults from totally different cultural background. This helped prove that this concept can be transcendent of culture (figure 4.4).

Figure 4.4: Dubai International Film Festival Teenagers during Synchrovibes Experience

Feedback and Observations

Dubai International Film Festival was a great opportunity to show my work both to people interested in the entertainment field and others in the industry. I was able to gather a lot of feedback. People said that they felt like they were producing music based on their movements. Everyone said they were very happy to be able to synchronize to music, and even people that could not dance were satisfied to notice that they could develop a sense of rhythm. Participants reported that the multi-modality helped them recognize the rhythm more easily, and the instant musical feedback was assuring them that they are on the right track. A salsa dance, however, wished that she did not have to lift her foot every time while moving for the system to recognize her motion. Many others were also dissatisfied with the size of the platform. Others said that they wanted more layers and that 3 layers per platform was not enough.

I also observed people's interaction with the device and found out that the aspect of collective music making resulted in smiles between users. Participants that were able to synchronize well felt closer to each other and wanted to prolong their experience. This observation helped further confirm the relationship between music synchronization and bonding. It also affirmed that this relationship goes beyond cultural differences. On the product design side, the addition of lighting helped enhance the element of surprise and increase immersion in the experience. I also realized that having to bang the platform for rhythm recognition was distracting and that more experienced dancers had different moves that were unrecognizable by the system. The size of the platform was also an issue. People were moving but feared falling off and the platform flipping over.

Future Work

This experience overseas helped enlighten my research further more and provided me with helpful insights. After the 5 day exhibitions, I had a clear idea about the components that I need to keep and build on and those that needed to be rectified. Moving forward, these are the points I would focus on:

- **Any Synchronized Movement:** I had to focused on people's synchronized movement regardless of that motion. In other words, even a slight movement should be recognized by the system and music layer should be activated as long as the movement is synchronized.
- **More Layers:** I decided to add more musical layers per platform to keep the users engaged longer during the experience.
- **More Interactions:** I had to think of more interactions to enhance the experience and elevate the sense of collaboration between users even more.
- **Size and Safety** The size of the platform had to be improved and something had to be done about the safety aspect of using this device.

4.3 Field-Test 3

Prototype 3

Product

The major iteration in the third prototype is the sensor system. I substituted the Piezo sensor and the pressure sensor for 4 Load Cell Sensors. These sensors were attached to each leg of the platform. Doing so, allowed me to track every slight movement of the person during the experience using the difference in weight.

Using 4 sensors per platform offered an opportunity to add more interactions (figure 4.5).

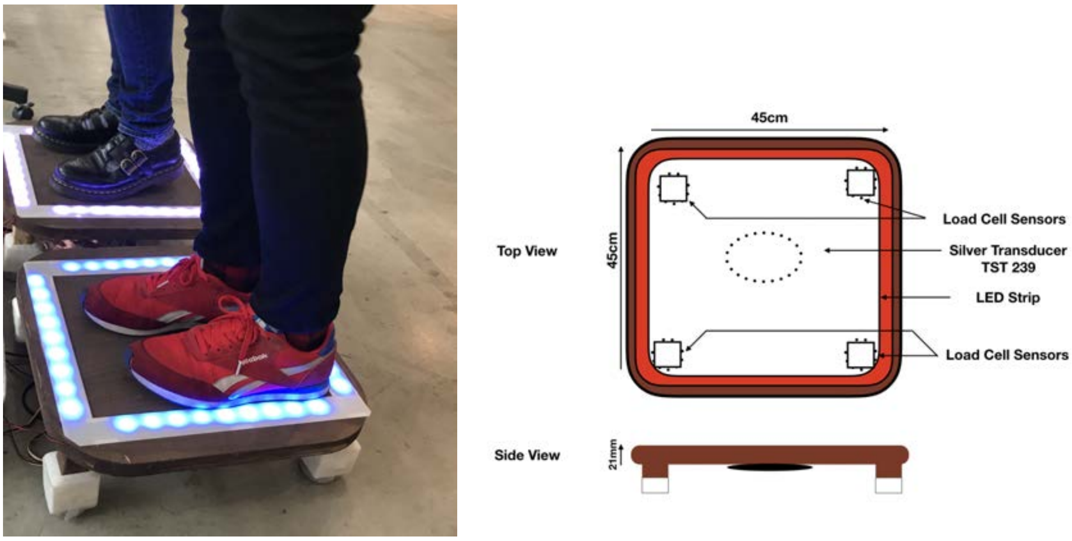

Figure 4.5: Prototype 3 Product design (left) Hardware Design (right)

Experience

The third iteration focuses on detecting slight motion and comparing it to the rhythm of the music. In other words, users can move freely and they can trigger musical layers as long as that movement is aligned with the rhythm of the base music being played on activation. 5 layers have been added per platform to keep the users more engaged. I added an additional interaction where users can add reverb or echo audio effect by leaning to the right or left respectively. This part aims to motivate the sense of collaboration more during the experience.

