Developing a Digital Polyphonic Theremin to Assist with Formal Music Education
(Technical Topic)

Investigation of GarageBand and the Digital-Audio Workstation and the Implications that They have Posed on the Music Industry
(STS Topic)

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

Music is one of the most ubiquitous and popular forms of art and it has been around for thousands of years. The first musical instruments known to archaeologists date back to 40,000 BC, and music of different forms has entertained populations to this day (Cassidy, 2019, n.p.). As seen in figure 1, the US music industry brought in nearly $20 billion in revenue in 2018 and this number has been on an upward trend since 2012 (Watson, 2019, n.p.).

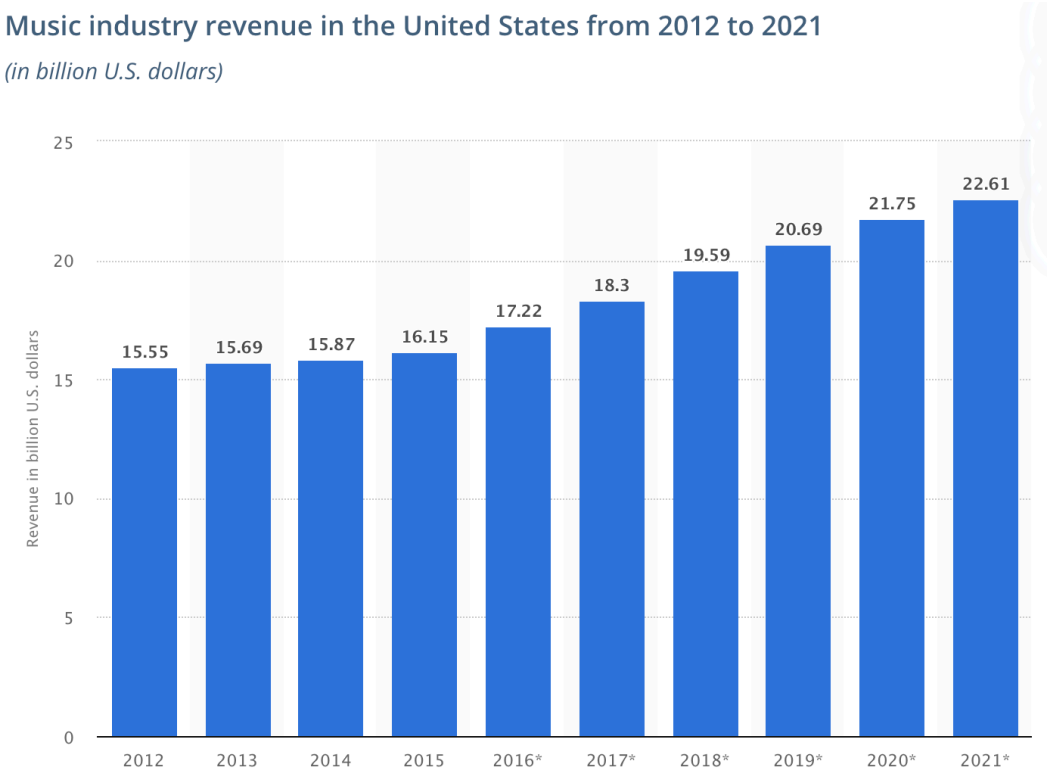

Figure 1: Music industry revenue in the United States. These figures include revenues for both live and recorded music, which are expected to exceed $20 billion in 2019. (Watson 2009 n.p.)

