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Master's Thesis  
Academic Year 2021

Haptic Cues for Improving Remote Band Sessions  
Experience: Time Synchronization and Emotional  
Connection



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

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Abstract of Master's Thesis of Academic Year 2021

# Haptic Cues for Improving Remote Band Sessions Experience: Time Synchronization and Emotional Connection

Category: Design

## Summary

With the popularize of the internet, a lot of human behavior changes from offline to online, band session, as one of the offline entertaining social behavior, also started getting into online services.

However, there is a lot elements during offline sessions that hardly provide by the online services, for example, the extreme synchronization of the timing, the visual contents increases the delay, the breathe of the other players, most of important, is that the feeling of the existence of the other players during the session is very different.

In this paper, we built a haptic device for the players especially focusing on those music beginners to have better online band session experience. The haptic device would focus on solving the problem of latency, giving out "hints" during the session and emotional connection. %.

Keywords:

Musical Instruments, Band Sessions, Haptic Devices, Music Socializing

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Yingting Huang

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# Chapter 1

## Introduction

### 1.1. Band Sessions

People have been doing band sessions since the derivation of human beings. Long long ago when people was still in clans, they started using different tools to make musical sound and that was the embryonic form of people playing sessions. And with the human derive, different forms of collaborating in music existed like orchestral band ensembles, modern rock bands, etc. However, with the existence of the internet, the social distance of people gradually changed. It could bring people located very far close, it could also make people next to each other apart. Online band sessions allows people play sessions with other people just stay in their bedroom with anyone who could connect to the internet. And it allows random people to play sessions together without booking time forehead. Online band sessions definitely creates more possibilities for musicians to collaborate, practice, learn from each other and socializing with others.

Learning and practicing instrument could be divided into two parts. One part is to practicing by oneself and the other part is to learn while play with other people. Due to Schiavio [1], learning music with other peers can be as beneficial as more traditional settings based on individual tuition. Suggest that play music together creates a great chance of peer reviewing in learning.

I always enjoy play sessions with other people, however, it is hard to find people to play together sometimes. In the school, there are usually clubs that gathers people together with the same interest, also, the practice space are usually provided, and it's easy to do a session after school because in school the schedule are likely shared. But after leaving the school, it is harder to get to know new people with same interest offline, and space for practicing usually requires money. Both energy and the cost for just organizing a session becomes higher. Also, I

am a people have been stayed in a lot of different places that it's hard to get back and do the sessions with old friends after moving to another place, so I always wish to still have the chance to have session online with them. also get to know more people by just playing music with online sessions. I tried doing online sessions several time, however, of most times, with longer distance, the internet connection become worse, and the latency of the internet make the session barely enjoyable. And the emotion sharing during online session is very different from offline experience. Since video usually requires large data transmission, cameras are usually turned off during the session, as a result, when the air stay silence, I start to wonder if the other people on the other side of the network is preparing for the performance or if the person has anything else going on. It is hard to share the emotion like it is offline within the same room. This gave me the chance to start thinking about online band session environment and improving them.



Figure 1.1 Typical band session

During the beginning of 2021, with the tedious daily life of hardly getting in touch with other people offline under the pandemic of covid-19, people started look for new possibilities of the form of entertainment. And the sudden break of clubhouse, a very popular drop-in audio chat mobile application, a lot of or-

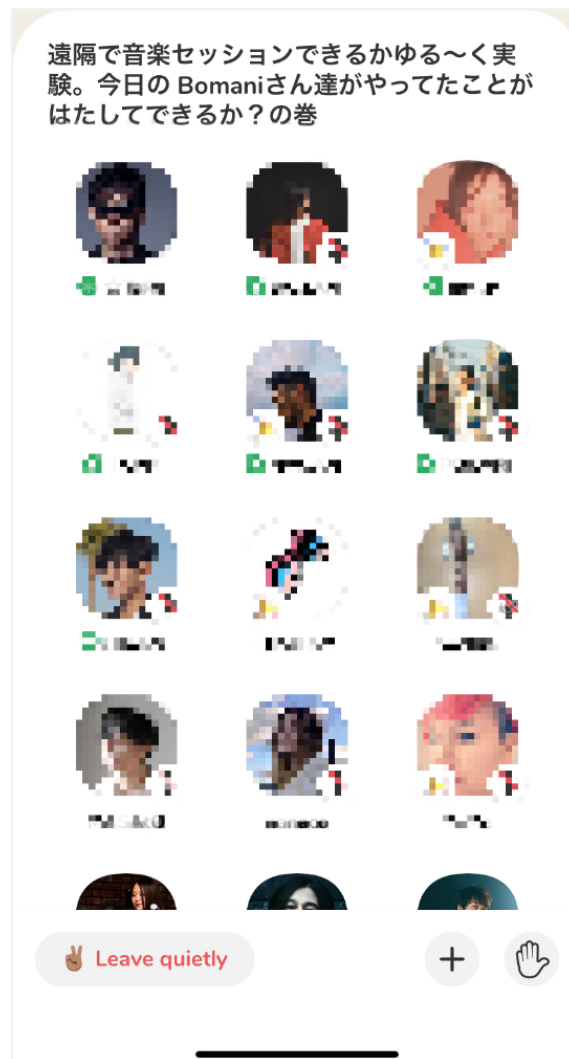
ganizers organized some online chill music event not only encourage people to performance by themselves, but also encouraging random people to collaborate with each other. Since clubhouse is an open chat for everybody without mattering experience and level of the skill of performing, everybody is allowed to perform in the chat. And it was very obvious that professional musicians collaborates better under the network with latency than others since they has a lot of stage experience to predict the timing and other performers' behavior. And the inexperience performers usually hesitates by the timing to start or changing the section of a song because of the latency and without knowing the existence of the other performer, they usually feels disturbed and lost confidence. From the experiences of chatting and having sessions on clubhouse, I vision that the online environment would be very important for collaboration between musicians, especially for the beginners and non-experienced performers. Also, I vision that a good online band session environment would very likely to encourage more and more musicians without the restrict of skill level to collaborate with each other and give them confidence. It has a big potential to create more possibilities for socializing between musicians all over the world online and might change the social behavior of the musicians.

Collaborating or practicing online with other musicians not only for professional musicians but also just for music beginners could be a very potential future for bring the music lovers all over the world together and possibly creating a new possibility of music socializing.

## **1.2. Reasons of doing Online Band Sessions**

There are a lot of difference between playing band sessions online and offline. Nowadays, due to historical social behavior and the difference of the experience, most people are still doing the band sessions offline, but with the rise of new online audio services, people start play sessions online. Online and offline band session gives people very different experience. Either playing band sessions online has its own advantages and disadvantages. And these advantages are the reasons of encouraging people doing online band sessions.

For the advantages of playing band sessions online, and one of the biggest advantages of it is convenient. People no longer need to worry about the time



(Source: screenshot of clubhouse)

Figure 1.2 Band sessions on clubhouse

and the space anymore. To organize a offline band session, adjust the schedule for every people joining the band session and booking a practice studio in advance is required. In addition, people usually needs to carry instruments with them and setup in the practicing studio. For the online sessions, people only need to open up the online audio service and get the instrument connected to the laptop whenever they want to have a session. Online band sessions saves people studio rental fee and time for transporting and organizing.

Playing in a session in general improves performance skill and brings people chances to learn from each other. For the offline sessions, most studio with practice purpose doesn't provide a good environment for recording and setting up recording equipment would take extra time from practice. Therefore during offline band sessions it is very common for people to use a phone to record the whole sessions of instruments. As a result, the recordings of offline band sessions usually doesn't give a good audio quality. With online sessions, it's easier to have higher quality recording since instrument of each person get into separated track. In addition, during offline band sessions, performers all shares the same monitoring speaker, so it is hard to hear the part they want to hear, and in a small space, the drum sets could easily become too loud that covers other instruments' sound. During online sessions, it is easier to adjust the volume of separated digital signals, and everybody would be able to have their own mix balance, the better monitor system would help people have a better practicing environment.

People have a very different social behavior online and offline. Online sessions bring new possibilities of socializing between musicians, that it's hard to break into a session offline, but people can do it easier online and get to know more people.

### **1.3. Current Problems of Online Band Sessions**

Currently, there are still problems for online sessions. The biggest one is delay. One of the main point of doing a session is get the sound in sync. Due to the speed of transferring data, there is always an inevitable delay during online sessions, for transferring audio data, the data usually has first go through the air into audio interface, from audio interface the digitized data go through the internet to the



other performer's laptop, and the data go through the audio interface again into acoustic signal in headphone or speaker.

The delay brings up the second weakness, to maximize the quality of sound and minimize the delay, only limited contents could be transferred. Sound wave is a array of numbers, as so it includes the information based on bit depth and sample rate, and video usually includes a much bigger byte of data to transfer.

As a result, for the current services out there, only audio would be shared, while offline sessions musicians usually have more "hints" for others like breathe, movement, etc. Therefore, in the research, I would like to find a way to use minimum transferred data to create "hints" between musicians online.

## 1.4. Proposal

The goal of the research is to find out how the latency affect instrument beginners collaborate or practice in a session online and improve the online session experience for beginners.

## 1.5. Structure

This paper includes seven chapters.

The first chapter is the introduction of the research that introduces the history, reason and the vision of current online environment of band/ensemble sessions and tells the story of the motivation of improving the online environment of band/ensemble sessions.

The second chapter is the experience and feedback with several intermediate instrument performers on existing services of online band sessions, and some existing related music gesture products that innovate the design of "hints" and emotion share haptic supply for online band sessions.

The third chapter is to introduce the goal and the theme of the paper.

