AUSTRALIA NATIONAL UNIVERSITY

An evaluation of touch-based music sequencer apps on iPad

by

Ke Ding

A thesis submitted in partial fulfillment for the
degree of Bachelor of Advanced Computing(Honours)
in the
Research School of Computer Science

Supervisor:
Dr. Benjamin Swift

May 2017

Declaration of Authorship

I, Ke Ding, declare that this thesis titled, 'An evaluation of touch-based music sequencer apps on iPad' and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Signed: ____

Date: ____

"We tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run."

Roy Amara, leader at the Institute for the Future

AUSTRALIA NATIONAL UNIVERSITY

Abstract

ANU College of Engineering and Computer Science

by Ke Ding

With the repid development of technoldge, mobile devices have become the new playground for musicians to express themselves. With a variety of sensors, as well as the exponentional growth in the processing power, iPad offer an attracitve platform for music performing. Thousands of music applications have been developed for the iPad. Music sequencer applications, as one of the major category of music making applications, have seen a lot of derivation and innovation. But the question is among those novel music sequencer interface which one supports musicians performance and stimulates their creativities? This thesis is trying to answer the above question from the perspective of musicians. The research was seperated into two consecutive study. In the first study, we investigated 55 music sequencer applications from App Store and created an interface taxonomy, in which music sequencer applications were divided into three groups according to the mapping of pitch, trigger and timber. In the second study, three most representative applications from each group were selected and tested by musicians to evaluate the pros and cons in the different design approaches. By employing the MPX-Q questionnaire, we quantitatively analyzed the strength and weakness of each sequencer applications. Follow by, a qualitative study was conducted to reveal the reason behind those design.

Acknowledgements

It has been a very interesting and challenging semester. I have many to thank for the support and guidence.

I would like to thank my supervisor Dr.Ben Swift for his patience and dedication throughout the project. My appreciation goes to Ben for his encouragement and selfless support. He always guided me when I was confused and pushed me at the time I needed most. I would like to thank Pro. Weifa Liang, as course convenor, he provided many useful guidence to the presentation and structure of academic report.

My appreciation goes to the participants who spent their time in the user study and gave me many valuable suggestions. Special thanks to Kirean Brown for his passion and experience. Jiang, for his suggestion on managing papers and academic report writing. Rich, for his advertisment to recuit participants on facebook.

Finally, I would like to thank my family, friends and classmates who have create a comfort and cozy study environment. In particular, I would like to thank Eva for her accompany and support thoughout the project. Thank you all.

Contents

List of Figures

List of Tables

Abbreviations

NIME	**N**ew **M**usical **I**nstrument **E**xpression
MPX-Q	**M**usicians's **P**erception of the E**x**periential **Q**uality
DMI	**D**igtal **M**usical **I**nstrument

Chapter 1

Introduction

Music sequencer, as an instrument, has been studied by musicians for a long time. In section 1.1.1 the development of sequencer was introduced.

With the rapid development of digital audio technology, computers are playing an increasingly important role in music, and providing unprecedented opportunities for people to create and manipulate sound. The iPad, a portable computer with touch screen, provides a new platform for musicians to express themselves (see section 1.1.2).

Since thousands of new musicial interfaces built on computers have been created and released to the world, it is natural to ask, what kinds of musical interfaces are taking better advantage of computers? To answer this question, a new community called NIME emergeed from the establised field of human-computer interaction (HCI) [Wanderley and Orio, 2002]. And in NIME, the evaluation of musical interface is mainly focused on expressivity, control and aethetic three aspects [Schmid, 2015].

1.1 Background

1.1.1 Development of Music Sequencer

By modern definition, a music sequencer (or sequencer) is a hardware device or software application which can handle music materials such as notes, sounds and many other forms of performance information. It is widely used in performing electronic music, and used as a processing tool in music composing. The history of music sequencer can refer to

9th century, the earlier sequencers worked as sound producing devices and depended on the preset inputs. A famous example of early stage music sequencer is player piano, a self-playing piano which play the music pre-recorded on a piano roll. When the technology matured, more forms of sequencer emerged. Analog sequencer which took advantage of analog eletronics was the first sequencer designed to live performance except music composition. Step sequencer, also known as drum machine, distriputed the note into steps with equal time-interval, which free musicians from acurately timing of each note.

In morden times, digital sequencer implemented on computers become popular. The advent of Musical Instrument Digital Interface (MIDI) made the digital sequencer with great vitality. In recent years, the popularity of mobile devices brought music sequencers to a new platform and many new elements have been put into practice.

1.1.2 iPad: a new playground for musicians

The iPad, a tablet computer with touchscreen display, has quickly occupied the market all around world since it's first release in 2010 [Nguyen et al., 2015]. The emergence of iPad have provided a new platform for users to explore digital world [Müller et al., 2012]. After 7 generations, the usage of iPad has shifted from the extension of iPhone to a powerful pruductivity tool. In this shift, thousands of applications which was designed to utilise the larger touch screen has emerged. According to Nations, there are over 1.5 million apps are currently hosted in the App Store and more than half of those apps are specifically designed for iPad [Nations, 2017].

Since the first release of iPad, there are practices to utilise the large tangible screen and wide variety of sensors of this cross-time product. Wang et al. designed *Magic Fiddle*, a new musical instrument, which combined the physical gesture of users and graphical display of iPad together. Martin et al. explored the possibility of using iPad as a percussive instrument and used iPad's network feature to ecourage cohesive improvisation [Martin et al., 2014].

1.2 Related Work

A lot of work have been down on evluating the interaction between users and mobile devices such as iPhone. However, there haven't been a paper specificly analyze musical instrument implemented on iPad. Stowell et al. evaluated the live music-making on computer through discourse analysis and turing test [Stowell et al., 2009]. A questionnaire-based evaluation method was proposed to evaluate the musical instruments, especially the new forms of instruments from NIME [Schmid, 2015].

Unexpectedly, music sequencers as the top three most popular instruments in iOS musical applications [Kell and Wanderley, 2014], has not attracted much attention. We can barely find papers related to recent years development of music sequencers application. The most related work was *Block Jam* (see figure 1.1), a sequencer with tangible interface consisited of several physical blocks [Newton-Dunn et al., 2003].

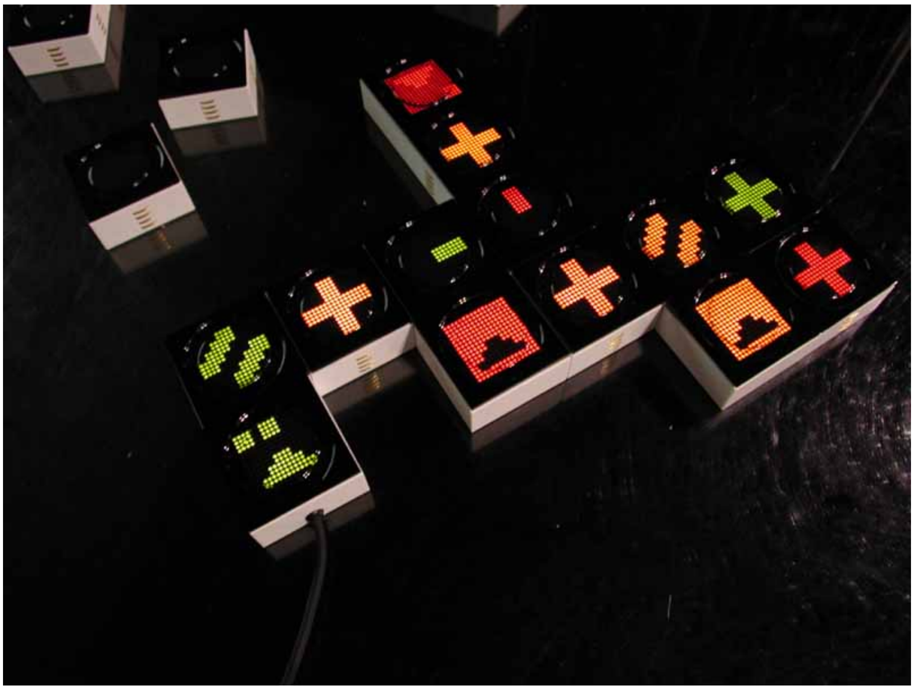

FIGURE 1.1: Block Jam: music sequencer consist of a cluster of blocks

1.3 Research motivation and goals

While musical interfaces have been studied for a long time, there have emerged thousands of novel twists on "grid-based" music sequencer. And to our knowledge there is currently no paper investigate the situation of this certain kind of musical application on App Store. What's more, there is no consensus on using what's method to evaluate those newborn musical application on mobile devices. This work is a first attempt to classify the music sequencers on iPad and adopt the evaluation method(MPX-Q Questionnaire) designed for NIME community. The goal of this thesis is to evaluate touch-based music sequencer apps on iPad by:

- Creating an interface taxonomy of current music sequencer apps on the iOS app store.
- Performing a HCI user study to measure user experience and musicians performance with different interface design approaches.
- Proposing design guidlines for musicians, developers and researcher for creating musical interface in the future.