A large portion of music consumption and revenue is driven by recorded music. However, in order to produce and distribute recorded music, one must go through the process of learning an instrument, procuring recording equipment, recording the song, mixing/mastering the recording, advertising the finished product, and distributing it to the masses. Because of the funds, expertise, and connections required by this process, record labels were formed and

functioned to provide artists with these services (Bielas 2013 p.3-23). Since their formation, these record labels have often been able to use their control over the industry to force artists into contracts which are non-negotiable, unfair, and indeterminate. (Eiriz & Leite 2017 p.875-885). This has been effective in deterring unaccomplished artists from trying to get into the recorded music industry and monetize their works (Guesman 2018 n.p.). However, in recent years, technological advancements have made it possible for artists to bypass these record labels and learn, produce, distribute, and promote recorded music on their own. Technologies like YouTube are useful for learning instruments, while digital-audio workstations such as GarageBand are useful for mixing/mastering recorded works. Technologies such as Spotify or SoundCloud are useful for distributing music, while social media applications like Instagram or Facebook are helpful with promotion. However, with what we now know, it seems as though there is a tradeoff between quality and accessibility. This thesis project will investigate GarageBand and how it has introduced a tradeoff between musical creativity/complexity and accessibility/ease-of-use. We will also investigate the technical project of creating a digital, easy-to-use Theremin and examine the tradeoffs between musical intricacy and accessibility.

Technical Topic: Developing a Digital Polyphonic Theremin to Assist with Formal Music Education

As the recorded music industry in the US has grown over the last eight years, an increasing number of musicians have entered the industry looking to monetize their works. Using the new technologies described previously, casual musicians have become professionals and inexperienced musicians have gained expertise. However, people do not realize the benefits that music learning and training can have on the musician, in ways that have nothing to do with

wealth or entertainment. Different studies have linked formal music training to an enhancement of cognitive abilities. These various studies have associated musical training with improved linguistic skills, spatial reasoning, and mathematical capability (Roberts, Shahin, & Trainor 2009 p.133-140). In a study performed in 2004, the cognitive effects of musical training were demonstrated by measuring the IQs of a group of students before and after a year of musical training. These results were then compared to the IQs of a control group, who did not experience any musical training between the pre- and post- IQ tests. Compared to the control group, the children who experienced musical training exhibited larger improvements in every subset of the IQ measure (Schellenberg 2004 p.511-514).

With this being said, it seems obvious to conclude that parents should involve their children with formal music education and that non-musical adults should sign themselves up for music lessons. However, the idea of formal education can be enough to deter many from participating in music training and from experiencing the neural stimulation and benefits that it can provide. In her research on formal vs. informal education, Strauss defines formal education as, "Any form of education that is deliberate, carried on 'out of context' in a special setting outside of the routines of daily life, and made the responsibility of the larger social group" (Straus 1984 p.195). Formal education creates a setting where students are discouraged from bringing informally acquired knowledge to the arena, which limits creativity. In her research about the impact of informal music learning practices in the classroom, Michigan State University professor Sheri Jaffurs discusses a 2012 study investigating 14 different informally-trained musicians and their different means of training. The study found that most were self-taught, having learned their instruments by imitating other musicians and by referencing recordings. Jaffurs reflects on the concept of musicality and how formal music education creates

an implicit disconnect in many students' minds between the music that they learn in the classroom and the music that they listen to in their free time (Jaffurs 2004 p.189-197).

For our technical project, we aim to create a device that assists with formal music training by providing an instrument interface for novices and informally-trained musicians to learn the basics of formal music creation. We will be manufacturing a polyphonic, digital Theremin device that employs the use of infrared proximity sensors. The Theremin is one of the first electronic instruments ever created, and it is unique in that it is played without any physical contact. Invented by Russian physicist Leon Theremin in 1919, the classic Theremin (figure 2) is a fully analog device that makes use of two different antennae to create a monophonic sound. These antennae, in the presence of a user's hand, generate variable capacitances that determine the pitch and volume of the output tune. A vertically-positioned antenna determines the pitch, while a second, horizontally-positioned antenna determines the volume. In our project, we aim to create a digitally-implemented Theremin device through digital signal processing. Our Theremin will use infrared proximity sensors to determine the distance between the device and the user's hands and it will be able to produce two notes concurrently, thus making it polyphonic. Additionally, our device will include two LED matrices that will inform the user of the two notes being played at any instance in time. We hope that this will help the users associate different sounds with different musical notes and develop an understanding of which notes sound good when played together.