Setting and Participants

This last iteration has been showcased at SXSW Education Playground as well as at Embodied Media Project Open Lab. In the first venue, the main goal of the conference was to present new tools for education. Synchrovibes is a system that helps users recognize the musical rhythm which is the first step to learning how to play music [1]. It also ensures human bonding and promotes collaboration, which are some of the most needed skills to succeed in the 21st century[2]. The attendees at SXSW were mostly educators with some industry people and few high school/ university students (figure 4.6). At the Embodied Media Project Open lab, there was a mix of university students interested in technology and some engineers/designers.

Figure 4.6: Left: Demo at Embodied Media Project Open Lab. Right: Demo at SXSW Education Playground

Feedback and Observations

Exhibiting at SXSW Education Playground was a great opportunity to meet with teacher and pitch the idea of Synchrovibes as a medium to learn rhythm synchronization, and the possibility of using it as an activity to increase bonding between students and motivate the sense of collaboration. Many educators expressed a lot of interest in the device. They were especially impressed by the playfulness of the experience. They said that it is a less intimidating introduction to music learning and team building among students. At The EM Open Lab, users said that they were satisfied with the fact that their unique movements are being recognized. Being able to add effects to different layers was interesting for them as well. I noticed many people dancing and at the same time putting pressure on the board to activate the effects. I also noticed an immediate gratification on the face of users between each other when they realize that collaboration is happening and that their movement is helps creating music together.

On the minus side, the size and safety of the device was still a problem and participants were not able to move freely and rather had to stay in the same place all the time. I also noticed that the addition of musical layers did not significantly contributed to the prolonging of the experience.

Future Work

After processing the amount of feedback and observations that I gathered at these two events I needed to tackle two different problems.

- **Sophisticated Content:** Simply adding layers was not enough to captivate users longer during the experience which resulted in exiting the demonstration earlier than desired. I had to find a better way to organize the musical track in order to make a more intricate musical progression that can engage the users more.
- **Size and Safety:** As mentioned before, The size and safety concerns have to be addressed.

4.4 Final Design

Product

Throughout all the experiences that I had and the field tests that I conducted, I arrived at the final stage of my design process. During this part, I addressed the product design concerns that I had before, which was the size of the device. From 45cm x 45cm, the new design now is 60cm x 60cm. This allows the users to move freely on top and provides a feel of own stage. Regarding the safety concerns, a layer of wood has been added to the bottom of the device to prevent it from flipping while the users are dancing on top of it. The sensors have also been attached to both the legs and the bottom wood partition to ensure a better data reading, regardless of the type of flooring that the device is used on (Figure 4.7). The shape has also been changed to a perfect square to allow participants to use if from a distant and also group devices together to make a mini stage where they can feel closer to each other.

Experience

The experience design has also undergone several improvements. The most common feedback that I received until now is that the users want more changes to the