The fourth chapter is to talk about the concept and the design of the prototype of the haptic device that is supposed to help people have a better hint and emotional connection during online band sessions.

The fifth chapter is to introduce the environment, steps and the participants of the experiment that test the functions of the haptic device built previously. And creates the survey for participants to learn the feedback of experiencing the haptic device with an artificial delayed band session environment.

The sixth chapter is to analyze the recorded data from the experiment and summarize the feedback from the surveys of the participants of the experiment.

The seventh chapter is to discuss the results of using the haptic device, the possible improvement of it, and possible applications of the haptic device.

## Chapter 2

# Related Works

### 2.1. Online Band Sessions and Social Community

For most offline band sessions, it's usually formed with fixed members occurs at a specific time and specific place. However, online band session may has a closer form to the Irish band sessions as Tolmie [2] described, sessions are, on the one hand, hugely informal with the players typically sitting in a circle and coming and going as they please, with other activities in the pub going on around them. Online sessions also allow people to create a room and let random players come and go as they pleased. As a result, improving online band session experience has a big chance of changing online music social behaviors. And there are a lot of researchers discussed about Irish music session and society.

O'Shea [3] discussed about Idealizing musical community and Irish traditional music sessions. As O'Shea said, the power of offline shared musical experience has inspired scholars to theorize collective musical performance as capable of producing an embodied, transcendent experience of an ideal society. Shared space creates opportunities of sharing experience, and based on the experience, community, society, culture are derived. As a result, building connection and relationship between the performers helps the overall sessions and makes a difference in society in the long term.

### 2.2. Human Tolerant of Latency During a Band Session with Audio Only

As mentioned in the introduction, one of the biggest problems of online band session is delay. The delay though online network environment is inevitable and



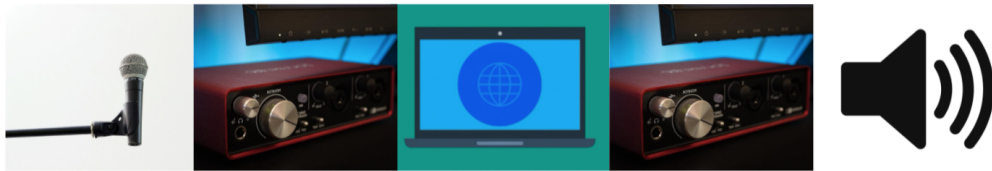
(Source: screenshot of syncroom)

Figure 2.1 Join room in Syncroom

always exists. For normal people, it's hard to realize the delay if it's in 10ms. Due to NetDuetto, one of the online session services, the delay needs to be less than 30ms to be possible play in a session, even with rhythm tracks, the delay needs to be less than 45ms. And a delay less than 70ms makes it ok to sing along with.

## 2.3. Existed Service of Online Sessions

There are several existing online live, in-sync music jamming, band session service over the internet like Syncroom and Jamkazam. For these services, musicians can innovated to play together and build a social network. Musicians could play music together in real time from different locations over the internet as if they are sitting in the same room without packing and transporting their gears and easily record anything as they want. However, the delay is always inevitable even all the online real-time services try to keep the latency low. The latency does not only comes from the internet transition, but also occurs in the audio interface and the speed of the sound. In current network environment, the most widely applied network is 4g, and the delay it has is around 50 milliseconds. In the near future, the existence and the popularization of 5g and 6g could give a faster network under 30 milliseconds, but there is also delay in audio interfaces for around three to six milliseconds.



$$\begin{aligned}
 \text{Delay} &\approx \text{Sound Speed (to Mic)} + \text{Interface Delay (Player 1)} + \text{Network Delay} + \\
 &\quad \text{Interface Delay(Player 2)} + \text{Sound Speed (from speaker)} \\
 &\approx 0.1 \text{ ms} + 3\sim 6 \text{ ms} + 50\text{ms}(4\text{G})/30\text{ms}(5\text{G}) + 3\sim 6 \text{ ms} + 0.1 \text{ ms} \\
 &\approx 36\sim 62 \text{ ms}
 \end{aligned}$$

Figure 2.2 Online delay time

As Figure 2.2 shown, based on calculation, the current delay of online audio transmission is around 36 milliseconds to 62 milliseconds. Except the latency, the relationship between participants during online band sessions while using these services need also to be observed. As a result, a fieldwork of using Syncroom is taken to find out online relationship of the two players and behaviors of the performers.

## 2.4. Relationship between Participants during On-line Sessions

Two advanced level guitarists are interviewed about the experience of online band sessions with the service of syncroom. From the interview, they stated that they didn't observe and obvious latency for the most time during the session. However, sometimes the internet would be skipped for a second, and with the metronome, the latency is obviously observed because it doesn't stay stable and delays with the network. During internet transmission of the online band session services, mainly UDP is applied, which gives a high speed connection but low accuracy, however, metronome is a tool that expected to be highly accurate and helps people control the rhythm. As a result, some information like metronome with strong pulse would mislead people for online session collaboration and make it harder than audio only. Also this feeling might depends on sensitivity and the sample rate of the hint. And the two people were asked about if they would like other contents like visual or haptic to be transmitted alone with the audio. Both of them would prefer haptic over visual because of the social behavior for meeting strangers and the fact of previous human sense is visual, so it might distract the performance rather than help it. Also, based on the distance, the latency was totally different, and people outside the country was hardly collaborate in the session with extreme noticeable delay.

Schroeder [4] stated that

”playing music is always a multi-tasking experience. This implies that performers tend to have a much more abstract reading of another human being's presence.”

”playing music is always a multi-tasking experience. This implies that performers tend to have a much more abstract reading of another human being’s presence.” Though giving only audio making people focus on the sound over the other contents, it is human nature to use other contents to help the performance. As a result, it is important for the performers to learn about how to adapt and use other information from other players during the daily performance. Giving extra task for the performances could also train them use information other than sound to learn about the possible action of what the other player would play the next.

Malloch [5] designed a human-computer music interaction system called MIDWAY that giving wide availability of low-cost, user-friendly tools—sensors, actuators, micro-controllers, and a variety of software tools for creating/manipulating sound and defining map-pings—everything seems possible. With the possibility, the approach of musical expression becomes more precise and it leads of new possibilities of the online format of music expressions.

There were research discussed about joint music making of playing music online and physically together during the lockdown of covid-19 period. Onderdijk’s [6] survey on in total of 234 participants as the music performance has to change from offline to online, frequency of joint music making in live music settings substantially decreased, as the musical network also decreased from such the reason. For the people that never tried online band sessions, unawareness of the existence of such tools, technical and equipment barriers are mostly considered. For the people plays online sessions, latency have always been one of the biggest distracting problem. Despite latency, the main problem stated is that the feeling of social connection is lost during the online session. People could not feel the vibration between each other, which one of the main purpose is the social connection but it does not achieve. Therefore, it is important to improve the online band session experience in order to encourage more people to use the service. And the main problem need to be solved is the latency and social connection.

## 2.5. Movement and Instrument Performing

The haptic would effectively help with instrument performing or learning is basically because that playing a instrument itself first involves a lot of body move-

ments. Gonzalez [7] analyzed the movement fluency in musical performance for generic measuring in the technology enhanced learning resulting fluency in music performance as a combination of movement smoothness and co articulation, reflecting effort minimization through coordination strategies. Also devices might influence the natural of the performance, therefore to use device minimize the influence of the instrument performing is important for analyzing and designing.

As for drummers, the movement, timing and precision becomes extreme important because the drum is the major rhythmic instrument that leads the tempo of the whole session during most performances. Dahl [8] outlined the way of measuring the movement. Describing some general movement strategies used in drumming movements, and how tempo, dynamic level, and the surface struck affects the player-instrument interaction and timing control.

## 2.6. Haptic Designing

Haptic devices are designed to simulate movement of human hands. With the better knowledge of how human selves moves the hands and fingers, and the application of the haptic devices, there comes more possibilities of what haptic devices could do. Tamaki [9] built a PossessedHand that uses techniques for controlling human hands using electrical muscles stimuli, with the designing, PossessedHand can control the motion of 16 joints in the hand. And this could enable non-human also possible to play the instruments.

For some project that already allows using haptic playing instrument is Passalenti [10]. Without attaching physical string on guitars, only use haptic designing, they enabled guitar playing with noticeable no significant differences were found between the conditions involving either vibro-tactile or force feedback.

## 2.7. Applications of Haptic for Instrument Performance

There are various haptic applications for instrument performance mainly with the purpose such as assisting multi modal music learning, enhancing emotion for the



performance, etc. The gesture focused music performance is important to research about the relationship of physical music performance and the digital. For online environment, every media need to digitized. The trend of gesture controlled music helps analyze body movement and instrument performance. Hence, the haptic device could be applied for online band session system.

Tanaka [11], state gestural, which is also sensor based instrument, is an inclusive term that encompasses a wide range of related musical instruments. He states that

”If the limitations of an acoustical instrument contribute to characteristics giving it a personality or identity, the open-ended nature of computer based instruments at first preclude this kind of identity. The separation of gestural input from sound production means that here is no hardwired gestural vocabulary connecting action to sound.”

Digitizing the gesture with sensors helps analyze the character of each instrument and brings physical music connection to the digital world.



(Source: Company Soundbrenner’s web page)

Figure 2.3 Soundbrenner

Soundbrenner, a watch-like product that gives different kind of vibration as metronome for practicing, uses haptic to help with the individual music learning

sessions. One of the reasons of using the product is that sound masks each other but it is much easier to feel a vibration versus listen for a click while playing.