1.4 Thesis structure

In the next chapter, literature relevant to the research topic was introduced, so as to establish a theoretical framework of the research (see Chapter 2). And the research project was divided into two consecutive studies. In the first study, we analyzed the music sequencer applications (designed for iPad) on App Store and create an interface taxonomy (see Chapter 3). Then base on the classification of music sequencer interfaces, we selected one most representative application from each category and conducted an user study to evlauate the effect of different interface design (see Chapter 4). In Chapter 5, we discussed the results and provided a conclusion of the study as well as the future work.

Chapter 2

Literature Review

2.1 The development of NIME

The New Interfaces for Musical Expression (NIME) conference is an international conference for musicians and researchers from all over the world to demonstrate their latest work on musical interface design [NIME, 2012]. It first started as a workshop at the Conference on Human Factors in Computing System (CHI) in 2001. After that, annually conferences have been held around the world. The hoster are research groups who devote themselves to interface design, human-computer interaction and computer music. The latest conference was held at Griffith University in Brisbane, Queensland, Australia in 2016.

In the last sixteen years, NIME has explored different approaches on new musical interface design. The *reacTable* which was designed for live music performance on tabletop led a new trend on tangible music interface [Shaer and Hornecker, 2010]. Many researchers shifted their attention to this new media. Toolkit such as reacTiVision was developed to detect movement of performers and allow further development to turn any surface into a musical instrument [Kaltenbrunner and Bencina, 2007].

The success of *Smule* initiated a new era of mobile music [Wang, 2009]. After that, thousands of musical applications such as *MoMu, MadPad and Magic Fiddle* which were specifically designed for mobile devices were developed [Wang et al., 2011, Bryan et al., 2010, Kruge and Wang, 2011].

2.2 Mobile Music

With the increasing popularity of mobile device such as smart phone and tablet, a new research field called Mobile Music emerged [Flores et al., 2010]. According to the definition by Gaye et al., *Mobile Music* wich employing portable technolodge does not only include the scope of playing music, but also involve music composing, synthesizing and sharing[Gaye et al., 2006].

In the last sixteen years, there is a growing number of researchers start concerning the development of applications in mobile devices. This new trend was first highlighted by John after analysing 98 NIME procedding papers related to mobile music during the period from 2002 to 2012[John, 2013].

The expanding capabilities of mobile devices inspired researchers to exploit the new features.The wireless network ability of mobile device is the first area attract researchers' attention. TunA is the first practice of building connection among PDA users though wireless network[Bassoli et al.]. By accessing the playlists of nearby users, TunA help users in same network to exchange their music. Tanaka extended Bassoli et al.'s work from music sharing towards collaborative musical creation [Tanaka, 2004]. Tanaka propsed a system which exploits ad-hoc wireless networks to allow a community of people using their PDA to work on the same piece of music [Tanaka, 2004]. Some research started from a different approach by investigating the possibility of utilizing the touch screen on the mobile devices. Geiger designed a paradigm for using touch screen on mobile device like iPaq [Geiger, 2003, 2006]. MoGMI, which stand for Mobile Gesture Music Instrument, is a research project focused on using the accelorometer inside the mobile phone to perform music. Through examing three different axis mapping models, Dekel and Dekel explored how to turn mobile phone into a standard instrument. Smule Ocarina is the most successful mobile musical artifact, which take advantanges of the global popularity of iPhone [Wang, 2014]. It leveraged the microphone to take input from breath, and combined with command from the multitouch screen to mimic the physical interaction of ocarina. Besides, Smule Ocarina also utilizing the GPS module to connect users all around the world and create a new social experience [Wang, 2009].

2.3 Musical Interaction Patterns and Sequencer

Musical interaction patterns, also konw as design patterns, are common solutions for developers to design a specific interface,like music sequencer. Flores et al. stated since designer can reuse the proven discipline in their work, design patterns can assisit multidisciplinary design, improve communication between designers and facilaitae knowledage transfer between teams with different background [Flores et al., 2010]. In Flores et al.'s work, following four most common music interaction patters on mobile devices were given: 1). Natural Interaction. 2). Event Sequencing. 3). Process Control 4). Sound Mixing. In which, event sequencing was the second most popular interaction patterns. The general decription of event sequencing pattern was illustrated as: editing the sequence of musical event which maybe individual notes, several piece of samples or parameters that can modify the sound of music [Flores et al., 2010]. In Kell and Wanderley's paper, sequencer was put into an independent category of musical application on App Store, and it's nature of mapping was briefly discussed.

2.4 Evaluation of digital musical instruments

Digital musical instruments (DMIs) refer to instruments whose sound are generated digitally. It is not uncommon to ask what does evaluation means in the context of digital musical instruments. But as Stowell et al. mentioned, evluating the expressivness and creativity of an musical interface were very difficult [Stowell et al., 2008]. Stowell et al.'s paper followed by providing a methodology based on discourse analysis. An evaluation framework was given by O'modhrain, in which DMIs were evaluated from four interdependent prosepective: audience, performer, designer and manufacturer [O'modhrain, 2011]. Also, three general design goals were listed at O'modhrain's paper, which were *Enjoyment, Playability and Robustness.* Barbosa et al. proposed a process to evaluate DMIs from a performer's view [Barbosa et al., 2011]. A case study conducted by Jordà and Mealla was focued on the expressiveness and mapping of DMIs. Recently, by reviewed 89 papers published in NIME from 2012 to 2014, Barbosa et al. pushed forward the discussion to how to better use the evaluation tools to improve the design of DMIs [Barbosa et al., 2015]. Schmid proposed a questionnaire to evaluate the experiential qualities of musical instruments in NIME [Schmid, 2015]. Schmid indicated the following criteria for musicians to perceive musical instruments:

- **Experienced freedom and possibilities (EFP)**
- **Perceived control and comfort (PCC)**
- **Perceived stability, sound quality and aesthetics (PSSQA)**

EFP as the predominent facet, mainly targets at evaluating the musicianship and expressivity of music instruments. For example, questions like *"The instrument allows me to express myself."* are used to decide whether the instruments can let muscians to express themselves; *PCC* is used to assess the controbility of the music instruments. Questions such as *"I can control the sound appropriately."* are setted to identify how well the musicians believed they can control the instruments; *PSSQA* is the most unique facet which analyses the quality of the instruments from the material, the sound and the apperience perspectives. For instance, questions like *"The instrument pleases me sound-wise"* test the sound quality of the instrument. The above three interrelated facets construct the framework of MPX-Q questionnaire.

Chapter 3

Study 1: Classification of music sequencer

To achieve the goal of creating an interface taxonomy of current music sequencer apps onthe iOS App Store, a survey was conducted to analyze the current situation of sequencer apps at App Store. In total, 55 music sequencer applications have been examined (see Appendix B). Several search criteria are implemented to locate music sequencer on the App Store (see Section3.1.1). After analyzing those music sequencer apps, we proposed classification criteria based on the design of the user interface (see Section 3.1.2). The 55 music sequencer applications were classify into 3 major groups according to the classification criteria (see Section**??**).

3.1 Method

3.1.1 Search Criteria

Kell and Wanderley's created a list of whitelisted words for music sequencer apps, keywords such asrt *Sequence, Sequencer, Groovebox, Beatbox, Step, MIDI, Pattern, Tempo, BPM, Machine* were used to search on the App Store. Before each application was downloaded, it's description had been briefly overviewed to make sure it was designed for the purpose of making music. Also, when searching in the App Store, filter called “iPad Only”was chose to show the result only assocaite with iPad. And the search results were sorted under the relevance of keywords.

In total, 71 musical iOS applications associated with music sequencer had been downloaded from App Store. After examining them in details, 16 applications were removed from the study list either because the application could hardly be classified as music sequencer or caused by the application was not designed for iPad. The rest 55 music sequencer applications were studied in detailed (see Appendix B).

3.1.2 Classification criteria

The different approaches of interacting with the applications were used to classify the user interface of the music sequencer applications into several categories. The mappings of the sequencer were broke down into 4 operations, which were *changing pitch, triggering sound, timing and changing timbre.*

Changing Pitch. Most traditional instruments' pitch were changed discretely, for example, piano, guitar and violin. The majority of musical application including sequencer follow this trend. Besides, pitch is dominated by grid-like, buttom-to-top mapping in music sequencer hardware. Therefore, grid-based, buttome-to-top and discrete pitches layout is widely adopted.

Figure 3.1 is a good example of this classic interface, in which the interface is divided into 16x16 grids. The time, which is separated into 16 steps, only moves one step at a time from left to right. The blue vertical line works as a reminder of current time, and also indicates what is coming next(in the next step). The white square, on the other hand, represents the sound of a certain instrument. In this case, it represents an electrical sound called *FUTURE*. The column in each step is divided into 16 scales and which are the pitches of the instrument. The white squares located in the top of the grids are high pitch sound of the instrument, on the contrary, the pitch of the sound from the bottom is relatively low.