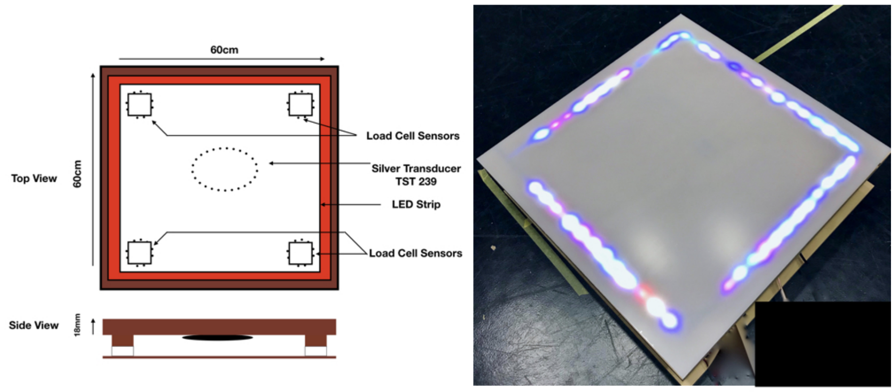

Figure 4.7: Left: Hardware Design Right: Final Product Design

music. Starting from effect changing to 5 layers of music addition did not seem to be satisfactory enough for my main users. Keep adding more layers to the music would only result in an overcrowding of sound and the experience would lose it immersion. To tackle this problem, I looked at my different instrumental songs that use the same instruments that I am applying to Synchrovibes. Following a similar structure, I decided to focus on "variation" instead of "addition". In other words, the users movement is not going to trigger layers of the music but it will make the music progress, adding layers, deleting layers and highlighting some parts of the music as well. I followed a classic music progression diagram of Intro, Verse1, Chorus, Verse2, Chorus, ending (Figure 4.8).

- **Intro:** This is the phase where the user gets on the platform and experiences the first base of the music when it is activated. During the intro part, the users can trigger one variation of the music through synchronization
- **Verse1:** During this section, 2 more layers of the song are activated after a certain time of synchronization (about 15seconds each).

Phase	Intro	Verse1	Chorus	Verse2	Chorus	Ending
Layers	2	2	3	2	3	2
Time	15s x 2	15s x 2	30s x 3	15s x 2	30s x 3	15s x 2

Figure 4.8: Final Experience Song Progression

- **Chorus:** The chorus is the most exciting part of the experience. It is where the participants get used to the experience and get immersed into it. The verse1 layers are deleted, the Intro parts will remain and 3 layers will get activated at an interval of 30 seconds each.
- **Verse2:** The second verse is different from the first one. Once this stage is reached, The parts of the chorus stop playing and two layers get activated with a interval of 15 seconds each. First the intro + 1 layer would play, and 15 seconds later the second layer will get activated. This will be for another 15 seconds, before going back to the chorus.
- **Chorus:** The Second verse would turn off and the 3 parts of the previous chorus will play again with a 30 seconds interval and playtime each.
- **Ending:** The ending consists of two layers of the music that play for 15 seconds each. Right after the ending, the music goes back to the base sound that it started at.

  This brings the total of the experience to a 4 minutes 40 seconds length.

4.5 Proof of Concept

Synchronization and Bonding

This first study focuses on the effect Synchrovibes has on the synchronization of movement between participants and the music they are listening to. The objective of this study is to prove that users can be in-sync with the music faster and can maintain that state longer.

Setting and Participants

This study was conducted at the Media Studio in the collaboration complex of Keio University Graduate School of Media Design. 6 participants took part in this experiment, 5 of them identified themselves as females and 1 identified himself as male. These participants were divided into two different groups. The first group (Control) only received sound as an output of their movements. The second group (Experimental) received a multi-modal output, with sound and haptics. Both of the groups were asked to synchronize to the music and continue synchronizing until the experience was over.

Results

During this experience, the music was recorded on a 120bpm and using a 1/4 note. This means that each note is played at a 500ms interval from the next one. The sensors recorded the change in weight every time the balance between the two feet of the user is broken. Since we have two feet, the balance is recorded at a half time the rhythm which is 250ms. In other words, the sum of both readings equals the full interval between notes, which is 500ms. As long as the participants movements are closer to 250ms, the system judges that they are in-sync. This data was recorded for both the "Sound Only" group and the "Multi-Modality" group. The graph below shows that even the sound only group members were able to move close to the 250ms time frame (Figure 4.9). The majority of their movements were recorded between 238ms and 273ms. If we compare these results with those of the group that received both haptics and sound, you can see that there is a trend of incrementation in synchronization, and accurate synchronization (figure 4.10). In fact, individual data shows a large number of movement between the interval of 254ms which is very close to the accurate rhythm 250ms. This trend proves that better synchronization can be achieved through Synchrovibes.

Synchrovibes and Collaboration

The purpose of this second study is to analyze the collaboration aspect of Synchrovibes. The approach taken to do this was purely qualitative using two official questionnaires and one own made survey.