Tanaka [12] used three different protocols to test the embodied interaction with music, and he found that there is a potential to improve audio task performance amongst the visually impaired, to enhance expressively in computer music performance onstage, and to facilitate the understandings of our relationships with sound with haptic interface in the daily lives.

As in a lot of existing researches, haptic devices has widely designed as a replacement of instrument performing that people could use body movement to simulate air performance of instruments and control such sounds. For example, Maekawa [13] has developed a device named CosTune-prototype that allows people create and play musical pieces everywhere, which creates more possibilities of daily space direction and musical communication between people. As haptic devices could provide more connections to support the music playing in between people.

## 2.8. Haptic Devices Supporting Instrument Learning

Haptic Devices has widely used for help supporting instrument learning. Especially because playing instruments involves a lot of body movement that could hardly just described by words. Fujii [14] used 3D haptic support for a musical instrument. With this kind of device, beginners could understand the body movement of playing the instrument better and play it back later as they need. Using the device effectively help people improve the skill and gives them good feedback in terms of playing a song at a correct speed and rhythm.

Holland [15] designed a Haptic Drum Kit to help the beginning drummers to learn intricate drum patterns from its stimulation and resulting successfully that although haptic plus audio is the mode of presentation preferred by subjects.

## 2.9. Online Collaborative Works of Haptic Sensation

Haptic sensation between people at offline environment and online environment is very different. Touch is a very straight forward way of emotional communication. Body language, facial expressions, hand gestures, and sign language all shows and communicates individual emotion through offline daily lives. Haptic sensation could separated into different parts as temperature, vibration and movements and these parts could be also divided into more detail parts to apply for the digital number analyzing. As a result, online haptic sensation would be very different from offline, and it has a chance of changing the behavior and communication between people. Through the current online environment, since all of the complicated movement or touches need to be replaced by digitized numbers, it is hard to restore the straight emotion communication as so it is very limited. Therefore, it is important to understand about online collaborative works of haptic sensation.

Kim [16] analysed the performance of differing the time-delay for haptic and video. With the designing of Teleoperation, they observed the feedback information apply to improvement of people performance in remote place. From their result, they gathered into three main point of that haptic is critical to the performance and sensitive, synchronize force feedback let performance of system reduce, by minimizing the haptic time delay, the quality of the performance improves. As a result, haptic feedback is likely to provide misunderstanding hints to the performers, therefore controlling the delay time for the haptic device to separate it from the audio delay is also important.

Due to Sithu [17], also to discuss about network delay problem, they approached the solution by investigates the effect of local lag control on the synchronization quality of sound, interactivity, and comprehensive quality as QoE (Quality of Experience) in a networked haptic drum system. And found that there exists the optimum value of local lag according to the network delay.

Joung [18] explored about tactile hand gesture recognition through haptic feedback for effective online communication. And Joung found that opportunities and promises to use tactile hand gestures for the communication of emotions among people using online digital communication devices at a distance. And different

emotions are statistically associated with different tactile hand gestures although the exact correlation still needs to be found. This actually shows that haptic online, though not accurately tells the exact emotion communicated, it gives a very different feeling to the other people with distance, which could be a hint to gives "hints" during online band sessions. And since music has very different dynamic with the movement of performance, the connection might be better built for abstract communication like music.

## Chapter 3

# Objectives

The purpose of the research is to build a haptic supplement for online session players and find out what kind of improvement would haptic feedback for online band practice session experiences provide to instrument beginners.

As the problems of online sessions are all described in the previous chapters, the remote band session environment could be separated roughly into five stages. First stage is to make sound with the latency that enable people to play in the remote band session, which requires professional experience in music performance. Second stage is to enable people to play in the remote band sessions without extra knowledge that any performers on any level would be able to play comfortably with limited latency. Third stage is to transmit contents other than just audio, that it could also gives other in formations performers usually need in the offline band sessions. Fourth stage adding multiple elements to the remote sessions to provide as possible as to improve the experience. And the final stage is to perfectly simulate the actual live environment online.

Therefore in this research it is to find out a way of building haptic device to help improve the experience of the online band sessions. The focusing of building the haptic device is on improving the latency, giving hints and make the participants in the remote band sessions feel more about the existence of the other players.

### 3.1. Playing a Session

As observation and experience from pop music band sessions, since most time people don't have a exact score and have never collaborated before, it always evolves some element of jamming that in a lot of time, the synchronization of timing especially for the key notes, people would naturally find some way to

connect each other with "hints". During offline session, these "hints" are usually given by eye contacting or observation of each other's body movement. As for online sessions, these "hints" are also needed, haptic is considered as a way that gives connection for performers during a session, therefore it is used to find out the feasibility of giving the "hints" to the other performer.

### 3.2. Target Users and Reasons

For building the haptic device, based on the introduction and the background research, it is majorly targeting non-experienced players, instrument beginners intermediate level players, and those players does not has enough remote or offline performance experience.

Performers even for those only experienced offline lives has experience to deal with the delay because in most performance halls or spaces, because of the time of travelling of the sound ,there is also delay. And during offline lives, it's usually adjusted and recovered by the live mixers, like front of house and monitoring mixers. With the limitation of some performing spaces, sometimes only front of house exists. As a result, musicians are usually learned to deal with the even small amount of delay themselves.

Building this device might not necessarily help the experienced players play at a remote sessions since they already have the natural reaction and knowledge of dealing with it. However, for those just started playing instruments, or even just online collaborating in karaoke live, it is hard to learn about the delay timing based on only audio, even though some already have a very good skill to play at certain instrument. The uncertain of delay time makes people confusing and some times people just stop at the middle of the session and question about the whole collaboration.

As a result, since the online audio services are becoming more and more common especially with the boom of the clubhouse. For more people to enjoy collaborating during a remote session, it is necessary for those non-experienced players. And to designing a haptic device for them to get familiar with the online delay and learning with dealing the delay problems might be a possible solution.

### 3.3. Haptic as a Cue

Discussing about the relationship between audio and haptic, work by Lee [19] found out that audio cues extend the range of successful mirroring to regimes where visual information is sparse remarkably. Such cues could facilitate joint coordination when navigating visually occluded environments, improve reaction speed in human-computer interfaces or measure altered physiological states and disease. Based on this idea, the feasibility of switching haptic as a cue is worth to try as if it has physiological effect on instrument performance.

### 3.4. Timing of Triggering the "Hints"

As designing the haptic device. One of the focus of the designing of the device is the timing of triggering the "hints". Based on the observations of the sessions and the experience of the sessions, the synchronization is check mostly at the switching of the parts of the songs like verse and chorus. And it would occur at the key point of the songs. Which usually also would reflect in players' body movements. As a result, the research would be focusing on the how the body movement changes reflects on the data, and how to build an algorithm for triggering them.

### 3.5. Emotion Connections in Remote Sessions

Based on existing related works in previous chapter, haptic device is one of the most effective way to build emotion connection during a remote session without visual contents. As actual trying the existing services of the remote sessions, the participants shows nervousness during the switching parts between the verse and chorus, Also, in between the sessions, while the players adjusting personal instrument, usually the players would focusing on their own instrument and occurs a long time of silence. With the existence of the haptic feedback, the players would connect each other more easily and effective of comforting through the emotion. Which also gives a strong feeling of the existence of the other players.

### 3.6. Designing the Haptic Device

To design haptic device for instrument players needs to be very detailed and specific because of the different characteristics of the instruments, and the fact instrument could be divided into a lot of different groups just by the different way of performing them. As a result, designing haptic device would be extremely different for different instrument. In this research, the design would be very focused on the main instrument of the most common ones used in the band sessions.

This thesis would focus specifically on the effect of the haptic device on how it change people's behavior during timing of triggering the "hint" and how it build emotion connection between the players.

The following chapters would be detailed discussing about the process of designing a haptic device for specific instrument players in the remote band sessions and the reason of the parts of the design.



# Chapter 4

## Concept Design and Proposal

In this chapter, the relationship between emotion and body movement through instrument performance and how "hints" are communicated between musicians during offline sessions would be discussed. The reasons of using haptic device to improve online band sessions would be introduced based on the discussion. To actually design a haptic device for improving online band session experience, the behavior of body movement for the performers is to be observed and the application of the kind of sensor and motors to be used for haptic communication is to be discussed in the chapter.

### 4.1. Proposal

To build a haptic device for performer based on their body movement, it is important to observe the behavior of guitarists during daily practice and find out what kind of haptic device would be best to be used for triggering the "hints" for the other player.

This paper will focus on the collaboration between guitarist and percussionist. The guitarist would be the one to send the "hints", and the percussionists would be the ones to receive the "hints". Below will be introducing about the reason of focusing on the players of the instruments and the reason of setting the transmitter and receiver. Guitar is one of the most common instruments to be played in contemporary bands, and it's the most instrument that used to be played and sing along with. Guitar performance could break down into various parts including finger-style, lead, rhythm. In a band session, guitar parts are usually break into lead and rhythm. Therefore, the body movement of these two play styles would be observed. Based on the observation, the format of haptic device, including

the body part to put it on and the kind of sensor to be used would be discussed and tested. Haptic device for guitarist is to send "hints" especially at the timing between section changes.

Clapping hands are the basic percussive sound that typically everybody could make. It's a way people learn about sequencing and rhythm. As a result, it reflects the behaviors of a lot of music beginners, so it is how the participants response to the music during online session in this research.

During offline performance, it is most usual for drummers to set up the whole rhythm and conduct the whole rhythm of the band. However, percussion usually have a very fast attack, and usually doesn't sustain long, which means people need to react comparably faster to it to reduce the response to the latency. As a result, making the guitarist the sender of the "hints" is logically more reasonable based on the characteristic of the instrument.

