ChordKeys: Accessible Music Improvisation and Interaction

Yi-Ting Wu*
yiting31@stanford.com
Stanford University
USA

Christine Cheng*
ccheng18@stanford.edu
Stanford University
USA

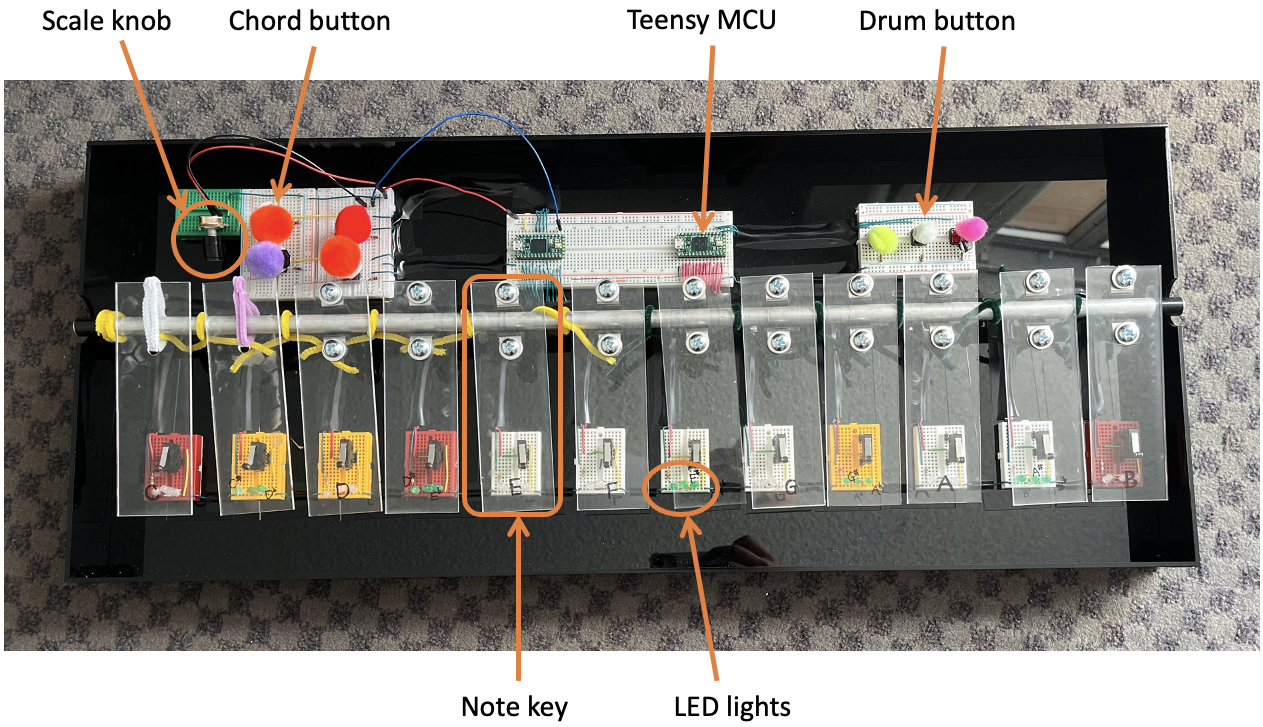

Figure 1: ChordKeys Prototype

ABSTRACT

Music improvisation is a creative activity in which musicians compose in the moment. It involves communicating emotions, employing instrumental techniques, and responding spontaneously to other musicians. Although music improvisation can be enriching, it requires proficiency in instrumental performance and familiarity with musical theory, making it difficult for novices to participate. However, ChordKeys, a keyboard-like musical interface, provides an opportunity for novices to learn basic musical structure while improvising with simple structures. The system utilizes LED lights to guide users through different chord progressions and allows them to freely explore scales, notes, and percussion sets. It successfully achieves the goal of lowering the threshold for musical improvisation and provides an encouraging first step for novices in the musical education field.

KEYWORDS

music, tangible computing, improvisation

ACM Reference Format:
Yi-Ting Wu and Christine Cheng. 2023. ChordKeys: Accessible Music Improvisation and Interaction. In *CS 347 '23: Human-Computer Interaction: Foundations and Frontiers Presentation, March 06–16, 2023, Stanford, CA.* ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/nnnnnnn.nnnnnnn

1 INTRODUCTION

Music is an intricate form of expressivitiy in which emotions are woven into tones and rhythms. By bringing together various chords, beats, and notes, we can create rich melodic lines that carry vibrant

*Both authors contributed equally to this research.