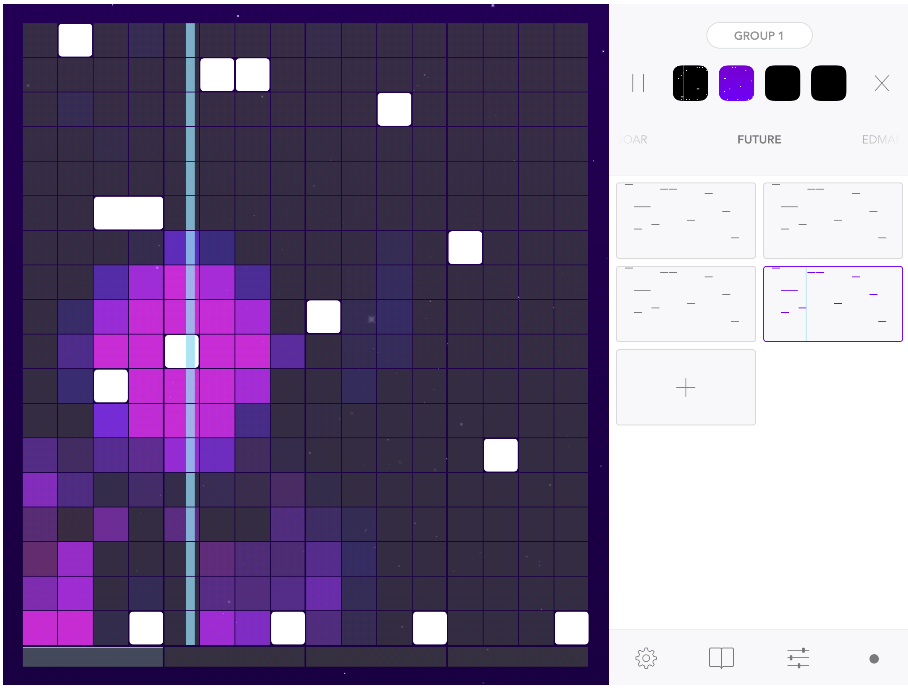

FIGURE 3.1: Beatwave: grid-based, buttome-to-top and discrete pitch layout

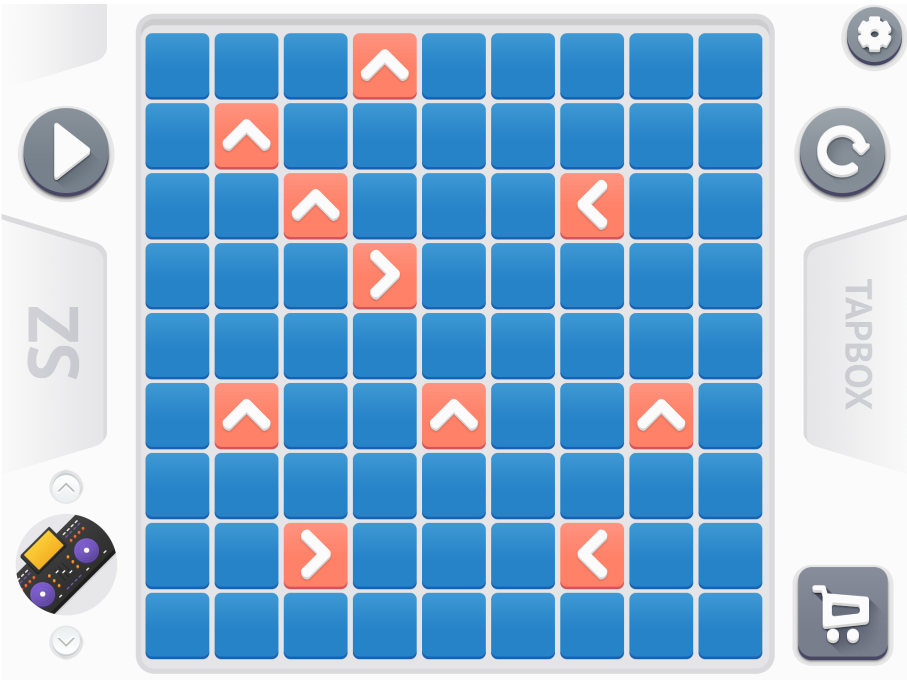

FIGURE 3.2: SoundZen: grid-based, right-to-left and discrete pitch layout

However, not all the grid-based sequencer applications increase pitch from bottom to top. There is a small portion of sequencer increase pitch from left to right. For instance, SoundZenHD used a left-to-right pitch mapping (see figure: 3.2).

In addition to the discrete pitch mapping, there are attempts to implement the continuous pitch. *CSketch Lite* followed the classic grid-based layout, but it implements continuous sequencing (see Figure 3.3). By implementing the continuous sequenceing, *CSketch Lite* is able to prodecue continuous sound in a series steps rather than make discrete sound step by step, which breaks the bound of the traditional music sequencer. Therefore, the pitch is changing continuously in *CSketch Lite*. In figure 3.3, the yellow and blue line denote the trend of pitch changing. Take the top-left yellow line as an example, the pitch of the sound is continuously droping from G# to F. Even though, the pitch of the above music sequencer applications are still linear mapping.

Except for the linear mapping though the grids, some few Apps adopted the non-linear pitch mapping. For instance, *Orbita* simulates the movemment of a small planet orbits around a central planet along an elliptical path. And in this case, different color of "planet"represent different instruments, which produces sound while elliptical orbit. The pitch is changing continuously based on the distance between the small planet and the central planet(see figure 3.4).

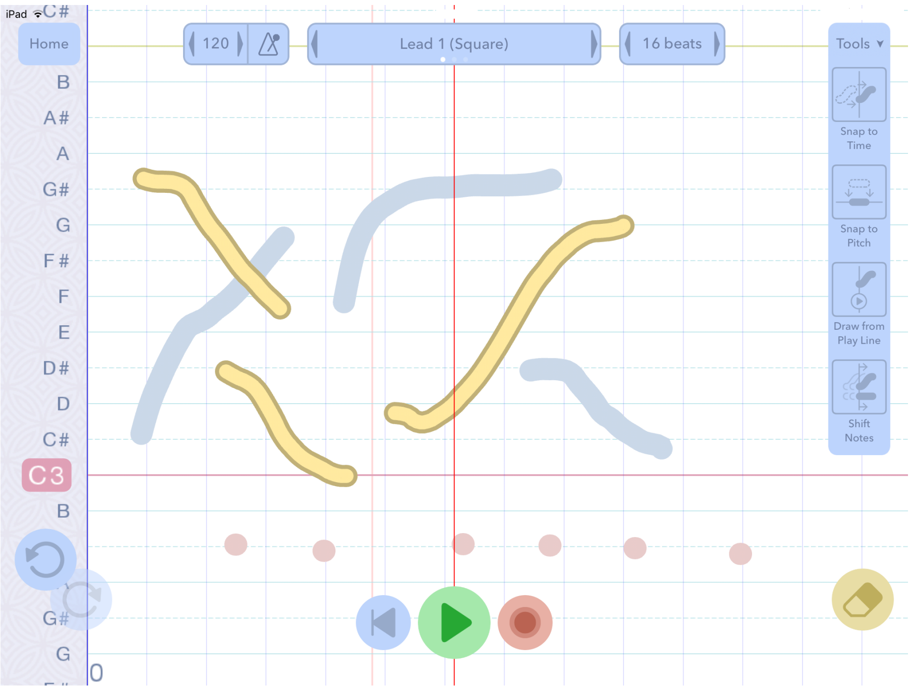

FIGURE 3.3: CSketch Lite: grid-based, top-to-bottom and continuous pitch layout

It is not unusal of mapping pitch to colour in music applications [Kell and Wanderley, 2014]. However, there was only one music sequencer found to represent pitch with different colors (see Figure 3.5). In *Volotic*, there is an emiter which continuously emits red little dot sequently. The red color, in this case, means note C or **Do** which is the first note of the fixed-Do solfge scale. Once the red little dot passed though a tone assigner, it's tone changed relatively and so as it's color. In Figure 3.5, the green symbol is a tone assigner called TUNNING, and the number in the middle denotes what note it is going to assign. There are seven different TUNNINGs which together consist the key of C(or C major).

However, this color-based mapping is not intuitive. It takes significant effort to link different keys to colors. Besides, in this case, the two colors between pitch E (**Mi**, the third note of the C major scale) and pitch F (**Fa**, the fourth note of the C major scale) is very difficult to distinguish. This unintuitive mapping could be the reason why the color-based pitch is not widely implemented, and we will look into the details in the next chapter.