## 4.2. Emotion through Instrument Performance

The sound tells the emotion of the performer of the instrument and the body movement controls the sound of the instrument. In this section, relationship between emotion and body movement during instrument performance will be discussed. Schiavio [20] showed that pre-reflective embodied and interactive awareness is to be understood within the setting of musical interaction, and it concretely works in driving the musical interaction. He stated that " With the fundamental level of pre-reflective embodiment, interaction, and enacted meanings established, the role of higher-level awareness and attention may be elsewhere, for instance in the constant refinement of musical expression, instrumental techniques, or other concurring factors." So the pre-reflective embodied and interactive part between the musicians drive the awareness into experience. It is one of the main goal of using embodied medium to improve the experience.

### 4.2.1 Emotion and Body Movement

During solo performance, emotion is shown based on haptic movement, the detailed movement of body changes the dynamic, tone of the sound made by the instrument.

Emotions are sent and received through the five human senses, touch, sight, hearing, smell and taste. In general, sight is usually the previous sense people use to sense the world. During a session, the most activated sense is hearing, and the movement of other people also give others the "hints" of their next part of performance, because the sound would be very different based on the very detailed movements and is connected with the emotion of the performers. As a result, the performers usually communicate with each other by their body movements during a session. For example, it is very typical to see performers deeply breathe or tilt the whole body back when they giving signs to other players which implies them of changing sections of the music. Besides, eye contacts are very frequent during session to share the current situation of each performer. However, the network environment haven not yet become enough to keep the latency within the time range for people to play session together with visual contents. As a result, with most online audio communicate services for playing instrument together, only audio data are transmitted. Therefore, all the other senses of people to communicate with others are isolated, isolating other senses could strengthen the sense of hearing to help performers focus more based on what they hear, however, without other senses, other possibilities of emotion connection are blocked. As a result, body movement could be considered to become another way of performers playing instrument together online. Furthermore, most body movement sensors like acceleration sensors require only three variables which means a small amount of data to transmit. So sense sharing based on body movement should be considered of one possible way to improve the experience of playing online band sessions.

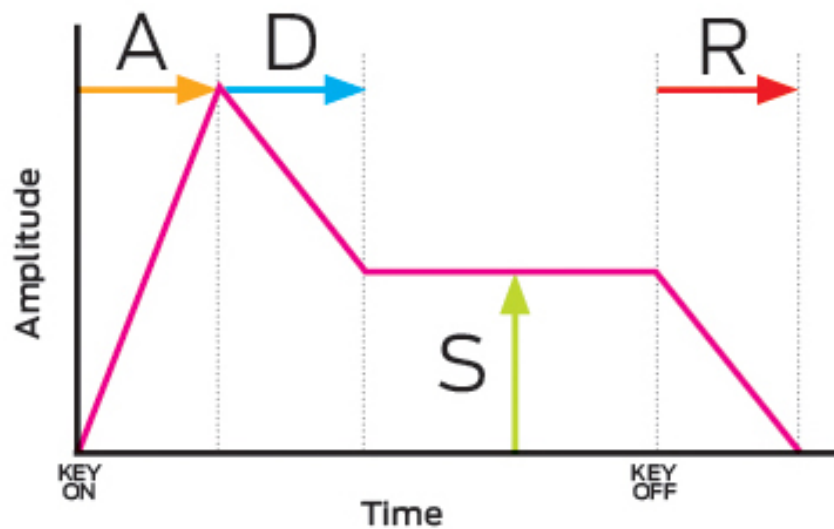
#### 4.2.2 "Hints" During Sessions

When the instrument players trying to match the timing with each other, there two main hints of breath and tilting their body before making the note. Also, they will give the whole movement of arm, wrist and hand to play the sound, which gives a bigger body movement. During offline sessions, these are the visual "hints" to be observed face to face, however the visual contents takes a huge amount of data to transfer and the resolution of the video contents may also be unstable factors of online performance. Therefore, this research want to find out the possibilities of using haptic device to replace the these "hints" from the sense of sight to the

sense of haptic. Haptic could easily sync the movement of people, and during band sessions, the rhythm of the same song should be connected. As a result, haptic may be one of best solutions to create "hints" for the performers trying to use online band session services, and it might also bring emotion share to the players. Therefore, to build a haptic device is to replace this kind of "hints" online. And how the data of the sensor actually changes during the performance, the timing to trigger the "hints" and the way of receiving the hints will be discussed.

### 4.2.3 Characteristics of Common Instruments in Contemporary Bands

In sound and music, an envelope describes how a sound changes over time. Every instruments has a very different characteristic based on envelope. And envelope could strongly affect the timing during instrument performance. It may affects the amplitude, frequencies and pitches of the sound.



(Source: MusicRadar website)

Figure 4.1 sound envelope

The most common kind of envelope generator has four stages: attack, decay, sustain, and release. The first stage is attack, it is the time taken for initial run-up of level from zero to peak, beginning when the key is pressed. The second stage is decay, it is the time taken for the subsequent run down from the attack level to the designated sustain level. The third stage is sustain, it is the level during the main sequence of the sound's duration, until the key is released. And the last stage, release, is the time taken for the level to decay from the sustain level to zero after the key is released. Percussion sound like clapping, snare, hi-hats have envelop of a very significantly fast attack, barely no decay and sustain and a very fast release all occurs with in 1 millisecond. Based on technique and style of playing, guitar could have very different envelop. The very basic of hitting the string giving a fast attack, long decay, sustain and release time. With the different characteristics of the instruments, people would have a very different feedback on the latency. And a longer attack in theory should give people longer time to get prepared for the next note and should be better for giving the "hints".

In addition, to give out the "hints", different instrument would have very different gesture. Even most instrument would mostly focus on elbow and wrist movement, when they get digitized, it would give out a very different data. Imagine the arm movement of pianists, drummers and guitarists. And as Figure shown, the movements are distinguishable and different. As a result, gesture need to be designed differently based on the specific instrument. And for this research, it would be specifically focus on guitarists' movement to trigger the "hints".

### **4.3. Data and Analysis of Guitarists' Wrist Movement**

To design the wearable device based on guitarists' wrist movement, the approach used in this research is to first find out about how is the parameter of different sensors changing based on the movements and find the difference of the data when guitarists are trying to make "hints" and when they play normally. The measurement is to put a sensor with acceleration sensor and gyro sensor with coordinate in x, y and z, and a attitude sensor with pitch, roll and yaw on the back of the wrist where people usually wear watches. In the section, the body

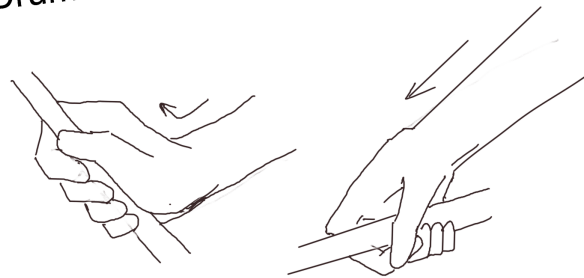
**Piano****Guitar****Drum**

Figure 4.2 movement of different instrument

movement of the guitarists is first observed based on fieldwork, videos of guitar performances, experience of guitarists, this will explain why the sensor is placed on the wrist of the hand that hitting the strings. And the second part is data based observation to use different sensors to observe how wrist moves during the performance to find out which sensor would be the best to create "hints" during online sessions and finally building the algorithm of triggering the "hints" to the other player.

### **4.3.1 How Guitarists Moves Wrists**

There are four fundamental movements when guitarists play guitars, elbow flexion and extension, forearm rotation, wrist deviation and wrist extension. Elbow flexion and extension is the movement that the arm flexion and extension with the center of elbow joint. The most focus of guitarists' body movement is focused on elbow and wrist. Especially for the wrist part, it also moves when the elbow moves and wrist movement usually creates very detailed sound of the notes. Therefore, wrist is the body part moves the most and most related to the notes that played on the string. So I assume it would be a good place to putting the sensor and giving "hints" to the other performer.

### **4.3.2 Sensor Tests**

Acceleration sensor, gyro sensor and vibration sensor are used to find out which could best analyze the wrist movement of guitar players and trigger "hints" while section changes as people usually have eye contact or tilting the back deeply. Usually while changing from verse to chorus and from finger-styling to strumming, since the whole movement of the arm controls the tone and the amplitude of the notes being played. As so it is to compare which sensor would give a most distinguishable data to differ the verse from chorus as so it could give out a "hints" on a comparable better and precise timing.

### **4.3.3 Building Algorithm**

Based on the collected data, vibration sensor has the least information of guitarist's movement since it includes only one variable. As a result, using accel-

eration meter for triggering the "hint" is focused. For the prototype, AXDL345 acceleration meter is used.