CS 347 '23, March 06–16, 2023, Stanford, CA

ACM ISBN 978-x-xxxx-xxxx-x/YY/MM…$15.00
https://doi.org/10.1145/nnnnnnn.nnnnnnn

intonations. Music improvisation, a common form of music creation, allows musicians to create in the moment, and is often used in group performances such as in a jazz session. Music improvisation serves as a channel for impromptu musical conversations and often spurs positive interactions among musicians and between musicians and the audience. However, just like learning words before writing a novel, to participate in music creation, one must be equipped with musical proficiency, both in music theory and in instrument playing. Music theory is complicated; even simple chord progressions could seem like an entirely new language for those without the background. The high learning cost of musical instruments hinder interested novices from entering the field. In order to lower the threshold of music creation and construct an encouraging environment for novices to engage in musical interactions, this paper presents a system designed to support novices in engaging in the musical creation experience and learn the basic concepts of music theory.

2 RELATED WORK

The benefits of musical creation span across a wide spectrum. In [3], MacDonald et al. found that musical improvisation can lead to improvements in mood, reductions in anxiety and depression, and increased feelings of relaxation and wellbeing. On the individual perspective, musical improvisation can enhance creativity and self-expression, whereas on the social side, it promotes social connection and bonding. In [7], Schutz also argues that working together on music can enhance social relationships by creating a shared experience where participants become unified beyond other everyday activities. In the educational space, Sowden et al. inferred through experiments in [8] that improvisation acts as a tool for promoting creativity and divergent thinking in primary school arts education, which is beneficial not only in music but also other general aspects in their lives as well.

Given the numerous benefits that musical improvisation brings, there is a lot of research focused on incorporating musical improvisation into our daily lives, especially those of the novices. In [4], Biasutti proposes a process-based approach to teaching musical improvisation. With this approach, improvisation is broken down into component parts taught individually before gradually integrating them into a more complex improvisation. For example, the teacher may begin by teaching simple melodies or chord progressions before introducing complex musical structures and rhythms, and afterwards moving on to more complicated improvisational techniques like call-and-response or imitation and variation. By focusing on specific skills and strategies, we can demystify musical improvisation and make it more accessible to students of all levels.

Other HCI research focuses on how utilization of "tangible" music interfaces help with musical learning, interaction and collaboration. Tangible music interfaces allow users to interact intuitively and with versatility, and they also open for new possibilities for musical expression and creativity. In [6], Paradiso et al. built a system in which different musical sounds and effects would be generated in real-time by sensing the position and orientation of objects with magnetic tags. In [2], Hu et al. devised Music Wall–a panel of tap sensing blocks which offer direct manipulation to digital music information through the physicality of our environment. Users could tap rhythms to search for songs and tap different block sequences to loop and playback soundtracks. Targeting novices without any musical background, [1] by Esteves et al. explored the potential for novice-expert collaboration using tangible music interfaces. Similar to previous tangible musical interfaces, the authors built a system called jamTable which allowed users to manipulate musical sounds using physical objects and gestures. Through a series of experiments, they found that such tangible interface provided positive support for novices to improvise and create music along with experts, and is effective in bridging the gap between different levels of musical knowledge. However, tools like Music Wall and jamTable focused on the real-time collaboration rather than educational purposes. The users were able to create music by navigating the system; however, their ability to create music was highly dependent on the system since they learned to trigger musical sounds rather than understanding the grounding musical knowledge.

On the educational side, [5] studied the effectiveness of tangible music interfaces for in-classroom music learning through a fairy tale narrative. In the experiment, primary school children who learned improvisation through the ImproviSchool system demonstrated significant improvements in musical skills, including rhythm, melody and harmony as compared to children who learned through music instructions. The project suggested that the interface served as an effective tool for early musical learning as well as in fostering creativity and collaboration. Although this project covered more musical education, it was unclear how well the students could translate the abstraction from the fairy tale narrative to concrete musical foundations.

3 CHORDKEYS

To address the problem, we built ChordKeys–a keyboard-like tangible interface that allows users to learn basic musical theory through improvisation with guidance. As stated in [4], there are many musical components that constitute musical improvisation. Upon these components, we chose chord progressions as the main musical basis. ChordKeys consists of a "scale" knob, "chord" buttons, "note" keys, several percussive buttons, and LED lights corresponding to each key note. Upon choosing a scale, or key, users can press different chord keys to play chords within that scale. The corresponding keynotes to the chord light up to guide the users through improvisation on the given chord progression. The users can also experiment with different tones, for instance, minor 3^{rd} and perfect 4^{th}, to understand how different chords produce different music intonations. By guiding the users with lit-up chord progressions on the tangible interface, we can lower the threshold such that they do not need to have musical background nor instrumental expertise to create music. Furthermore, through interacting with ChordKeys, users learn about chord progressions, which can be applied to future musical improvisation.