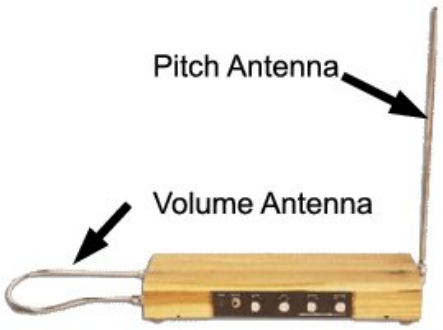

Figure 2: Classic fully-analog Theremin. The proximity between a user's hand and the pitch antenna determine the pitch of the sound, while the proximity between the hand and the volume antenna determine the volume. The output is a single pitch note. (Demiris & Yu 2011 p.235)

By creating this device, we aim to help those who lack formal music training learn and associate different sounds with different notes. Users will be able to experiment with different hand positions and they will be able to experiment with different two-note chords. However, in creating this device, much of the musical intricacy is lost. The frequency spectrum that our instrument will output consists of twelve discrete notes in an octave, while the frequency spectrum of the classic Theremin is continuous, encapsulating every possible frequency in the given range. This research will investigate the trade-offs between usability/ease-of-use and musical intricacy/creativity that our project provides compared to the classic, analog Theremin. By doing such, I hope to determine if our project can be an effective tool for users to learn and gain interest in music without over-simplifying their views on musical complexity or diminishing their potential musical creativity.

STS Topic: Investigation of GarageBand and the Digital-Audio Workstation and the Implications that they have Posed on the Music Industry

As beforementioned, when artists want to produce a recording of their work, they must go through the process of recording the song, mixing the recordings, mastering to produce a final

product, delivering the final product to listeners, and promoting their work. Before the invention of digital music, the mixing/mastering process was a very long, tedious process that required expensive equipment and highly trained audio engineers (Daley 2017 n.p.). An audio engineer's responsibility is to control the microphones, mixing boards, and other technical equipment to produce a desired sound. Despite the job title, the audio engineer is as much of an artist as an engineer. Ivan Ortiz is an audio engineer who has worked with setting up Coachella, one of the largest and most well-known music festivals in the US. In an interview, describing the artistic side of his profession, Ortiz said, "A record starts out as a blank canvas; the paints are the musicians and their instruments, and the brushes are my equipment" (Vangelova 2018 p.68). This quotation highlights the creative intelligence necessary in the audio engineering profession.

Things changed in the world of mixing and mastering in 1983 when the Musical Instrument Digital Interface (MIDI) standard was released to the world. MIDI is a set of standards that define a protocol for communications between electronic instruments and computers. The introduction of MIDI set the stage for the first digital-audio workstations (DAWs) to be created. Since electronic instruments and computers now had an interface through which to communicate, musicians could start recording tracks to edit and layer on their computers. The first DAW was created in 1985 by two men in Germany named Karl Steinberg and Manfred Rürup. By 1989, they had created a DAW for the Atari platform called Cubase, and it allowed for 16 tracks of MIDI recording and editing. A depiction of what this Cubase editing environment looked like can be seen in figure 3 below (Levine 2019 n.p.).