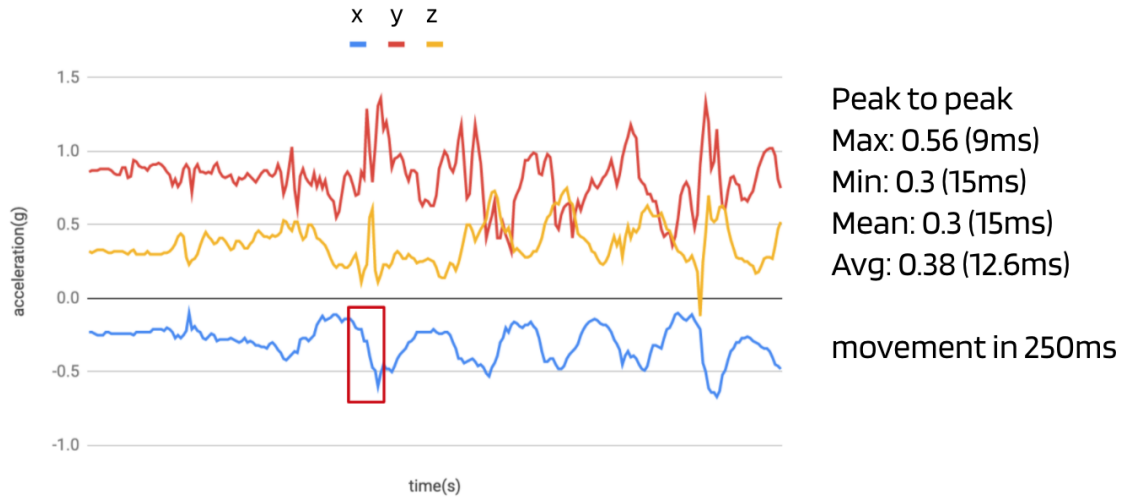


Figure 4.3 acceleration meter data collected while playing guitar changing from verse to chorus on x scale

Figure 4.2 shows the part of data of acceleration meter, AXDL345, collected while playing guitar changing from verse to chorus on x scale, which is the vertical movement perpendicular to the ground refers to the up and down movement of the wrist while playing guitar.. As the data shows the movement in 250 milliseconds, and the peak to peak values are analyzed. The maximum of the peak to peak value is 0.56g within 9 milliseconds, the minimum of the peak to peak value is 0.3g within 15 milliseconds, the mean of the peak to peak value is 0.3g within 15 milliseconds and the average of the peak to peak value is 0.38g within 12 milliseconds. From the data, it is to see that for most movement, the peak to peak value stays consist and stable, however, while changing to the chorus, the time taken from peak to peak decrease and the acceleration increase. Based on the number, the algorithm is built as it is going trigger a pulse for the vibration to the other player if the acceleration changes over 0.45g within 10 milliseconds.



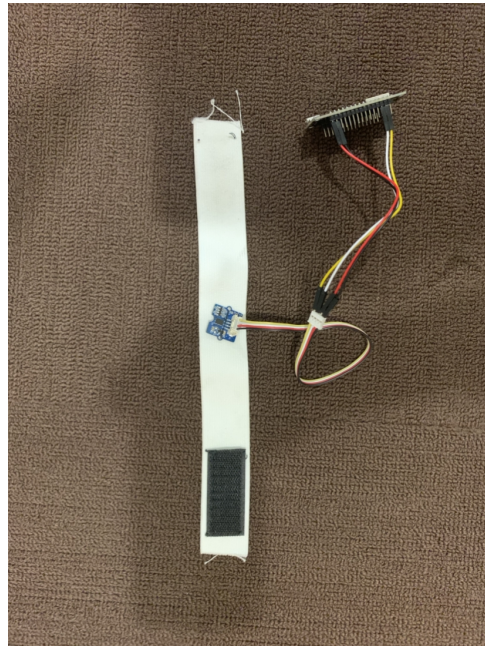


Figure 4.4 Haptic Device built with AXDL345

## 4.4. Online Network Environment

Through online network communication, different protocols are applied. The haptic device is also using wireless transmission between each other. The most common network used right now is 4g. Though in the future the speed of network will be fast, since the data need to travel in medium, the latency is always inevitable. And the whole feeling of the environment would still be different from offline. As a result, finding a way to help recreate a similar environment with offline is necessary.

### 4.4.1 Data Transmission

There are two main internet protocol during internet transmission, UDP and TCP. UDP, which is stand for user datagram protocol, faster, simpler, and more efficient than TCP, though it only has the basic error checking mechanism using checksums, the data is sent continuously that it usually gives the real-time information. TCP provides extensive error checking mechanisms. It is because it

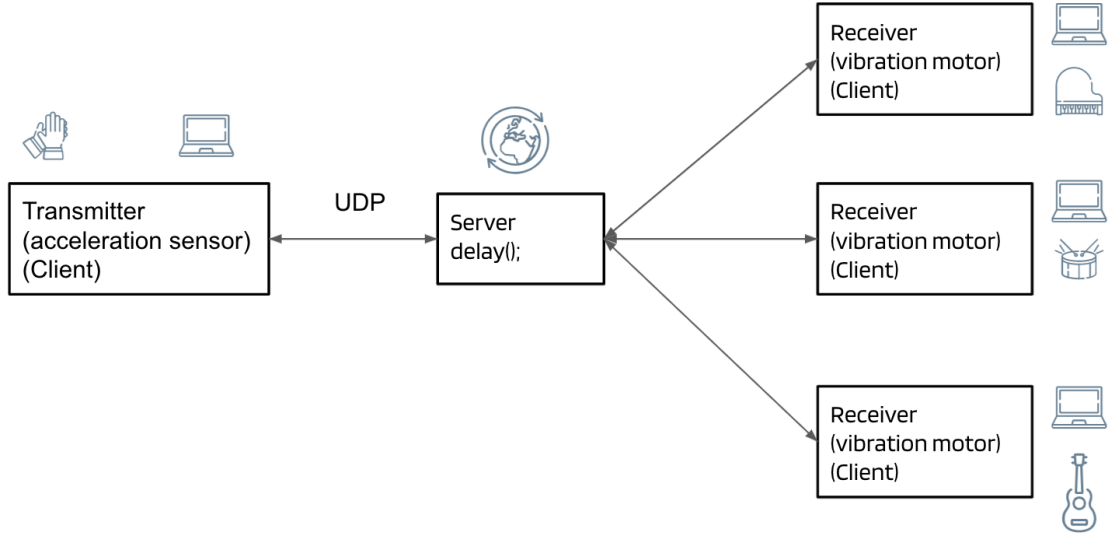


Figure 4.5 Server design

provides flow control and acknowledgment of data. However the accuracy it gives makes it slower than UDP. As a result, during the session and for solving the latency problem, the data should be continuous and it should be sent and shared as soon as possible, UDP is used for data transmission to sending the movement of the guitarist's wrist, and the receiver would analyse the data to calculate the "trigger" point and activate the vibration motor on the other player's wrist.

#### 4.4.2 Delays

There are different approaches of play music together under high delay in the Internet, such as parameter controlling. Hadjakos [21] built a parameter controlled remote performance system to solve such problem. It is a system allows control of tempo, dynamics, and articulation of a pre-recorded score. This system provides an illusion of a traditional musical interaction. However, the player has to anticipate the note timing ahead in time. Therefore the offer of control over delicate deviations is limited. Through the result, parameter controlling is more likely to be a method of changing around the elements horizontally based on timeline, so to change the elements vertically on the timeline, it is worth trying of using different

sensations with delay to change the experience of online band sessions.

### 4.4.3 Rebuilding Online Environments and Artificial Delays

To rebuild the online environment, different amounts of time of delay would be applied during the experiment. Ignoring the perfect network environment and assuming the normal situation under 4g internet nowadays, which usually has a delay time of 50 milliseconds, and considering extremely awful network environments that only provide basic possible networks for people to play a session together, which is 70 milliseconds. And the participants' behavior would be tested based on the network during these two situations without knowing about the artificial delay time.

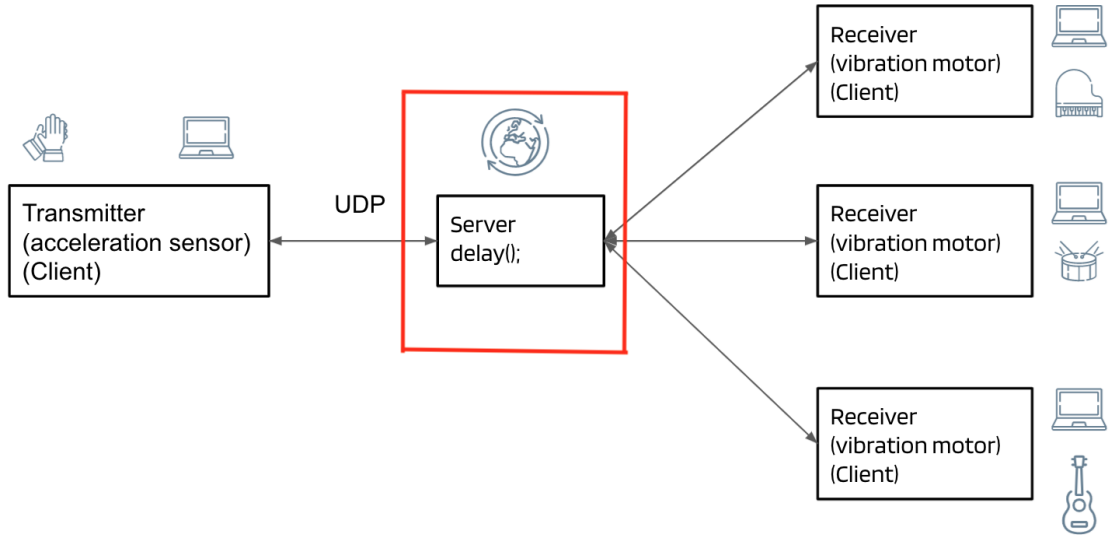


Figure 4.6 Server delay

Artificial delay could be easily created by tape delay with the plug-ins in the digital audio stations(DAW). In this case, Logic Pro is used for the whole experiment and the pre-set plug-in, sample delay is used for the experiment to restore the online delayed environment. Although there is still a difference between the

artificial delay environment with the actual online delay environment that the plug-in used in the digital audio stations are very stable that it keeps the delay at a certain amount of time. The actual online delay could be unstable and very randomly changes with different milliseconds. As a result, the experiment is only to observe how people would behave in a stable delayed environment.