4 METHOD AND IMPLEMENTATION

4.1 Background

A chord progression is a succession of chords, also denoted as a harmonic progression. They build the foundation of harmony in Western music and are the often the foundation on which melodies

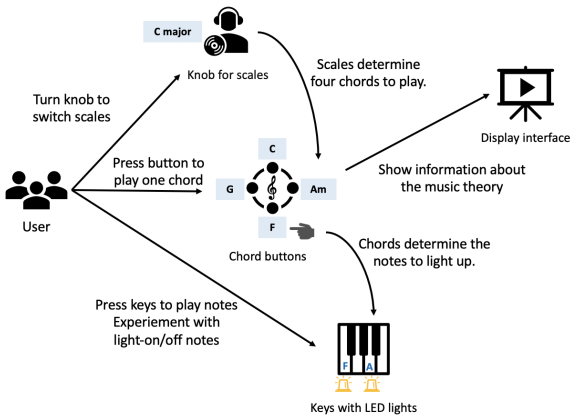

Figure 2: ChordKeys system workflow

SCALE	CHORD	NOTE	EMOTION
C Major	C (I)	C E G	Positive Uplifting
	G (V)	G B D	
	Am (vi)	A C E	
	F (IV)	F A C	
C Minor	Cm (i)	G C Eb	Downbeat Grim
	Bb (VII)	F Bb D	
	Ab (VI)	Eb Ab C	
	G (V)	D G B	

Figure 3: Popular Chord Progressions

and rhythms are built. When improvising, particularly in jazz improvisation, the key foundation to improvisation is an understanding of basic chord progressions, Using that understanding, musicians build 'licks', or short melodic lines, that complement the particular progression on a particular backing track.

While hundreds of different chord progressions are possible, there are popular patterns, such as (I → V → vi → IV), created from a base scale and the numbered chords within the scale. Two examples are listed in Figure 3. We use these chord progressions as the underlying for our 'tangible' learning and 'jamming' interface.

4.2 Design

Within our design, we grab inspiration from the foundational jazz trio, consisting of a keyboard, percussion, and bass. Therefore, as stated above, ChordKeys consists of the "scale" knob, the "chord" buttons, "note" keys, several percussion buttons and LED lights corresponding to each key note.

The scale knob represents the bass playing a walking bass line within the key that the user would then improvise off of. The chord buttons provide the chords within a chord progression of the key. With each chord button press, the corresponding harmonic chordal notes of the chord light up, providing a guide for users to improvise off of. Finally, the several percussion buttons allow users to add a beat to their music.

In short, we created a keyboard-like system that illuminates key notes corresponding to each chord within a chord progression to guide users when creating music. Lit keys are based on the chords within the scale of the backing track, providing recommended harmonic keys to play.

Users therefore have control over the backing scale, chord, percussion, and tangible key notes to play, providing an easy guide to follow, and also allowing them to explore different melodies freely. This minimizes the threshold into beginner improvisation. In addition to this, a simple visual interface displays information of music theory in correspondence to their current backing track, chord, and note state to help users better understand what they are playing.

In light of 'tangible' education and enjoyable 'jamming', we chose to create a rather large system. Music is a way to bring people together, and to many, the joy stems from creating with others. Therefore, the large size of Chordkeys allows for single-user or multi-user use. The wide spread of wide keyboard keys in addition to the placement of the chord and percussion buttons allow for different users to surround the system and play together. We also use a keyboard-like system in order to incorporate an intuitive feel for chord spacing and note placement in relation to other notes within the key and chord.

4.3 Hardware Implementation

The physical prototype of ChordKeys resembles a keyboard-like musical instrument device (MIDI) station, with key notes, chord buttons and percussion buttons. As shown in Figure 4, the keyboard contains 12 keys, denoting the span of notes within an octave. The laser cut keys are attached to a metal bar via U-Clamp, allowing free movement to be pressed down. For extra mechanical support, we used a pipe cleaners for additional attachments. The outer case is also built using laser-cutting.

For the electronic parts, limit switches are installed below the key plates to be triggered upon pressing the corresponding key notes. Apart from having the functionality like buttons to initially act as a pull-up resistor and connect to ground when pressed, limit switches also provide the mechanical bounce ideal for key pressing. LED lights are placed under each key notes to display the illumination (Figure 5). In addition, we used buttons for chord and percussion playing, and a potentiometer as the knob for scale selection. All of the electronic components are connected to the central motherboard, where two Teensy microcontrollers are in place, that provide the computational work.