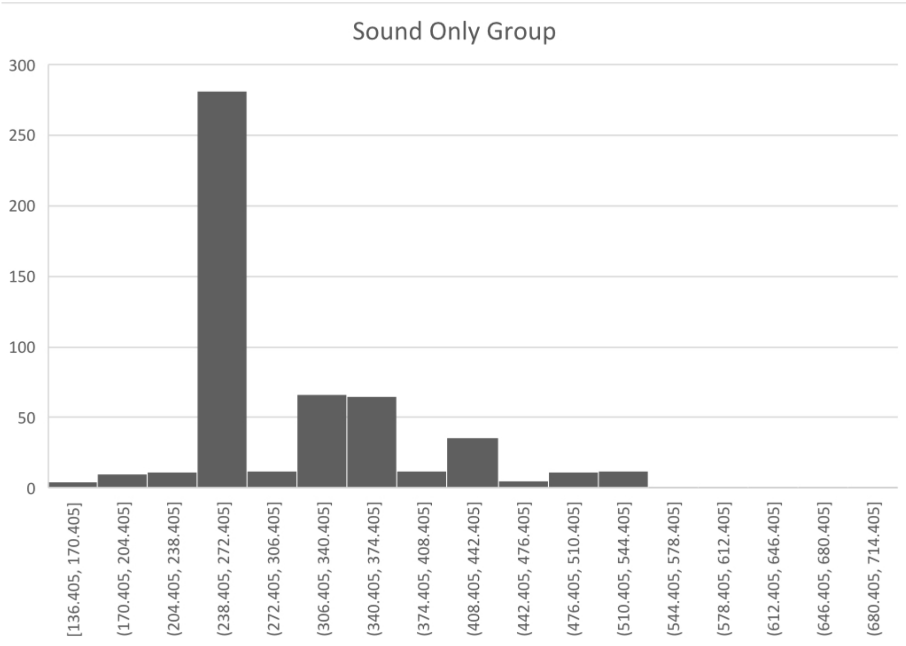

Figure 4.9: Synchronization of the sound only group in milliseconds

Setting and Participants

This experiment was conducted in the Media Studio at Keio University Graduate school of Media Design. 6 participants took part in this study, with 50/50 male to female ratio. This was a within subject experiment, where the users were put into two different groups, but each group went through the control and the experimental phase. The control phase consisted of routing all the instruments that make the experience in each one of the devices. In other words, each device would play Bass, Drums and Synthesizer at the same time. The experimental phase was the Synchrovibes experience, with each device having a unique instrument. During the control phase, movement synchronization of each user results in the same music output. In the experimental phase however, each individual's movement synchronization results in a different musical output that complements the other users'. The participants were asked to take the Working Alliance Inventory (Figure B.1) survey revised to only include the bond scale. They were also asked to take the Team effectiveness survey (Figure B.2) and one more own made bonding survey based on the Rocking chairs research [3]. The users took these 3 surveys

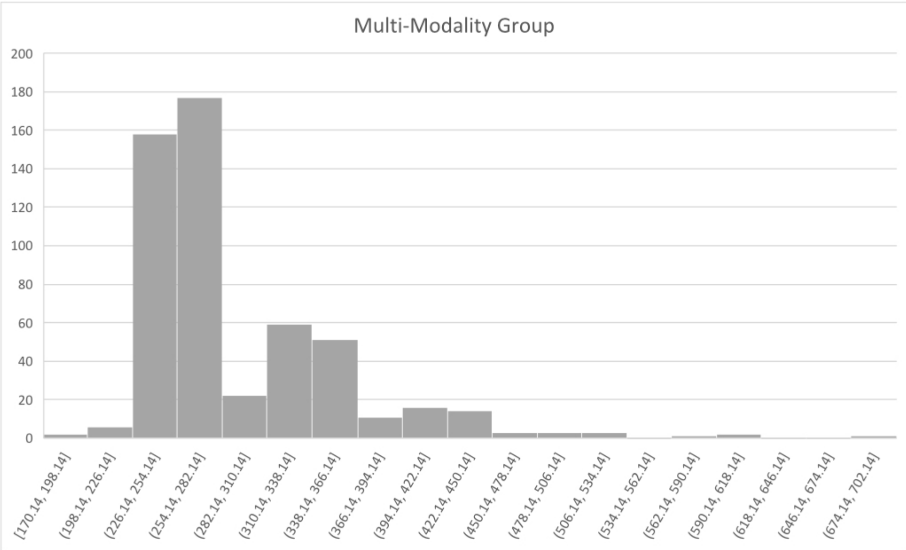

Figure 4.10: Synchronization of the sound only group in milliseconds

twice after each phase.