## Chapter 5

# Preparation and Experiment Design

### 5.1. Summary

Based on the previous concept design, a prototype of haptic device set is built. This experiment is designed to test how this haptic device performs under a simulated delayed network environment. The audio would be recorded to compare the human reaction to the latency with and without the haptic device. The survey and the interview will question them focusing on the emotion connection and social behavior through the whole performance.

The purpose of the experiment is to observe how to improve the online band session environment with haptic devices. And if the design that describe in chapter four has any improvement to the actual simulated performance.

#### 5.1.1 Experiment Environment

To simulate an online band session environment, two separate isolate booths are required for the experiment. The two participants doing the band session together would not be able to get in touch directly in physical format by any sense of feeling. Only digital transmission of information would be available for the other participant. Considering the above requirements, the experiment is setup in Keio University Media Studio.

Keio University Media Studio

As Figure 5.1 shown, the media studio in Keio University is divided into three

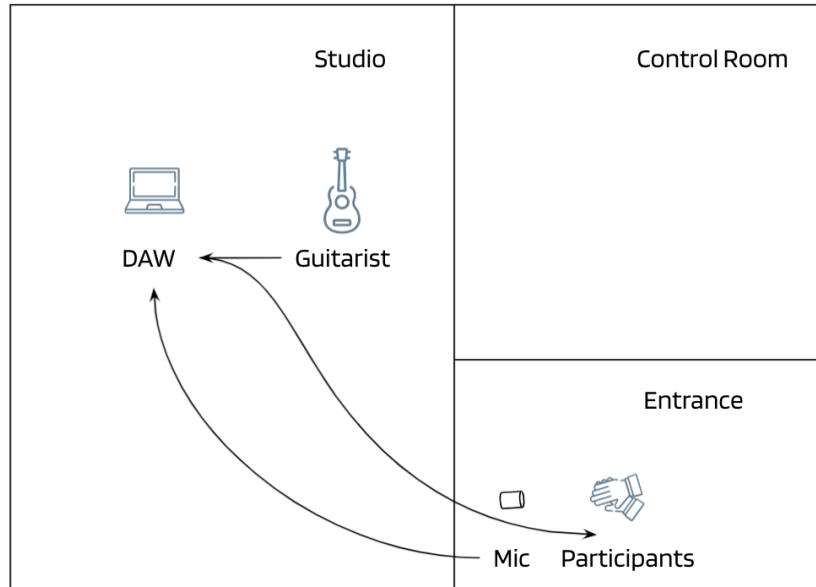


Figure 5.1 Keio University Media Studio

separated room of studio, entrance room and the control room with high quality of isolating the sound of each room, so the participants would not be able to hear any sound of people in the other room acoustically, the only way they communicate with each other would be digital transmission.

#### Routing of the Equipment

The experiment includes two participants of one playing guitar and the other response to the guitarist's performance by clapping hands. The two performers would be setup in two separated rooms. The guitarist would be stay in the studio with the laptop with digital audio workshop for recording and transmitting the sound to the other player. The digital audio workshop would create artificial delays which simulate the online environment. The haptic device that reads guitarist's wrist movement would be sending data to the participants in real time. The comparison test would be done two times with the guitarist play with and without the haptic device. In the entrance, a microphone would be set for the

participants to record them clapping. Same as the guitarist, the comparison test would be done two times with and without the haptic device that response with vibration based on the data from the guitarist's haptic device.

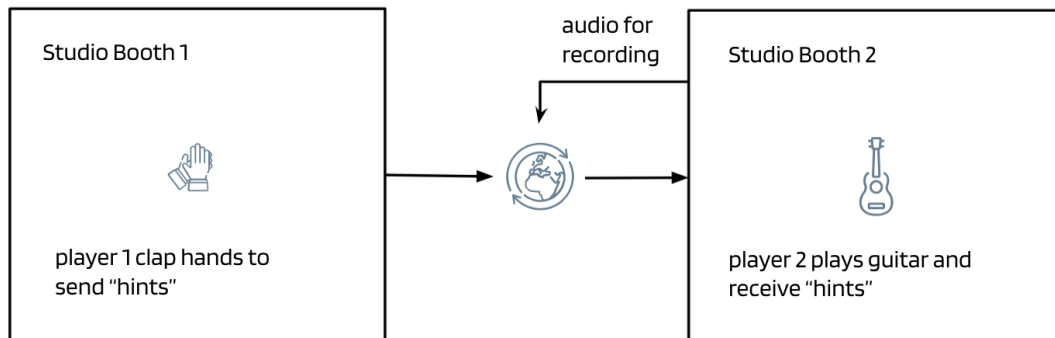
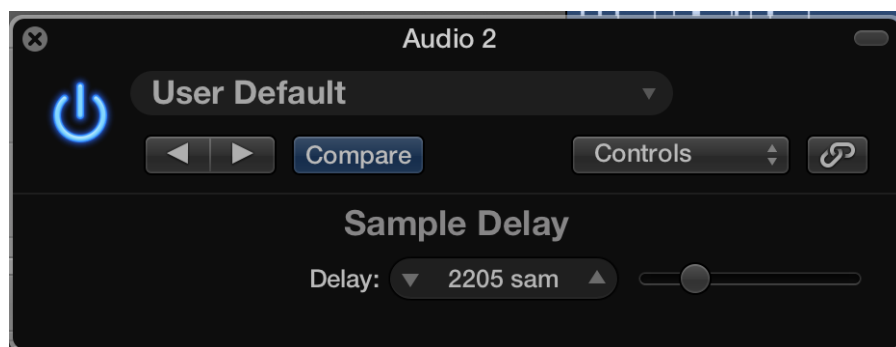


Figure 5.2 Digital Routing

The digital diagram of the whole experiment is show in the figure. Focusrite 2i2 is used as the audio interface in this experiment. The guitar uses the direct input of the audio interface, and the mic would record the clapping of the participants in the other room. The guitarist will play the chords following a rhythm with metronome, and the participants would be able to monitor the guitarist with the headphone and play alone with it.



(Source: Logic Pro X)

Figure 5.3 Sample delay in Logic Pro X

As Figure 5.3 shown, sample delay is used to recreate the delay. As 50 milliseconds and 70 milliseconds are set during the experiment, as for converting milliseconds to samples, the sample delay is set to 2205 milliseconds and 3087 milliseconds for bpm at 60, and 1323 milliseconds and 1852 milliseconds for bpm at 100.

### 5.1.2 Participants

The guitarist stays the same for every participant clapping hands. And the participants clapping hands would be the main objects of observation of the experiment. During the experiment, the haptic device for the two participants will have a very different function as one is acted as the transmitter, and the other is acted as the receiver.

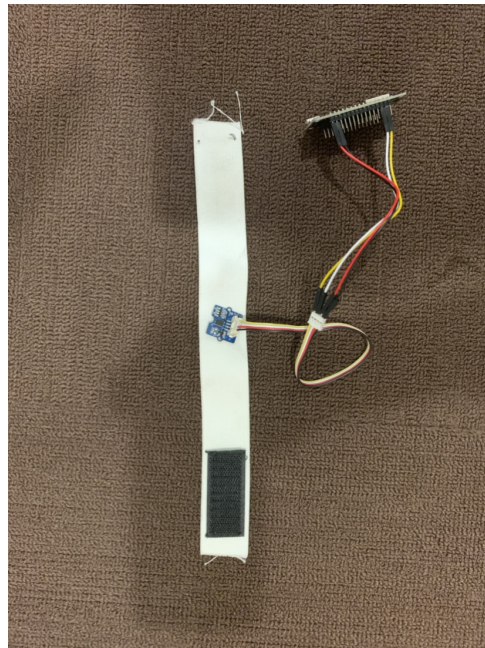


Figure 5.4 Haptic Device - Transmitter

The transmitter, as Figure 5.4 shown, which is at the guitarist side, detects guitarist's wrist movement with the ADXL345 acceleration meter, and send the x,y,z axis data to the receiver.



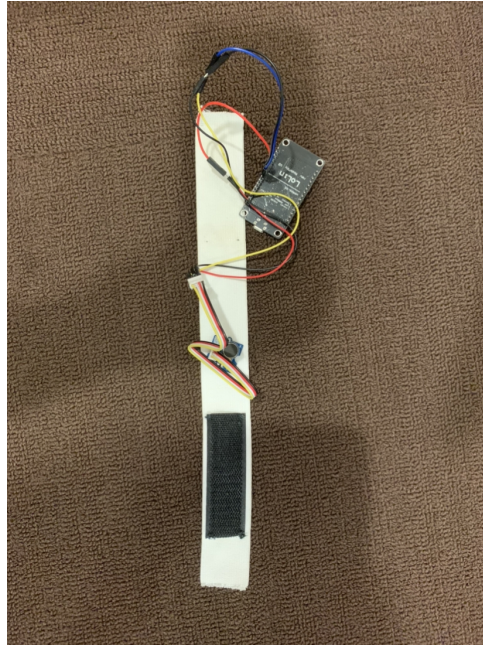


Figure 5.5 Haptic Device - Receiver

The receiver, as the Figure shown, responding to the guitar track with clapping of hands, will receive vibration pulse while the guitarist has a certain big movement triggered as a "hint" of changing the song from verse to chorus. The guitarist will perform the loop of the chords C-Am-Dm-G of four sections for each participants with different bpm of 60 and 100 each under different delay of 50 and 70 milliseconds. The difference between verse and chorus of the guitarist is that during the verse, the guitarist would play single note separately, and during the chorus, the guitarist is going to strum multiple strings with larger volume. Each participants of clapping is recorded alone with the guitar track and interviewed with a survey after the session.