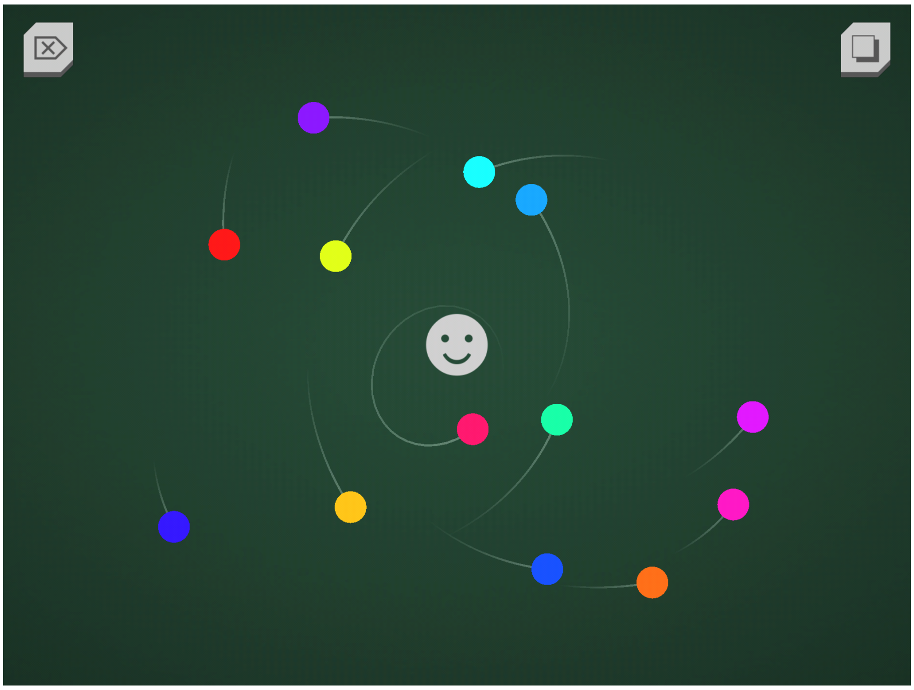

FIGURE 3.4: Orbita: elliptical orbita, non-linear and continuous pitch layout

Triggering and Timing. In Kell and Wanderley's study, the mechanics of how users inteacted with applications and the methods of how time was represented were studied seperately. However, in most music sequencer applications, time is used to triiger sounds. Therefore, triggering and timing were analyzed together in our study.

Unsuperisingly, given the fact that toggles are primary used on sequencer hardware, virtual toggles are the most commonl method for users to control sequencer applications to start producing sounds. In Figure 3.1, 3.2 and 3.3 there are virtual toggles acting as main switch to control the play/stop operation. After the main switch turned on, time is uesd to determaine the triggering sequence of a series of notes or several pieces of sounds. Likewise, timing in the majority of sequencer applications follow the convention of sequencer hardware, which time move from left to right. Some very few applications don't have an explicity display of time, such as *Orbita* and *Volotic* (see Figure 3.4, 3.5).

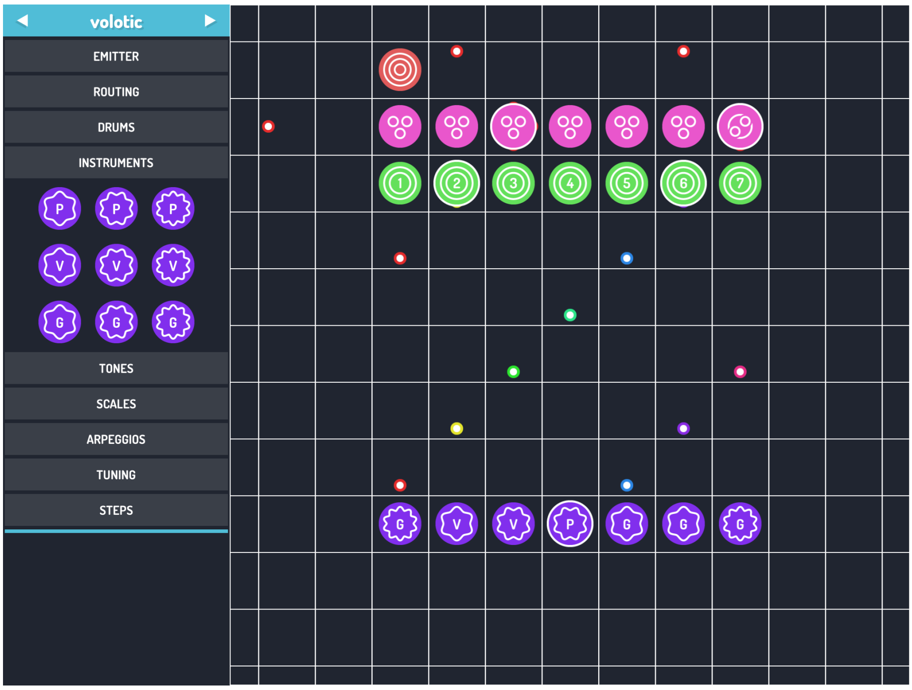

FIGURE 3.5: Volotic: game-like, linear and color-based pitch layout

Timber and Volumn. The majority of music sequencer applications use toggles to change timbers and volumn. Normally, there are several preset timbers and users can shifted between different timbers by selecting one of the preset timbers. Only a very small number of applications use additional control over timber. *Volotic* uses the the symbol of different instruments to represent the unique timbers (see Figure 3.5. Essentially, it is still a toggle but in a twisted form.

The reason why mapping of volumn is combined with timber is the majority of music sequencer use the same mapping which is a slider or toggle. Other volumn controls are very rare. *Orbita* is the only example of using the distance between the satellite and the planet to control the volumn. The volumn is turn up when satellite get close to the central planet. Conversely, the volumn goes down when two planets move apart.

3.2 Results

According to the classification criteria illustrated on section 3.1.2, we divided the music sequencers' interfaces into the following three categories. Novel Interfaces, Multi-track Interface and Traditional Interface.

Novel Interface. In total, thirteen applications were classified into this category. Novel interface was probably the most intuitive classification, because the apps under this group use entirely different mapping of time and timber. For example, *Volotic* deployed a game-like sequencer interface (see Figure 3.5), and *Orbit* imitated the celestial motion in the interface design. The list of apps under novel category were given in figure 3.6 below.

FIGURE 3.6: Apps under the Novel category

Traditional Interface. There were twenty-five apps belong to this category. The majority of music sequencer apps in this group followed the layout of sequencer hardware, and which was grid-based paradigm. The applications with traditional interface were listed in figure 3.7.

FIGURE 3.7: Apps under the Traditional category

Multi-track Interface There were eighteen applications grouped under multi-track interface category. Essentially, multi-track interface still followed grid-based. But an extra management system was developed to edit different layers of sounds, in which the trigger of different sound can happen simultaneously. For instance, *Beatwave* the most representative application of this kind, can play four different traks at the same time. The applications in this category were listed below (See Figure 3.8).

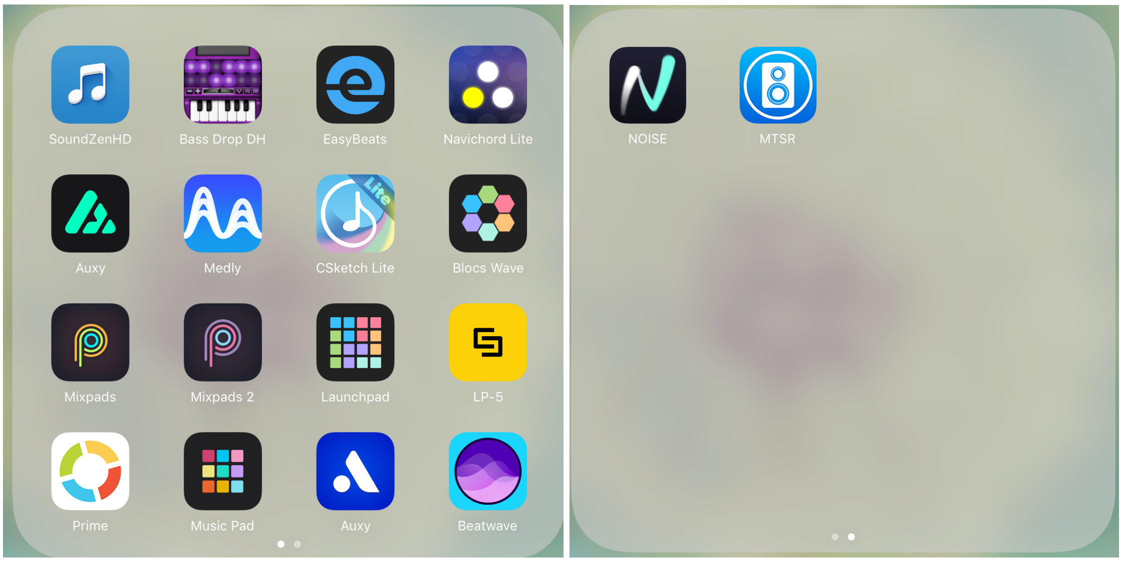

FIGURE 3.8: Apps under the Multi-track category

Chapter 4

Study 2: User Study

Following the first study (See Chapter 3), A laboratory study was conducted to evaluate user experience on different design patterns of music sequencers. In section 4.1.1, one representative sequencer application was chose from each interface category presented in the first study. Based on the previous work of evaluating music NIME, a questionnaire was designed to measure muscians experience (See Section 4.1.2).

4.1 Method

4.1.1 Representative Sequencer Applications

Considering the duration of the user study, we decided to select three apps that can represent it's own group most. In order to pick one representative application from each group, we first selected several apps from each category. Then, in order to eliminate the unnecessary disruptive factors such as the robustness of apps, the application shared the similar building quality were chose. In the end, *S.A.M.M.I* from the traditional category, *Beatwave* from the multi-track and *Volotic* from the novel category were chose to use in the user study.

In addition, took the influence of the presenting order of the above three apps in consideration, we futher disrupt the order of these three sequencer apps in the user stury.