Results

The averaged results of the Working alliance Inventory only show a slight increase in bonding from the first and second phase between 5 and 5.5 out of 6. The team effectiveness survey also shows a slight increase between both phases (Figure 4.11). When the results are isolated by factors, the team relationship factor shows a more significant change between the phases (Figure 4.11). Most of the participants however showed signs of collaboration where they created their own choreographies and moves to go through the experience. This proves the potential of Synchrovibes to induce collaborative behavior between participants and influence their behavior. I believe that a more significant data driven result can be achieved with a larger poll of participants.

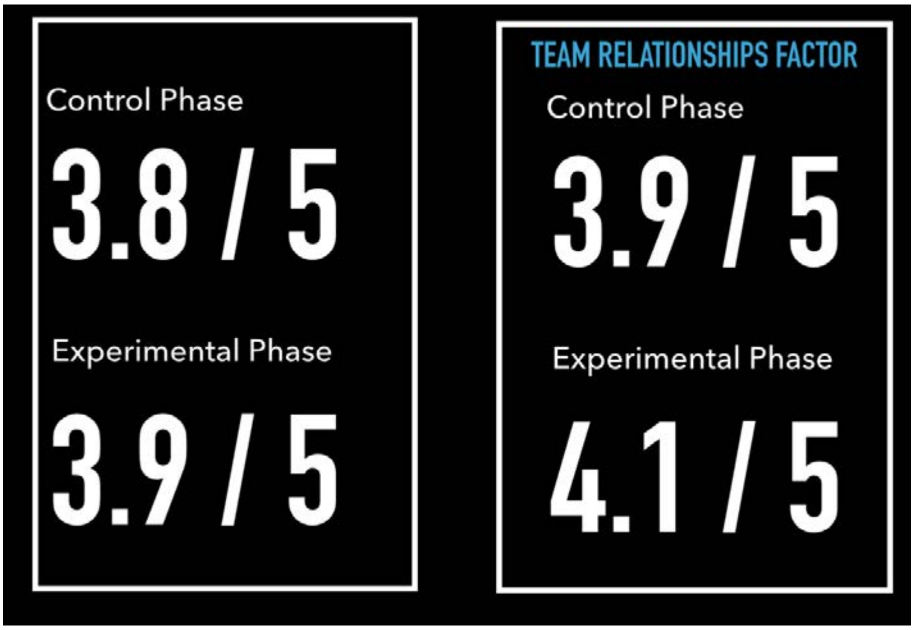

Figure 4.11: Left: Results of the Team effectiveness survey between phases. Right: Results Isolated by the relationship factor of the survey

Feedback and Observation

During these two experiments I was able to gather lots of feedback. Some of the most prominent opinions were that the multi-modality approach created a more immersive environment for the participants. Participants also reported that the experience was a team effort and that they developed a sense of team accomplishment post trial. I observed that many people stayed in the experience more than 3 minutes during the experiment phase that included all the different modalities. I also observed that some people wanted to be closer to each other and changed the placement of the devices to achieve that. Others wanted to face each other while moving. This was especially interesting for me because it provides an opportunity to try Synchrovibes in many different space settings and compare them to find the best way to create bonds and induce collaboration between participants. Some of the suggestions I received from the participants were to dim the lights during the experience to increase the effect of the LEDs and increase immersion. They also stated that a triangle or circle shaped placement of the device would feel more intimate.

Notes

1 (Zatorre et al. 2007)

2 (Soffel 2016)

3 (Demos et al. 2012)

Chapter 5
Conclusion

This project introduces a multi-modality music experience that creates bonds and promotes collaboration using synchronization. Throughout extensive background research, it was discovered that bonding and movement synchronization are highly connected. This research explored better ways to achieve synchronization and prolong it using music as a medium. During the experience, synchronization was achieved more efficiently using a combination of sound, haptics and lighting. The immediate reaction of the system helped users stay synchronized throughout the experience. Overall, Synchrovibes was successful in captivating users and creating bonds between people that did not even know each other before. They were able to let loose and enjoy the experience while being aware that they are sharing it with others. The idea that every person matters helped Synchrovibes tap into the realm of collaboration. Every participant was directly impacting the others experience and vice-versa. In other words, it was a collective effort with each person being a valuable piece of the puzzle.