### 5.1.3 Process

A performer of guitar and a performer of clapping hands would be separated in two isolated booths. The performer of clapping hands would be able to hear the audio of the guitarist with artificial delay of 50 milliseconds and 70 milliseconds.

Guitarist plays songs with bpm of 60, 100 from verse to chorus in the studio room first without the haptic device with different amount time of delay. The first half of the experience is to perform without the haptic device, and the second half of the experience is to perform with the haptic device. Participants are asked to response by clapping hands based on the audio first, and then with the vibration sensor that receiving signal from transmitter.

The "hints" during a session usually occurs during the change between the sections. As a result, to observe if the haptic device actually provide "hints" to the other performers, participants are asked to clap hands once per measure during verse and clap hands twice per measure during chorus.

As Figure 5.6 shown, during each section, to prohibit the participants to predict, get used to the guitar track, the length of the verse would be randomly played from four to sixteen measures, and the length of the chorus is also random. The participants wouldn't be told about the bpm or the delay of the play. The nature performance each time is expected.



Figure 5.6 Recorded sound waves

All the tracks will be recorded and there will be a brief survey after experiment.

## 5.2. Survey

Every participant that responded to the guitarist with clapping hands would fill out a survey after the experiment. The survey is to learn about their background of instrument performance, their feeling of using the device, the difference of the experience with and without the device and their feedback on it. The exact time of delay would not be told to the participants since it might change their performance during the tests. In the survey, previous experience of instrument performance is to observe if there is change of behavior for different level of instrument skills. The question of if people feel the latency with and without the haptic device is to observe if the haptic device gives possible solution for improving the latency problem during online sessions. The question of if the participants feel the hints and if they would use such haptic device is to find out if the haptic device changes or improves the online environment of band session and to find other possible improvement and application for this haptic device.

# Chapter 6

## Evaluation

In this chapter, the result of the experiment will be discussed. The discussion would be focusing on two part of the audio data recorded during the simulated on-line session to analyze the effect of the haptic device of the performance especially for the instrument beginners, and the survey and interview of the participants to analyze the effect of haptic device on the actual experience of the instrument beginners.

### 6.1. Experiment

#### 6.1.1 Summary

The experiment is occurred in Keio University Media Studio in total of three days from 2021.06.03 to 2021.06.05. During the experiment, in total of eleven participants are tested. None of the participants tried and online band session experience. Nine people out of the eleven participants have experience on instrument including piano and guitar. Seven out of the nine people are at beginner level, one is at intermediate level, and one is at advanced level.

#### Participants

Participants are separated in the entrance of the media studio, with is sound and visually isolated with the guitarist. They are asked to clap alone the guitar performance they hear first without the haptic device and second with the haptic device. The process was repeated for every participant. Interview was taken for every participants, the short ones lasted for around ten minutes and the long ones lasted for hours.



Figure 6.1 Participant with Haptic Device

## Process

During online sessions, there is a chance that people does not know about each other music performance behavior, and jam sessions is very usual even for decided songs because for most pop songs there is no specific score, instead, most time people play with the chords and tabs. As so there is a lot of unknown elements during online session. And only a loop of certain chords with different technique specifically of finger-styling and strumming is played for the participants. Each session includes different bpm and delay time, each session lasted around 30 minutes

### 6.1.2 Target User

Though the haptic device is previously designed for music instrument beginners. The participants were not asked about their music instrument experience in advance. Instead, it is asked in the survey. The point is that during online session, people with all possibilities of music instrument experience would participate. As

so it could be also an observation on if the haptic device has different impact on beginners and masters.

## 6.2. Result

The result includes two parts of the audio sound wave data that recorded during the experiment and the survey from each participant. In total of twenty-two tracks were recorded and each track includes four sections of different bpm and delay.



Figure 6.2 Missing beat

As shown in Figure 6.2, below is guitar track and up is the clapping track, when guitar strumming a new chord, the participants should be clapping which would reflect as a pulse on the waves, however, participants missed the clap on the

position. Comparing with clapping with haptic device, the participants reflects commonly on missing a beat when it transfer from verse to chorus. And with the haptic device, the participants all notice about the change of the verse and chorus, though they have some unstable rhythm clapping with chaos timing, they all changes their clapping mode immediately and was able to recognize the "hint".

Numbers of people missing a beat is counted and the relationship between missing a beat and the bpm and delay is shown in the Table 6.1. As shown, the number of participants missing beats during bpm=100 section significantly increased. And during bpm=60 session, people barely miss a beat, which means if the bpm is bigger, the chance of missing the beat during transition part of the song is bigger.

Table 6.1 number of participants missing a beats without haptic device.

	bpm=60	bpm=100
delay=50ms	0	3
delay=70ms	1	6

Comparing sound waves of participants with and without the haptic device, The time difference between the peak of guitar and clapping would be calculated. To find out if there is a remarkable difference, t-test is applied between four sections of pairs of the data.

The data are split into four sections of bpm equals to 60 and delay equals to 50, bpm equals to 60 and delay equals to 70, bpm equals to 100 and delay equals to 50 and bpm equals to 100 and delay equals to 70.

As figure 6.3 shown, to give the number of comparison, the peak to peak time is calculated and collected as a array. Because most of the participants are music beginners, the missed beats and wrong beats are considered as noise, only though notes they clap on the right place are considered as the collection of the data. A hundred of pair of the time difference between peak and peak is collected for each section.

Table 6.2 shows the result of t-test for the audio data. For bpm equals to 60 and delay equals to 50, results in p value equals to 0.0416, meaning the data is statistically significant. For bpm equals to 60 and delay equals to 70, results in p value equals to 0.0073, meaning the data is very statistically significant. For bpm

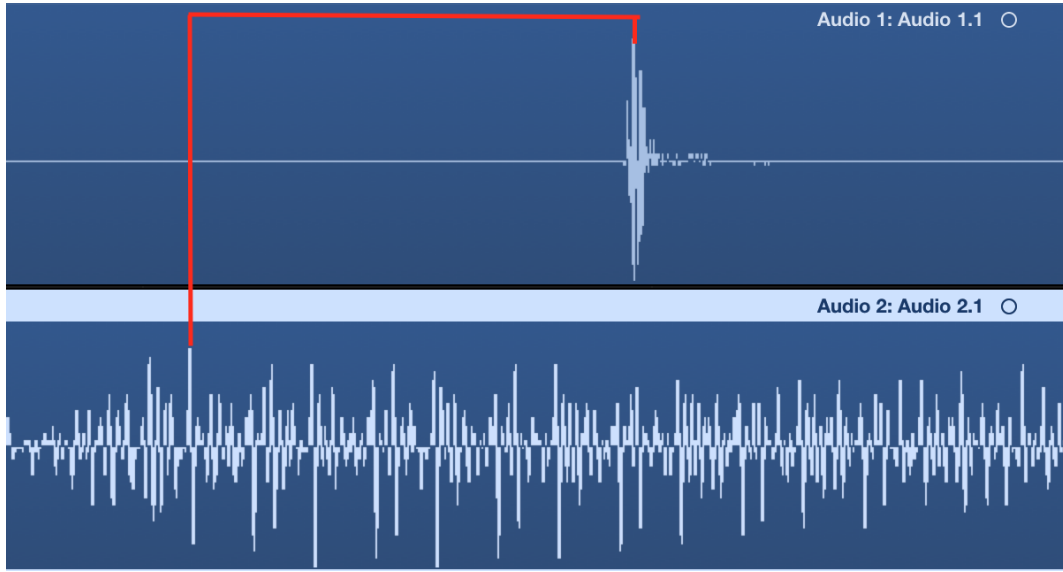


Figure 6.3 peak to peak

Table 6.2 p values of t-test

	p value	difference
bpm=60, delay=50ms	p=0.0416	statistically significant
bpm=60, delay=70ms	p=0.0073	very statistically significant
bpm=100, delay=50ms	p=0.0008	extremely statistically significant
bpm=100, delay=70ms	p=0.0001	extremely statistically significant

equals to 100 and delay equals to 50, results in p value equals to 0.0008, meaning the data is extremely statistically significant. For bpm equals to 100 and delay equals to 70, results in p value equals to 0.0416, meaning the data is extremely statistically significant.

As the result shows, wearing the haptic device during the online band session gives a significant difference comparing to without the haptic device. Especially for the fast bpm as bpm equals 100, it gives an extremely statistically significantly difference.



## 6.3. Discussion

As the data shown, the haptic device does give a different experience of online band sessions. Especially for the faster bpm, as long as the haptic device could stay in sync with the movement of the other player and trigger the "hints" at a timing that usually people breath or tilt body offline, it does change the performance of the performers in the session.

### 6.3.1 Survey

**If the haptic device improves the feeling of latency during online band sessions**

Do you feel latency without wrist band?

11 件の回答

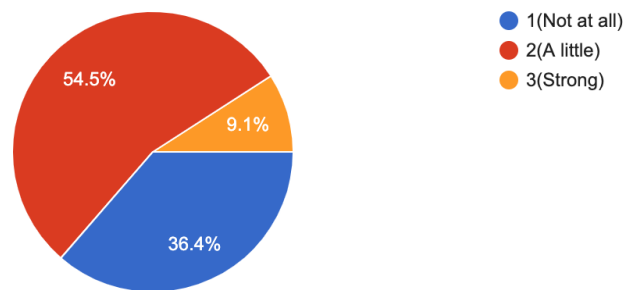


Figure 6.4 Latency without the Wristband

Eleven participants in total participated in the experiment. Figure 6.3 and Figure 6.4 shows how the participants feel differently about latency with and without the haptic device. Even though the guitarist stays strictly with the metronome and stays in the rhythm without reacting back to the clapping, which the participants should not feel the latency, however, seven of eleven felt the latency, and six had a very vague feel of latency. It could be able to explained as psychology cue words because of reading certain question. Make this question as a standard,

Do you feel latency with wrist band?