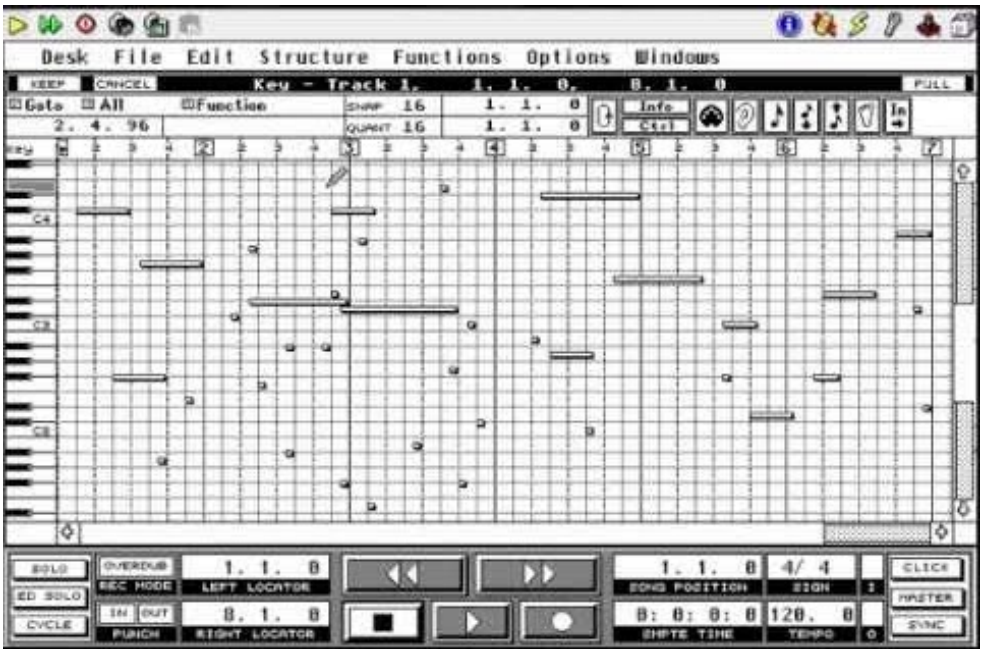

Figure 3: Cubase window for MIDI editing. The dots and dashes shown on the grid represent notes and can be manipulated digitally to produce a desired output. Before this technology, if one wanted to edit individual notes in this manner, they would have had to re-record the song and play these changes themselves. (Levine 2019 n.p.)

The introduction of the digital-audio workstation has had serious implications relating to the mixing/mastering process in creating recorded music. With this new software the user is able to make perfect digital copies of recorded music that can be manipulated, imported, and layered amongst projects. These recordings can be stored in digital libraries for future use, allowing the mixing artists to import, layer, and manipulate them wherever in whatever project they would like (Petrick 2004 p.5-7).

In 2004, Apple released its own DAW called GarageBand, and now it comes pre-installed on most MacOS and iOS devices. GarageBand is very user-friendly, and its omnipresence gives Apple users the power to mix/master tracks wherever they go. GarageBand is free software that allows the artist to make professional grade music. Before the DAW, tens of thousands of dollars in equipment investments would have to be made to produce music of this quality (Petrick 2004 p.6). The introduction of the DAW has seemingly eliminated barriers of

cost and expertise required to produce recorded music, thus allowing new, unaccomplished artists to enter the recorded music industry and monetize their works.

Conversely, the simplification and cost reduction of the music recording and mixing process has had some adverse effects on the music industry and how people perceive it. In his paper investigating the implications posed by the digital-audio workstation, Montclair State University professor Adam Bell states that, "We live in a tech-saturated culture that communicates a parallel message with regard to music: possession of music technology is the key to unlocking the hibernating musician within" (Bell 2015 p.45). Bell's analysis highlights an interesting point: owning an instrument does not make you a musician. Bell also describes the purpose of his paper as, "Not to pick apart Apple or its PC competitors, but rather to problematize the reality that software developers are the music educators with the greatest reach and influence in the computer-dependent world" (Bell 2015 p.45). With these two quotes, Bell highlights two problems that have resulted from the introduction of the DAW: that it creates an inaccurate, over-simplified perception of what it means to create music, and that the software developers indirectly assume an inappropriate level of responsibility in the music teaching process through the DAW platforms that they create. In this paper, an actor-network theory approach will be taken to analyze the implications that GarageBand and the digital-audio workstation have had on the music industry.

Conclusion

The expected result of the technical project described is a digital, polyphonic Theremin device that makes use of infrared proximity sensors to produce two concurrent notes and to display those two notes on LED matrices for the user to see. The anticipated goal of this

deliverable is that our device plays a role in the early stages of a user's music studies or that it may spark a user's interest in music-making. The expected result of the STS research is to use actor-network theory to gain a deeper understanding of how GarageBand and the digital-audio workstation has impacted the music industry and various stakeholder groups, both positively and negatively. Lessons learned from this investigation will be applicable to analysis of the trade-offs between quality and accessibility that are posed by many new technologies that are playing an increasing role in the music industry. (removed last sentence)

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