Overall, I believe that the extensive field testing played a major role in shaping this experience, and help bringing it to life. What started as my idea of a good experience, got painted by peoples' feedback, emotions and reactions to become a complete canvas. I found out that bond creation transcends cultures and language barriers. I also found out that the love of music and dancing is universal, so was the fear of embarrassment. Moreover, people's delight, surprise and positive reactions proved the novelty of the experience over and over again. Whether they were kids or grandparents everyone was surprised and compelled to participate.

Even though Synchrovibes was perceived positively by different participants, and successfully induced bonding and collaboration, It still needs improvements to achieve complete immersion. This can be attributed to the fact that people are fearful of embarrassment. Since not everyone has confidence in their dancing and movement skills, it was difficult to encourage some to move. I am confident that further design process could remedy to this and help reach full immersion.

5.1 Future Work

Moving forward, I want to explore the several limitations that I ran into during my thesis project. I believe that further work regarding content and direct implications in regards to collaboration should be explored. So far, post experiment follow up have not taken place and whether Synchrovibes has a long term effect on participants has not been proven. In my postgraduate, I would like to research the effect that different musical content has on participants. I also want to investigate more ways to engage the participants to collaborate within Synchrovibes. I have no doubt that more field testing is important to gather different insights and collect people's feedback in order to achieve the ultimate experience.

The first step towards my goal will be exhibiting at the Inter-Communication Center (ICC), NTT's Media Arts Museum. We will be showcasing Synchrovibes in a different setting, and mainly involving both kids and their significant adults. During this exhibition, the same experience will be used with a more emphasis on freedom of participation. Since this will be a 1 month long exhibition, several musical content will be created and rotated during that time. This will allow me to compare the effect different content has on people and gauge the level of interest such an experience can attract.

Moreover, I will be presenting my findings alongside with the testing done at ICC to the Computer Human Interaction conference (CHI) in 2019. This will allow me to publish my work and make it available for anyone interested in the same field as me to access.