11 件の回答

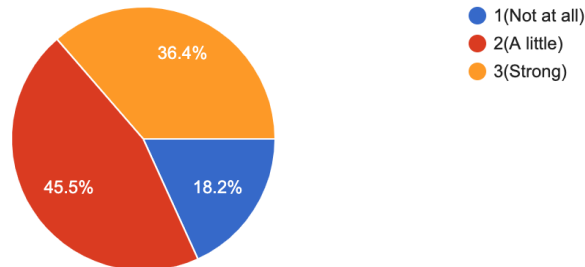


Figure 6.5 Latency with the Wristband

comparing to doing the simulate band session without the haptic device, the feel of latency is enhanced with the haptic device. Only one participants does not feel the latency at all, and the participants have the strong feeling of latency has increased from one to four people.

#### **If the haptic device improves the experience in general during online band sessions**

As one of the main purpose of the haptic device is to provide "hints" to the other performer, the participants are asked if they feel the "hints" during the session with the haptic device. And in result of five of the participants was satisfy about the device, and they think that the haptic device gave a great hint on the right timing. Five of the participants was satisfy with the function of haptic feedback, however, they would like changes of the device because they feel the hints comes at a strange timing, and they said in the interview that the algorithm of the trigger of the "hint" sometime is not very stable. It depends on very detailed position of wearing of the haptic device of the guitarist. Also, the behavior of performance is very personalized, therefore, the algorithm needs to be adjusted for different people. And most people state that, comparing to giving "hint" or reduce the feeling of latency, the haptic device enhance their connection with the other people. They feel more relaxed because the haptic device gives them a

Do you feel the vibration help gives you hint of the other player?

11 件の回答

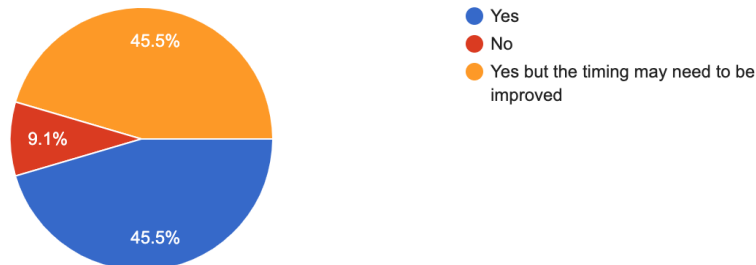


Figure 6.6 If Participants Feels Hints

better imagination of the existence of the performance far apart, which they felt a little bit worried when they were clapping without the haptic device.

The question of if the participants would use such haptic device was asked after the experiment. Four participants answered yes, and the rest would consider using such kind of device. As every participants states that the vibration does give a strong impact and emotional connection with the other player, however, the design of the vibration could be more detailed and various. Also, as the participants are clapping, the vibration of the haptic device sometimes get canceled that they could not actually feel it.

### 6.3.2 Observations

#### Analysis

Based on the audio data and the survey, though the haptic device enhance the feeling of the latency, it does improve the actual performance that the timing of actual time on the audio files are more precise with the haptic device, which would feedback to the guitarist in the real cases. As a weakness in this experiment is that guitarist was not responding to the actions of the participants' clapping, which is to control the variable and easier observing the one specific object in the experiment.

Would you use certain haptic device if you starts instrument and play with other people online?

11 件の回答

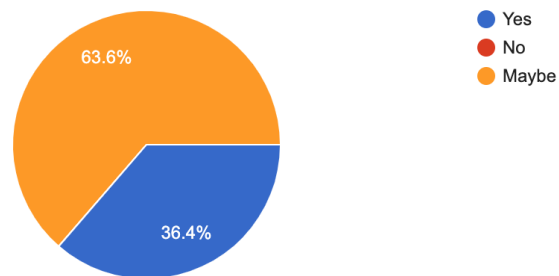


Figure 6.7 If Participants would use such haptic device

The experiment does found that the haptic device does help people connect during online band sessions better, and performs better. For the performance, the haptic device has more significantly difference with the sessions of faster bpm. And from the interview and the survey, it is able to conclude that the haptic device does help improve the whole experience of the online band sessions.

## Chapter 7

# Conclusion and Future Works

### 7.1. Conclusion

This research paper discussed about the online band sessions environment. The online band sessions solves a lot of problems might occur during offline session like booking space, too far for transportation, etc. and makes having a session between people easier regardless of physical place. In addition, the online band session has the potential of bring a new social styles for the musicians. However, with the current technology, there are a lot of insufficient parts for the online band sessions like latency, and limited elements of information from other player. In the research a haptic device is built and tested with eleven participants.

#### 7.1.1 Effect of the Haptic Device on Latency

Data wise, the haptic device does help the participants perform better during the remote band sessions that it provides "hints" and prohibited the participants to miss note during the transition of the verse to chorus. However, experience wise, most of the participants states that the haptic device enhanced the feeling of the latency. The experiment environment may also be the reason of this result since the guitarist is not responding to the clapping of the participants as if the guitarist response to the clapping, the participants would also have a strong feeling of latency from the audio. Instead, the guitarist is just keeping playing on a stable rhythm, which might lead into a different result. As discussed, further experiment of guitarist responding to the clapping is needed to test if the haptic device actually helps improve the latency problem.

### 7.1.2 Discussing the Algorithm

The algorithm of detecting peak to peak acceleration movement on certain axis needs to be improved. Because the algorithm is simply number based, the trigger changes unstably with the behavior and the situation of the guitarist. And this kind of real-time transmission would consider of a lot of noise for the participants. Machine learning of each guitarist's movement by analyzing their behavior of playing several songs and customize personal changing algorithm would be one of the possible solutions to give a better experience.

### 7.1.3 Response of the Vibration

Three out of eleven participants mentioned that the vibration would be hardly felt during the clapping because clapping itself creates vibration especially for the wrist part of people. To improve this problem, there would be several possible solutions. First is to chance the place for feeling the vibration. Instead of wrist, the body parts that doesn't involves into the movement during the performance would be considered, like neck, ears, etc. Second solution is that to chance the type of the vibration. There are two basic types of vibration motor. An eccentric rotating mass vibration motor (ERM) uses a small unbalanced mass on a DC motor when it rotates it creates a force that translates to vibrations. A linear resonant actuator (LRA) contains a small internal mass attached to a spring, which creates a force when driven. And motors could also considered into different axis. Changing axis of the vibration motor different with the direction of body movement could make it more noticeable to the performers.

## 7.2. Future Works

As described in the conclusion, for the haptic device, there are still a lot of parts need to be improved, and different kind of experiment would be needed to be done with various methods.

### 7.2.1 Further Research

#### Algorithm of the Haptic Device

The timing of the haptic device to giving out the "hints" is not precise and stable, because current algorithm only uses an equation to decide when to trigger such "hint", to supplement the algorithm part, more complicated program and system would be needed, for example, using machine learning to first learn about how numbers of guitarists' wrist movement changes between finger-styling and strumming, and then personalize the system for individual based on their personal behavior would be ideal. There are still a lot of other possibilities to improve the haptic device, and improving the algorithm would lead into a very different result.

#### Vibration Design

Several participants stated that because of the clapping also vibrates the wrist, it weakens the feeling of vibration of the device. In addition, vibration applied for example, play station 5 and some of the music videos on some video website like bilibili, has already designed a great system of the experience with the vibration. As there are multiple types of vibration, and vibration could be divided into axis, a more detailed vibration could be designed instead just turn it on or off. The vibration could tell about the detailed movement and the actual power of the other player and it could also be designed based on the frequency being played.

#### Designing Haptic Device for More than Two People

In the research, the haptic device only built for two people of one transmitter and one receiver. However, during real remote band sessions, usually two or more players would be participating. As a result, haptic device and the whole digital network for data transmitting needs to be built for more people to be able to get connected. And the more haptic devices involves, the more complicated the system will be.

### **Latency Problem**

Latency problem of online band sessions is more likely to solve by the improvement of the speed of internet with the development of 5g, or in the future, 6g or 7g might be widely applied in the society. As so the feeling of latency have a huge chance to be much improved and getting in the tolerant of human feeling. And a good network environment would help players focus more on the audio part. Therefore, improving the speed of the network might be the best way to improve the latency problem for the remote band sessions.

### **Instruments with Different Characteristics**

In the current research, only the relationship of guitarist and the percussionist with haptic device during a session is discussed, and the trigger of the "hints" has been previously focused on designing based on the guitarist's body movement. There are other common used instruments in band sessions like bass and keyboards. It is also important to observe how the haptic device would change their behaviors during the remote band sessions since they have a very different body movement and different envelope. And for instrument like keyboard, it includes a lot of different frequencies and sounds inside which would also influence the experience of designing and applying the haptic device.

## **7.2.2 Applications**

Remote haptic device for music performance might also brings other changes to the other categories in music. For example, it would bring a refreshing experience of socializing using music and online live for the audience. There would be a lot of other possibilities of applying the haptic device for the online

### **Music Social**

As stated in the related works, the social mode of online band sessions has similarity with traditional Irish musical community. As the form of getting into a room with a lot of strangers. However, during offline session, people would get familiar faster because of the body movement, the visualize information. Haptic device during online sessions could enhance the communication of the players that could



only hear but not visualize each other. And it could analyze the other players' behavior for the other players. Also, the existence of the haptic feelings gives the performance the existence of the other performer and makes the whole environment more comfortable, that even when people stop and adjust their instrument quietly the anxiety of the other performer decrease.

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