4.1.2 Questionnaire

Likert scale questionnaire is widely used approach to represent people's reponse to a topic. For each topic there are normally five satisfaction items used to describe people's feeling. And a satisfaction item is a number between one to five, which represents interviewee's level of agreement over the topic. The higher number a topic scored means the more the interviewee agreed with it. Based on Schmid's work, which developed a 80-item pool ordered by descending mean importance for questionnaire, 10 questions that scored the highest mark from 9 different categories were used in the user study (see Appendix B).

Factor	Category	Item	μ
EFP	Creativity	The instrument allows me to be creative	6.25
	Enjoyment	I have fun playing the instrument	6.08
	Expressiveness	The instrument allows me to express myself	6.06
PCC	Conformance	The instrument responds well to my actions	6.23
	Control	I can control the sound appropriately	6.04
	Engagement	The instrument allows me to be engaged when I'm playing it	5.98
	Engagement	I feel the urge to play the instrument again	5.79
	Play Comfort	I can recognize that the instrument responds well to my playing	5.85
PSSQA	Stability	I can rely on the instrument when playing it	6.21
	Sound Quality	The instrument pleases me sound-wise	6.02

Table 4.1: Items in the questionnaire with thier factor and category(ordered by descending mean importance)

Follow the framework of MPQ-Q questionnaire, 10 questions from 3 factors were implemented in our questionnaire(see Table 4.1). For each factor, only the items score the highest mean importance value in the certain category were picked. Under the EFP factor, we focused at the creativity, enjoyment and expressiveness of the music sequencer. The reason for this, it's because we want to figure out whether the design of the interface is encouraging musicians to explore new possibilities and inspiring musicians' creativity. As for the PCC, items associate with conformance, control and engagement are chose. The reason behind this is when musicians performing on instruments there are a lot of physical interaction between musicians and instruments, whether the musiciain feel conformance and engagement have impact on their overall satisfaction. For items under PSSQA, we only look at the stability and sound quality. Because the more stable of the music sequencer the more confident musicians can rely on it. Same with the sound quality, only the instrument that can satisfy the muscian is able to please the audience.

4.1.3 Participants

In total, twenty participants with different music background were invited and took part in the user study. Fifteen of them are male and five are female. All the participants have at least one year of formal training on at least one instrument. Among the participants, the majority only had experience with traditional instruments such as piano, guitar and violin. Only three musicians had experience on electronic music and had tried on music sequencer software on the laptop before. All musicians still play music regularly.

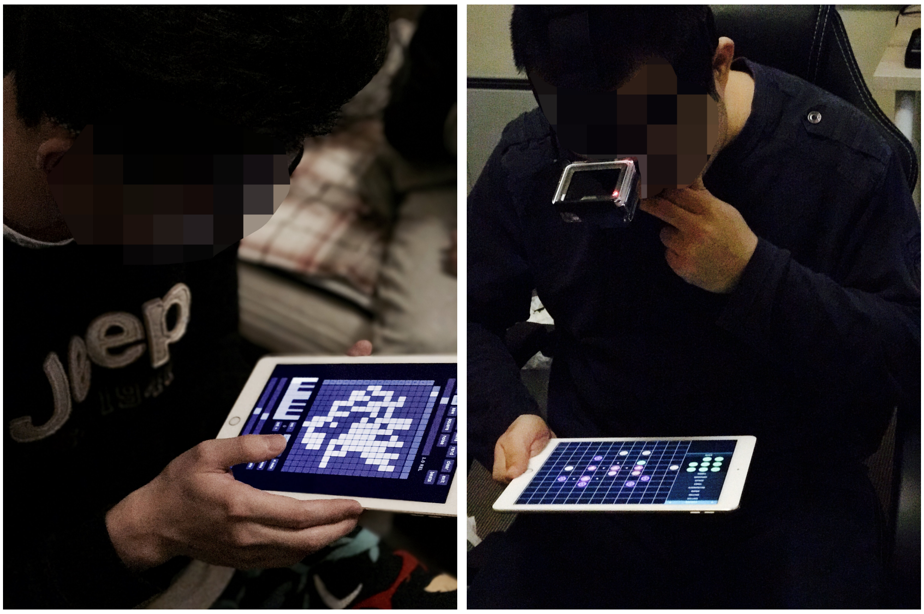

FIGURE 4.1: Participants test on the music sequencer on iPad

4.2 User Study Process

The duration of the user study was planned as approximately one hour. The first fourty-five minutes was the try-on section which quantitively analyzed the interface (see 4.2.1). In the last fifteen minutes, an interview was designed for qualitative analysis purpose (see 4.2.2).

4.2.1 Apps try-on

In this try-on section, all the participants were asked to play on the selected music sequencer applications on iPad. For each apps, musicians were given 15 minutes to explore the apps by themselves, and assistance was given only in request. The suggested time allocation was given as: in the first five minutes try to figure out the how it works, then impovise with the apps in the next ten minutes. After trying on each sequencer application, participants will be given a questionnaire with 10 questions to decide their feelings on the app in terms of expressivity, control and aesthetic(see Appendix C).

4.2.2 Interview

Participants were intervied at the end of the user study. The main purpose of the interview is to find out the reason behind their decision on the questionnaire. Besides, the music background of participants such as *"how many years of music training"* were recorded for further analysis. The sample question was given in the appendix D.

In order to acquire the deeper reason, all the interview followed the same procedure: 1) Since the majority of the participants did not know music sequencer before, they were asked to describe the similarities among the three different music sequencer applications, and then defined what is music sequencer. which was designed to help them to form a general idea of music sequencer. 2) After that, interviewees were asked to choose their favourite application based on different scenario. Also, the interviewee needed to give reasons why certain music sequencer application was better than another. 3) In the final step, all the questions shifted to an abstract level, where they were asked whether music sequencer application on iPad were an instrument ,and what features that made them thought it is or it is not an instrument.The interviews were recorded on video and audio based on the participants agreement. The recording lasted between 10 to 20 minutes.

4.3 Results

My supervisor (Dr. Ben Swift) assisted in the preparation of the graphs and statistical tests discussed in this section.

4.3.1 Quantitative Results

In total, 600 satisfaction items from twenty participants were extracted from the questionnaire. The raw data was recorded on an Excel workbook (see Appendix E). An overview of the participants response on the 10 questions with the selected music sequencer application is given in Figure 4.2.