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Appendix

A Example Codes

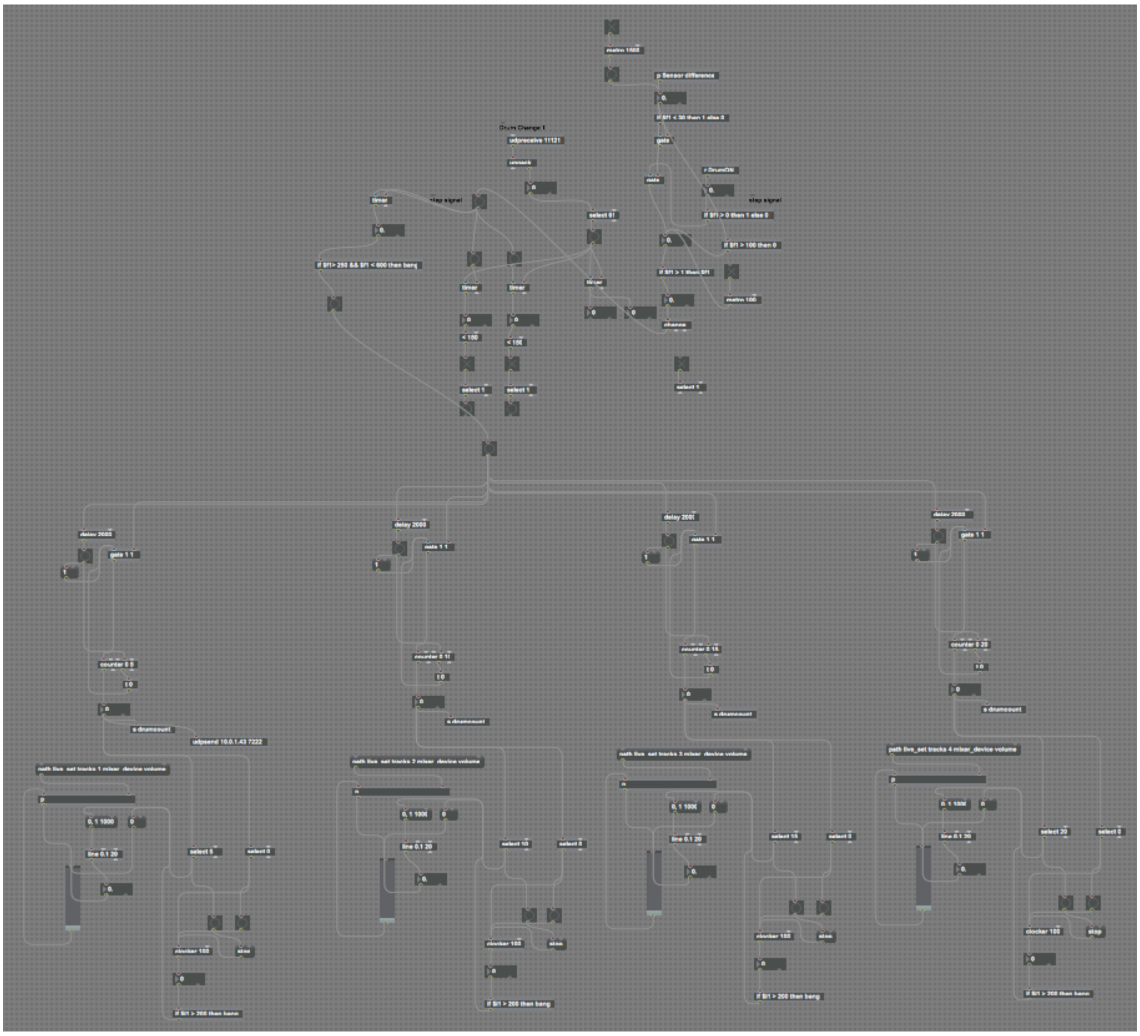

Figure A.1: Example of Layer Control Patch on Max for Live

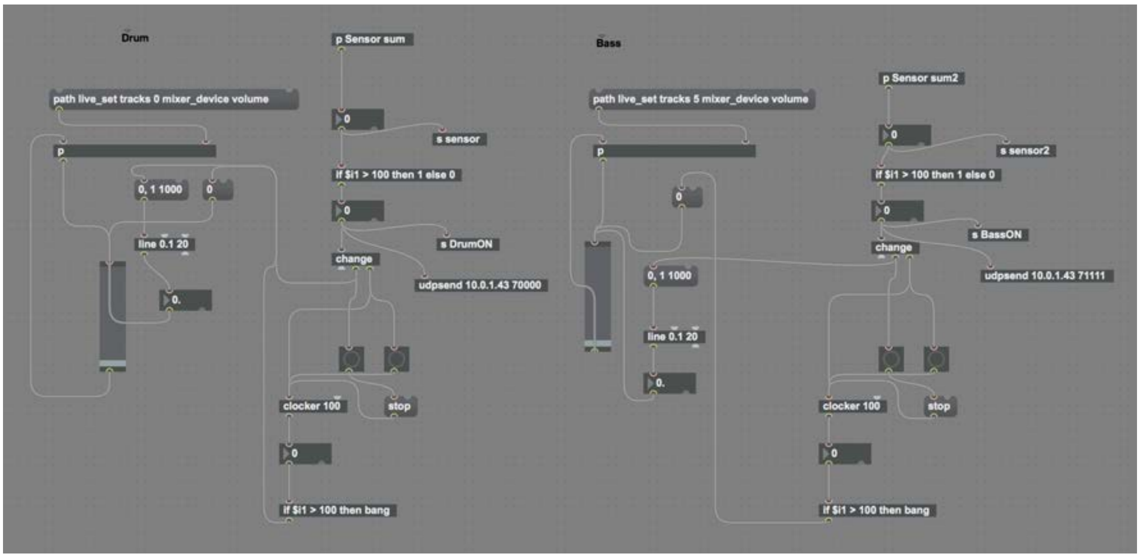

Figure A.2: Example of Music Activation Patch on Max for Live

B Surveys

Working Alliance Inventory

1. **Group**
Mark only one oval.
- C
- E

2. **Number**

____

3. **Gender**
Mark only one oval.
- Female
- Male
- Prefer not to say
- Other: ______________

4. **I felt Comfortable with my partners**
Mark only one oval.

	1	2	3	4	5	6	7	
Never								Always

5. **My partners and I understood each other**
Mark only one oval.

	1	2	3	4	5	6	7	
Never								Always

6. **I believe my partners liked me**
Mark only one oval.

	1	2	3	4	5	6	7	
Never								Always

7. **I believe my partners were genuinely concerned with my performance**
Mark only one oval.