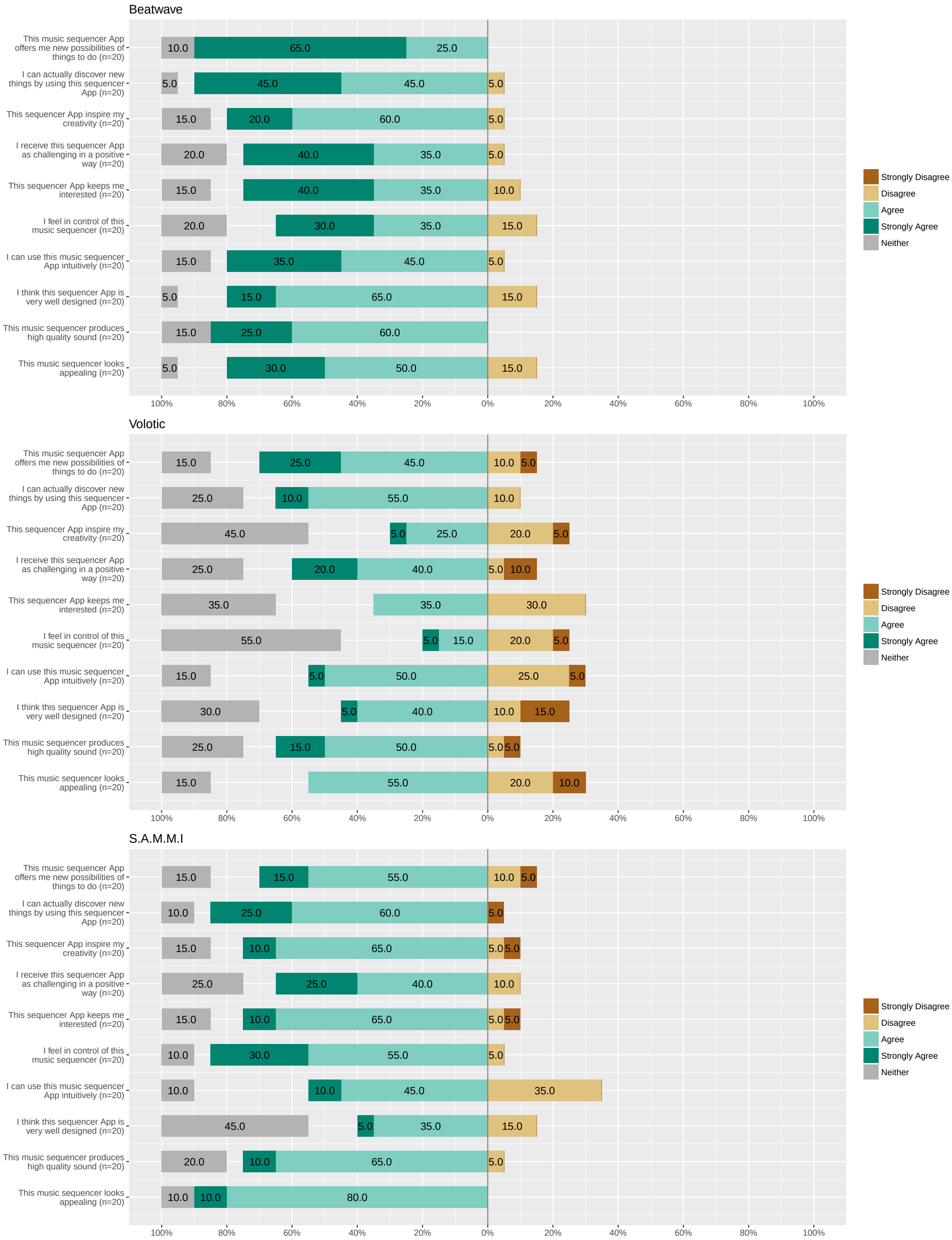

FIGURE 4.2: Participants response on Beatwave, Volotic and S.A.M.M.I

4.3.2 Qualitative Results

Types	Expresivity	Control	Aethentic
Traditioanl	• can not fully express myself • don't have too much options	• very easy to control • intuitive design	• the interface is dull • not appealling
Multi-track	• inspire creativity • a lot of options	• not easy to get start • the layout can be confusing	• the interface is awesome • the visual is very helpful
Novel	• inspire creativity in some degree • it's fun	• very condusing • would be better with with an instruction	• it looks interesting • the interface looks like a game

TABLE 4.2: Musicians opinions summarised from the interview (grouped with the types of interface)

4.3.3 Discussion

When dealing with statistical significance and Likert scale responses,it is important not to make assumptions of the data which are not true in the likert case[Norman, 2010]. The Aligned Rank Transform[Wobbrock et al., 2011] (ART) has become popular in the CHI community to perform non-parametric factorial analyses of likert responses. Although finding statistical significance is not the main point of this user study, an ART was performed (using the R ARTool package[Kay and Wobbrock, 2016]) to see if there was any difference in the responses between the apps. Table 4.3 shows the results after applying a Bonferroni correction to account for multiple tests. In the table the questions in shade were regarded as not significant, because the adjusted p-value of these two question were greater than 0.05.

From the statistic results extracted from the questionnaire, it is clear to say that the multi-track interface represented by *Beatwave* is the most popular design among musicians. By contrast, the non-traditional interface represented by *Volotic* received most of the nagative comments.

Questions	adjusted *p-value*
The instrument allows me to be creative	0.0014
The instrument responds well to my actions	0.0234
I can rely on the instrument when playing it	0.0009
I have fun playing the instrument	0.3093
The instrument allows me to express myself	0.0010
I can control the sound appropriately	0.0009
The instrument pleases me sound-wise	0.0121
I feel the urge to play the instrument again	0.0486
The instrument allows me to be engaged when I'm playing it	0.1523
I can recognize that the instrument responds well to my playing	0.0006

Table 4.3: Questions with adjusted p-value.

Considering the factor each question belong to (see Table 4.1), we can look in details of what specific aspect an interface good at. In Figure **??**, statistic result for questions belong to *EFP* were grouped together. Apparently, *Beatwave* was the best applcation to encourage musicians creativity. And *Volotic* was slightly better than *S.A.M.M.I* in this category. In enjoyment category, *Beatwave* still gathered most of "Strong Agreement". But *Volotic* was not that fun compaied with *S.A.M.M.I.* For the expressiveness of the applications, *Beatwave* and *S.A.M.M.I* were quite similar, the only difference was musicians had stronger feeling on *Beatwave*. However, opinions on *Volotic* were equally distributed, it looked like musicians had a substential differences on whether the interface of *Volotic* supported them to expressed themselves.

Chapter 5

Conclusion

This thesis has described studies that have been conducted to evaluating the touch-based music sequencer apps on iPad. In Chapter 2, we illustrated the background of DMIs and highlighted the fact of apparent popularity of mobile devices. Also, we introduced the development of NIME community and current situation of evaluating the newborn musical interface. Then we carried out two consecutive studies to investigate factors that affect music sequencer interface's expressivity, control and aesthetics. In the first study, we examined 55 music sequencer downloaded from App Store. Results of the first study presented an interface taxonomy of current sequencer apps on iOS App Store (see Chapter 3). And in the second study, followed by the interface taxonomy we concluded in the previous chapter, we perfomed an HCI user study with twenty musicians of the selectedapplications. We summarized the influence of different design appoachon on music sequencer interface (see Chapter 4).

Through the evaluation of music sequencer on iPad, we identified the following contributions:

• An interface taxamony of music sequencer apps based on the mapping of interaction has been created, and which can potentially benefit future study on classifying touch-based musical interface on iPad or other similar mobile devices.

• Conducting an HCI user study and present an example questionnaire for analyzing musical interface on mobile devices.

• Providing design guidelines for future music sequencer development.

5.1 Limitation and Future Work

Associated with the contribution there are some limitations with the research. We only collected music sequencer applications from the iOS App Store. There are still more similar apps developed for Android OS have not been stuied. The various music background of participants may affact their judgement on single senquencer apps. Last but not least, in the user study, we only analyzed the musicians opinions from a short impression.

Future work may expand the study object to Android applications, and further investigate the music sequencer interface from a long time study.

Appendix A

Independent Study Contract

Australian National University

INDEPENDENT STUDY CONTRACT

Note: Enrolment is subject to approval by the projects co-ordinator

SECTION A (Students and Supervisors)

UniID: _u5541558

SURNAME: _Ding FIRST NAMES: _Ke

PROJECT SUPERVISOR (*may be external*): Ben Swift

COURSE SUPERVISOR (*a RSCS academic*): Ben Swift

COURSE CODE, TITLE AND UNIT: COMP4560 Advanced Computing Project

SEMESTER _S1 2017_________________

PROJECT TITLE:

An evaluation of touch-based music sequencer apps on iPad

LEARNING OBJECTIVES:

- Conduct a survey & create an interface taxonomy of current music sequencer apps on the iOS app store
- Perform an HCI user study of a selection of these apps (based on the taxonomy) measuring the user experience & preferences of musicians in creating music with these interfaces
- Propose some design guidelines for creating interfaces for music sequencer apps

PROJECT DESCRIPTION:

While musical interfaces have long been studied in HCI, the iPad and app store has produced thousands of novel (and not-so-novel) twists on the "grid-based" sequencer paradigm.

By reviewing a selection (20+) of current iOS sequencer interfaces in depth, this project will create a taxonomy of design approaches, drawing out the common patterns (and areas of divergence/innovation) in these interfaces.

Having performed this classification, the project will further explore the major design axes through a user-study. In this, musicians will be given various apps in an open-ended music-making task, and will answer a user-experience questionnaire and short interview to further probe the impacts of these design choices. As a result, a set of design guidelines/considerations will be produced for the construction of interfaces for music sequencing.

Australian National University

ASSESSMENT (as per course's project rules web page, with the differences noted below):

Assessed project components:	**% of mark**	**Due date**	**Evaluated by:**
Report: name style: research report (e.g. research report, software description..., no less than 45% weight assigned)	90		(examiner)
Artefact: name kind: ______________________________ (e.g. software, user interface, robot..., no more than 45% weight assigned)	0		(supervisor)
Presentation:	10		(course convenor)

MEETING DATES (IF KNOWN):

Every Friday

STUDENT DECLARATION: I agree to fulfil the above defined contract:

KE DING …………………………………………………..   ……2017.2.27……..
Signature   Date

SECTION B (Supervisor):

I am willing to supervise and support this project. I have checked the student's academic record and believe this student can complete the project.

…………………………………………………..   ………………………..
Signature   Date

REQUIRED DEPARTMENT RESOURCES:

SECTION C (Course coordinator approval)

…………………………………………………..   ………………………..
Signature   Date

SECTION D (Projects coordinator approval)

…………………………………………………..   ………………………..

Appendix B

App Store Music Sequencer Applications

App Store Music Sequencer Applications			
Application Name	Description	Seller	Link
Music Pad	dj player remix electronic music beat	Xinggui Zhang	<https://appsto.re/au/_Dkmeb.i>
Volotic	N/A	Scott Garner	https://appsto.re/au/-WW64.i
Beatwave	N/A	collect3	https://appsto.re/au/UzERv.i
EGDR808	Drum Machine free	Elliott Garage	https://appsto.re/au/rPfXO.i
LoopStation	N/A	Rene Zuidhof	https://appsto.re/au/UzMw7.i
Noise	N/A	ROLI Ltd	https://appsto.re/au/Zzkr8.i
Music Strobe Starter	N/A	Arun Bab	https://appsto.re/au/y4NFQ.i
Beatbox Looper	N/A	Pierre Guilluy	https://appsto.re/au/Sfk6R.i
Dubstep Invasion	Music And Song Hit Maker	Jochen Heizmann	https://appsto.re/au/Oane3.i

App Store Music Sequencer Applications(Continued)			
Application Name	Description	Seller	Link
Remix Pads	make groove beats record music app	Alexey Natarov	https://appsto.re/au/R7_pdb.i
Music Touch	Make Mix Music DJ Beats	Qiao He	https://appsto.re/au/D_ZTdb.i
Loop maker	Amazing music maker	Miguel Saldana	https://appsto.re/au/MpDthb.i
Drum Pads Machine	Beat maker dj music studio	Alexey	https://appsto.re/au/JZ9adb.i
Drum Pads Machine 2	Beat maker dj music app	Alexey Natarov	https://appsto.re/au/c5DZdb.i
MIxpads	Virtual dj pads sampler free app	Alexey Natarov	https://appsto.re/au/CPj1eb.i
Loopacks	Music Maker Loop Machine DJ Beats	Hernan Arber	https://appsto.re/au/oXKt1.i
Dubstep Dubpad 2	Electronic Music Sampler	FAD Games LLC	https://appsto.re/au/mCRXO.i
NOIZ	Make Epic Music	Studio Amplify	https://appsto.re/au/KK9Uab.i
Blocs Wave	Make Record Music	Novation	https://appsto.re/au/L0MTab.i
MIxpads 2	Dubstep Trap drum pad sampler for DJ	Alexey Natarov	https://appsto.re/au/oH_ffb.i
Polyphonic!	NA	Flip Studios LLC	https://appsto.re/au/u_PhS.i
Steve Reich's Clapping Music	Improve Your Rhythm	Amphio Limited	https://appsto.re/au/R-JA4.i
Music Pad	remix electronic music beat	Xinggui Zhang	https://appsto.re/au/_Dkmeb.i
Loop Community	NA	Loop Community	https://appsto.re/au/VyLNN.i
LP-5	Loop-based Music Sequencer	Markus Waldboth	https://appsto.re/au/Z6EDN.i

App Store Music Sequencer Applications(Continued)			
Application Name	Description	Seller	Link
Dubstep Song Construction Kit	NA	Jochen Heizmann	https://appsto.re/au/Knd0I.i
Dubstep Filth Factory	Sampler and Loop Machine	Ben Frost	https://appsto.re/au/iHnUX.i
Monolith Loop	Relax Meditate Sleep Zen	Monolith Interactive Inc.	https://appsto.re/au/vfGDy.i
Theremin Synth	Loop Record Download	Luke Phillips	https://appsto.re/au/gJI2bb.i
Music Makr JAM	Create remix share your music!	JAM just add music GmbH	https://appsto.re/au/EXEG0.i
Novation Launchpad	Make Remix Music	Novation	https://appsto.re/au/QNk1I.i
Multi Track Song Recorder	NA	Derrick Walker	https://appsto.re/au/Ygbsx.i
Triqtraq	Jam Sequencer music making on the go	Zaplin Music	https://appsto.re/au/G8XhD.i
Trigger Box	NA	Justus Kandzi	https://appsto.re/au/j4Hn1.i
Composer's Sketchpad Lite	NA	Alexei Baboulevitch	https://appsto.re/au/nWJO_.i
Orbita for iOS	NA	Keijiro Takahashi	https://appsto.re/au/kBIaN.i
S.A.M.M.I.	NA	Christopher Ayles	https://appsto.re/au/YDMeY.i
ScratchVOX	NA	ScratchVOX	https://appsto.re/au/e4aX0.i
Oro	Visual Music	Light the Music LLC	https://appsto.re/au/d6px5.i
Poly	NA	James Milton	https://appsto.re/au/LFspN.i
Mutone	NA	william LINDMEIER	https://appsto.re/au/IkoJM.i

App Store Music Sequencer Applications(Continued)			
Application Name	Description	Seller	Link
WR6000	NA	WEJAAM	https://appsto.re/au/pM3E3.i
SoundZen HD	NA	Tapbox LTD	https://appsto.re/au/dHrZB.i
SoundGrid	NA	Vitaly Pronkin	https://appsto.re/au/fSB3s.i
Visual Beat	Interactive Music Video	Max Moertl	https://appsto.re/au/B-8l6.i
MINI-COMPOSER	NA	Masayuki Akamatsu	https://appsto.re/au/Ar8Ez.i
Loopseque Lite	NA	Casual Underground	https://appsto.re/au/BTm8x.i
Bass Drop	Deep House Electronic music sampler and synthesizer	Ben Frost	https://appsto.re/au/k3rp0.i
Beat Boss	Electronic Dance Music Sampler	Ben Frost	https://appsto.re/au/DWLyU.i
TonePad	NA	LoftLab	https://appsto.re/au/nOx1s.i
Navichord Lite	intuitive chord sequencer	Denis Kutuzov	https://appsto.re/au/kTci2.i
EasyBeats Drum Machine Free MPC	Hopefully Useful Software	Christian Inkster	https://appsto.re/au/gJ1Ot.i
Fifth Degree	MIDI Sequencer	Bernie Maier	https://appsto.re/au/qFZM1.i
Keenzy	NA	Tek Min Ewe	https://itunes.apple.com/au/app/keezy/id605855595?mt=8
Medly	Music Maker	Medly Labs Inc	https://appsto.re/au/CP1c4.i

Appendix C

Questionnaire

An evaluation of touch-based music sequencer apps on iPad

Questionnaire *App*: ________ *Type*: ________ *Date*: ________

**Please indicate how strongly you agree or disagree with all the following statements which apply to you by selecting a number from 1 (strongly disagree) to 5 (strongly agree).*

Question #1: **The instrument allows me to be creative.**

1	2	3	4	5
Strongly Disagree	Disagree	Neither	Agree	Strongly Agree

Question #2: **The instrument responds well to my actions.**

1	2	3	4	5
Strongly Disagree	Disagree	Neither	Agree	Strongly Agree

Question #3: **I can rely on the instrument when playing it.**

1	2	3	4	5
Strongly Disagree	Disagree	Neither	Agree	Strongly Agree

Question #4: **I have fun playing the instrument.**

1	2	3	4	5
Strongly Disagree	Disagree	Neither	Agree	Strongly Agree

Question #5: **The instrument allows me to express myself.**

1	2	3	4	5
Strongly Disagree	Disagree	Neither	Agree	Strongly Agree

An evaluation of touch-based music sequencer apps on iPad

Question #6: **I can control the sound appropriately.**

1	2	3	4	5
Strongly Disagree	Disagree	Neither	Agree	Strongly Agree

Question #7: **The instrument pleases me sound-wise.**

1	2	3	4	5
Strongly Disagree	Disagree	Neither	Agree	Strongly Agree

Question #8: **I feel the urge to play the instrument again.**

1	2	3	4	5
Strongly Disagree	Disagree	Neither	Agree	Strongly Agree

Question #9: **The instrument allows me to be engaged when I'm playing it.**

1	2	3	4	5
Strongly Disagree	Disagree	Neither	Agree	Strongly Agree

Question #10: **I can recognize that the instrument responds well to my playing.**

1	2	3	4	5
Strongly Disagree	Disagree	Neither	Agree	Strongly Agree

Appendix D

Interview Questions

This document contains a list of questions that will be asked in the interview.

1. Can you tell me about your experience and training in music? How long have you been learning?

2. What kind of instrument you play most in your spare time, and what kind of instrument you instrument you prefer to play?

3. Among the 3 apps you just played, do you find one app attracted you most, or you think they are all very boring?

4. Have you heard about or used music sequencers before?

5. After playing the three apps, can identify any interface patterns in these music sequencer apps?

6. Did one particular interface most inspired your creativity? How?

7. Do you think the complexity of the interface has an effect on how enjoyable the app is to play?

8. Would you play any of these apps later, or will you tell your friends about them?

Appendix E

Questionnaire Data

Volotic	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
No.1	1	2	2	1	2	1	1	1	2	1
No.2	5	4	4	4	4	3	4	4	5	4
No.3	5	5	4	5	4	3	5	5	5	4
No.4	4	4	3	3	2	4	2	4	3	1
No.5	4	3	3	4	2	2	2	2	3	3
No.6	2	4	1	3	2	2	4	1	3	2
No.7	5	4	4	5	3	3	4	3	4	4
No.8	5	5	4	5	3	4	4	4	5	4
No.9	4	4	3	4	3	3	4	3	4	4
No.10	4	2	2	4	3	3	2	2	4	2
No.11	4	4	4	4	4	4	4	3	4	4
No.12	4	3	2	4	3	3	2	4	4	3
No.13	3	4	3	3	4	5	4	3	4	4
No.14	5	4	3	5	4	3	4	4	4	3
No.15	3	4	3	3	4	2	3	3	3	4
No.16	4	4	3	4	4	3	4	4	4	4
No.17	3	4	2	1	2	3	2	1	1	2
No.18	4	3	5	4	2	3	3	4	4	4
No.19	4	3	3	3	3	2	4	4	4	4
No.20	2	3	3	2	3	3	3	3	3	2
SUM	75	73	61	71	61	59	65	62	73	63
AVG	3.75	3.65	3.05	3.55	3.05	2.95	3.25	3.1	3.65	3.15