	1	2	3	4	5	6	7	
Never								Always

8. **My partners and I respected each other**
Mark only one oval.

	1	2	3	4	5	6	7	
Never								Always

9. **I feel that my partners were not totally engaged in the activity**
Mark only one oval.

	1	2	3	4	5	6	7	
Never								Always

10. **I was confident in my partner's ability to perform the task**
Mark only one oval.

	1	2	3	4	5	6	7	
Never								Always

11. **I feel that my partners appreciated me**
Mark only one oval.

	1	2	3	4	5	6	7	
Never								Always

12. **My partners and I trusted each other**
Mark only one oval.

	1	2	3	4	5	6	7	
Never	◯	◯	◯	◯	◯	◯	◯	Always

13. **My relationship with my partners was very important to me**
Mark only one oval.

	1	2	3	4	5	6	7	
Never	◯	◯	◯	◯	◯	◯	◯	Always

14. **I had a feeling that if I did something wrong my partners would stop working with me**
Mark only one oval.

	1	2	3	4	5	6	7	
Never	◯	◯	◯	◯	◯	◯	◯	Always

15. **My partners and I collaborated on completing the activity**
Mark only one oval.

	1	2	3	4	5	6	7	
Never	◯	◯	◯	◯	◯	◯	◯	Always

Figure B.1: Academic Alliance Inventory

Collaboration Survey (Team Effectiveness)

1. **Group**
   Mark only one oval.
   - ◯ E
   - ◯ C

2. **Number**

   ____

3. **Gender**
   Mark only one oval.
   - ◯ Female
   - ◯ Male
   - ◯ Prefer not to say
   - ◯ Other: ____________

4. **Our team has a meaningful, shared purpose.**
   Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	◯	◯	◯	◯	◯	Strongly Agree

5. **Team members clearly understand their roles.**
   Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	◯	◯	◯	◯	◯	Strongly Agree

6. **Team coordination results in effective experience**
   Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	◯	◯	◯	◯	◯	Strongly Agree

7. **Team members take personal responsibility for the effectiveness of our team.**
   Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	◯	◯	◯	◯	◯	Strongly Agree

8. **Collaborating as a team inspired people to do their best**
   Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	◯	◯	◯	◯	◯	Strongly Agree

9. **We have the skills we need to perform the activity**
   Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	◯	◯	◯	◯	◯	Strongly Agree

10. **We are strongly committed to a shared goal**
    Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	◯	◯	◯	◯	◯	Strongly Agree

11. **Team members are effective listeners**
    Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	◯	◯	◯	◯	◯	Strongly Agree

12. **My team has a strong sense of accomplishment relative to our work.**
Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	◯	◯	◯	◯	◯	Strongly Agree

13. **Team members understand one another's roles.**
Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	◯	◯	◯	◯	◯	Strongly Agree

14. **People on my team are rewarded for being team players.**
Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	◯	◯	◯	◯	◯	Strongly Agree

15. **Communication in our group is open and honest.**
Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	◯	◯	◯	◯	◯	Strongly Agree

16. **People are proud to be part of our team.**
Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	◯	◯	◯	◯	◯	Strongly Agree

17. **Everyone values what each member contributes to the team.**
Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	◯	◯	◯	◯	◯	Strongly Agree

18. **Members of our team trust each other.**
Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	◯	◯	◯	◯	◯	Strongly Agree

19. **We spend very little time complaining about things we cannot control.**
Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	◯	◯	◯	◯	◯	Strongly Agree

20. **We view everything, even mistakes, as opportunities for learning and growth.**
Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	◯	◯	◯	◯	◯	Strongly Agree

21. **Team members help one another deal with problems regarding experience**
Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	◯	◯	◯	◯	◯	Strongly Agree

22. **Team members seek and give each other constructive feedback.**
Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	◯	◯	◯	◯	◯	Strongly Agree

23. **Team members are sure about what is expected of them and take pride in a job well done.**
Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	◯	◯	◯	◯	◯	Strongly Agree

24. **Team members display high levels of cooperation and mutual support.**
Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	⬭	⬭	⬭	⬭	⬭	Strongly Agree

25. **My team is proud of its accomplishments and optimistic about the future.**
Mark only one oval.

	1	2	3	4	5	
Disagree Strongly	⬭	⬭	⬭	⬭	⬭	Strongly Agree

Figure B.2: Team Effectiveness Survey