S.A.M.M.I	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
No.1	5	4	4	5	5	5	4	4	5	5
No.2	4	4	4	5	4	4	5	4	5	4
No.3	2	3	1	3	3	4	3	3	3	4
No.4	2	1	2	2	1	4	2	2	3	3
No.5	4	5	4	5	4	4	4	5	4	4
No.6	1	5	4	2	4	5	2	2	4	4
No.7	4	4	4	4	4	4	2	3	4	4
No.8	4	5	5	3	5	4	4	3	3	5
No.9	4	4	4	5	4	4	4	4	4	4
No.10	4	5	4	4	4	4	4	4	4	4
No.11	5	5	4	4	4	4	4	4	4	4
No.12	4	4	4	5	4	5	3	4	4	4
No.13	3	4	3	3	4	5	4	3	4	4
No.14	4	4	5	4	4	5	2	3	4	4
No.15	3	4	3	3	3	4	4	3	4	4
No.16	4	4	3	4	4	3	4	4	4	4
No.17	4	4	4	4	2	4	2	3	2	3
No.18	5	4	4	3	4	2	2	3	4	4
No.19	4	4	4	4	4	5	5	3	4	4
No.20	3	3	4	4	3	3	2	2	3	4
SUM	73	80	74	76	74	82	66	66	76	80
AVG	3.65	4	3.7	3.8	3.7	4.1	3.3	3.3	3.8	4

Beatwave	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	SUM
No.1	5	4	4	3	3	2	3	2	4	2	32
No.2	5	5	4	4	4	3	4	4	5	5	43
No.3	5	5	4	3	2	2	3	4	4	4	36
No.4	3	3	2	2	2	3	2	2	3	2	24
No.5	4	5	4	4	4	5	5	4	4	4	43
No.6	5	4	3	5	4	4	5	4	4	3	41
No.7	5	4	4	5	4	4	4	4	4	4	42
No.8	5	5	5	5	5	4	5	5	5	5	49
No.9	5	5	4	4	5	5	5	4	4	5	46
No.10	4	4	4	3	3	3	5	3	4	4	37
No.11	5	4	4	5	5	5	5	4	4	4	45
No.12	5	5	4	5	5	5	4	5	5	4	47
No.13	3	4	5	4	5	4	4	4	5	5	43
No.14	4	2	3	3	3	2	4	2	3	2	28
No.15	4	4	4	4	5	5	4	4	4	4	42
No.16	4	4	3	4	4	3	4	4	4	4	38
No.17	5	5	4	5	4	4	4	4	4	4	43
No.18	5	5	5	5	5	5	5	5	5	5	50
No.19	5	4	4	5	5	4	3	4	4	5	43
No.20	5	5	5	4	4	4	4	4	3	4	42
SUM	91	86	79	82	81	76	82	76	82	79	
AVG	4.55	4.3	3.95	4.1	4.05	3.8	4.1	3.8	4.1	3.95	

Bibliography

Marcelo Mortensen Wanderley and Nicola Orio. Evaluation of input devices for musical expression: Borrowing tools from hci. *Computer Music Journal*, 26(3):62–76, 2002.

Gian-Marco Schmid. Evaluation of musical instruments from the musicians perspective. 2015.

Lemai Nguyen, Siew Mee Barton, and Linh Thuy Nguyen. Ipads in higher educationhype and hope. *British Journal of Educational Technology*, 46(1):190–203, 2015.

Hendrik Müller, Jennifer Gove, and John Webb. Understanding tablet use: a multi-method exploration. In *Proceedings of the 14th international conference on Human-computer interaction with mobile devices and services*, pages 1–10. ACM, 2012.

Daniel Nations. How many ipad apps are in the app store?, 2017. URL https://www.lifewire.com/how-many-ipad-apps-in-app-store-1994320. [Online; accessed 10-May-2017].

Ge Wang, Jieun Oh, and Tom Lieber. Designing for the ipad: Magic fiddle. In *NIME*, pages 197–202, 2011.

Charles Martin, Henry Gardner, and Ben Swift. Exploring percussive gesture on ipads with ensemble metatone. In *Proceedings of the 32nd annual ACM conference on Human factors in computing systems*, pages 1025–1028. ACM, 2014.

Dan Stowell, Andrew Robertson, Nick Bryan-Kinns, and Mark D Plumbley. Evaluation of live human–computer music-making: Quantitative and qualitative approaches. *International Journal of Human-Computer Studies*, 67(11):960–975, 2009.

Thor Kell and Marcelo M Wanderley. A high-level review of mappings in musical ios applications. In *ICMC*, 2014.

Henry Newton-Dunn, Hiroaki Nakano, and James Gibson. Block jam: a tangible interface for interactive music. In *Proceedings of the 2003 conference on New interfaces for musical expression*, pages 170–177. National University of Singapore, 2003.

NIME. Nime: The international conference on new interfaces for musical expression, 2012. URL http://www.nime.org. [Online;Accessed: 2017-05-11].

Orit Shaer and Eva Hornecker. Tangible user interfaces: past, present, and future directions. *Foundations and Trends in Human-Computer Interaction*, 3(1–2):1–137, 2010.

Martin Kaltenbrunner and Ross Bencina. reactivision: a computer-vision framework for table-based tangible interaction. In *Proceedings of the 1st international conference on Tangible and embedded interaction*, pages 69–74. ACM, 2007.

Ge Wang. Designing smules iphone ocarina. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 303–307, 2009.

Nicholas J Bryan, Jorge Herrera, Jieun Oh, and Ge Wang. Momu: A mobile music toolkit. In *NIME*, pages 174–177, 2010.

Nick Kruge and Ge Wang. Madpad: A crowdsourcing system for audiovisual sampling. In *NIME*, pages 185–190, 2011.

Luciano Flores, Evandro Miletto, Marcelo Pimenta, Eduardo Miranda, and Damián Keller. Musical interaction patterns: communicating computer music knowledge in a multidisciplinary project. In *Proceedings of the 28th ACM International Conference on Design of Communication*, pages 199–206. ACM, 2010.

Lalya Gaye, Lars Erik Holmquist, Frauke Behrendt, and Atau Tanaka. Mobile music technology: Report on an emerging community. In *Proceedings of the 2006 conference on New interfaces for musical expression*, pages 22–25. IRCAMCentre Pompidou, 2006.

David John. Updating the classifications of mobile music projects. In *NIME*, pages 301–306, 2013.

Arianna Bassoli, Cian Cullinan, Julian Moore, and Stefan Agamanolis. Tuna: A mobile music experience to foster local interactions.

Atau Tanaka. Mobile music making. In *Proceedings of the 2004 conference on New interfaces for musical expression*, pages 154–156. National University of Singapore, 2004.

Günter Geiger. Pda: Real time signal processing and sound generation on handheld devices. In *ICMC*, 2003.

Günter Geiger. Using the touch screen as a controller for portable computer music instruments. In *Proceedings of the 2006 conference on New interfaces for musical expression*, pages 61–64. IRCAMCentre Pompidou, 2006.

Amnon Dekel and Gilly Dekel. Mogmi: Mobile gesture music instrument. In *5TH INTERNATIONAL MOBILE MUSIC WORKSHOP 2008 13-15 MAy 2008, VIENNA, AUSTRIA*, page 6, 2008.

Ge Wang. Ocarina: Designing the iphone's magic flute. *Computer Music Journal*, 38 (2):8–21, 2014.

Thor Kell and Marcelo M Wanderley. A quantitative review of mappings in musical ios applications. In *International Conference on Sound and Music Computing (SMC2013). http://tide-pool. ca/papers/Thor% 20Kell*, 2013.

Dan Stowell, Mark D Plumbley, and Nick Bryan-Kinns. Discourse analysis evaluation method for expressive musical interfaces. In *NIME*, pages 81–86, 2008.

Sile O'modhrain. A framework for the evaluation of digital musical instruments. *Computer Music Journal*, 35(1):28–42, 2011.

Jerônimo Barbosa, Filipe Calegario, Francisco Magalhães, V Teichrieb, G Ramalho, and G Cabral. Towards an evaluation methodology for digital music instruments considering performers view: a case study. In *Proceedings of 13th Brazilian Symposium on Computer Music*, 2011.

Sergi Jordà and Sebastián Mealla. A methodological framework for teaching, evaluating and informing nime design with a focus on expressiveness and mapping. In *NIME*, volume 14, pages 233–238, 2014.

Jeronimo Barbosa, Joseph Malloch, Marcelo M Wanderley, and Stéphane Huot. What does" evaluation" mean for the nime community? In *NIME 2015-15th International*

Conference on New Interfaces for Musical Expression, pages 156–161. Louisiana State University, 2015.

Geoff Norman. Likert scales, levels of measurement and the "laws" of statistics. *Advances in health sciences education : theory and practice*, February 2010. doi: 10.1007/s10459-010-9222-y. URL http://www.springerlink.com/content/p1l1562668125341/.

Jacob O. Wobbrock, Leah Findlater, Darren Gergle, and James J. Higgins. The Aligned Rank Transform for Nonparametric Factorial Analyses Using Only Anova Procedures. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '11, pages 143–146, New York, NY, USA, 2011. ACM. ISBN 978-1-4503-0228-9. doi: 10.1145/1978942.1978963. URL http://doi.acm.org/10.1145/1978942.1978963.

Matthew Kay and Jacob Wobbrock. Artool: 0.10.2, March 2016. URL https://doi.org/10.5281/zenodo.48543.