4.4 Software Implementation

The software structure of the system can be broken into two parts–control and audio. In the project, we chose Teensy 4.0 development board as our microcontroller unit. Teensy runs on an ARM-Cortex

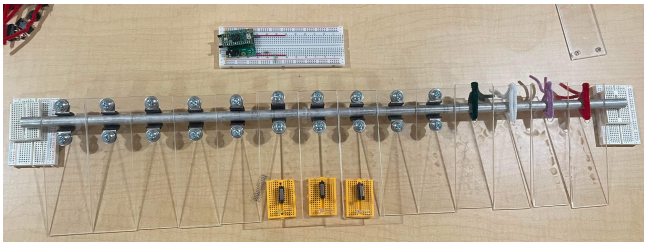

Figure 4: Hardware components–laser cut keys

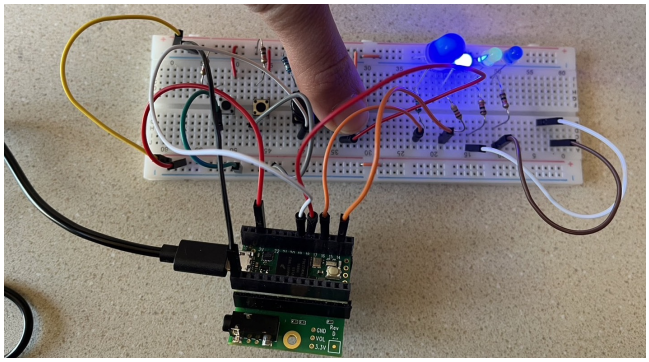

Figure 5: Electronic components–buttons and LED lights

M7 processor with 2MB of flash memory. It is equipped with 40 digital input/output pins and 14 analog input pins. One advantage of Teensy is its compatibility with Arduino IDE software; we can compile the Teensy simply by installing Teensyduino add-on to the Arduino IDE. Another advantage of Teensy board is its ability to output MIDI signals on the communication side, which is useful in our system and will be elaborated on later. Another possible usage of the Teensy board is its built-in digital signal processing features. Together with the audio library and an audioshield, it can output different waveforms and serve as an audio mixing station. The project did not utilize the latter feature, but it is relevant and can be incorporated in the future work.

On the control side, the Teensy board initially output high voltage to each of the digital pins connected to limit switches and buttons, thus making the digital inputs to be HIGH. Once the limit switches and buttons are pressed, they will be connected to ground, resulting in a LOW digital input. Teensy reads the digital input to determines which pins are pressed, and it maps the pin information to the pre-written pin map to know whether the pin is a keynote, a percussion instrument, or a chord. If a chord key is pressed, it will extract from the written header the information of the chord and its corresponding LED light pins, and send digital output signals to these LED pins to illuminate the lights. In addition, one analog input pin is dedicated to the potentiometer, which acts as the knob for users to change between scales. Turning the knob alters the internal resistance value of the potentiometer, thus affecting the voltage output read at the analog pin. The system then linearly maps the analog input of 0 to 1024 to the number of scales (0 to 2 in our case) to determine which scale is selected by the user. Once the scale changes, the chords mapping to the four chord buttons change accordingly.

On the audio side, based on the chord buttons, note keys and percussion buttons pressed, Teensy sends different MIDI signals to the music work station connected. For instance, if the note *C* is pressed, Teensy would send code 60 on channel 2 (the channel dedicated to the key notes) through the usbMIDI output. On our system, the keynotes, percussions and chords each have a separate MIDI channel. As for the digital music workstation, we chose to use Ableton in our project. Ableton is able to read from a single Teensy MIDI input and receive on multiple channels. The chord progressions are programmed in Ableton with its scale and chord plug-ins. When fed with a single MIDI note input from Teensy, Ableton will view it as the root note and translate it to the matching polyphonic chord. The instrument sounds representing the keynotes and percussive set and the rhythms added to the chords for a walking bass effect are both programmed on the Ableton platform as well. This provides users and producers much flexibility to use alternative sound effects on the Ableton interface without modifying the Teensy codes. For our software structure, it is sufficient to use one Teensy board. However, considering the large number of pins to accommodate, we ultimately opted to use two Teensy board in parallel under the same software structure.

5 EVALUATION

5.1 System Design Validation

Throughout the design process, we interviewed with professionals in related fields to validate our design scheme. To successfully incorporate musical compatibility and decide upon the features to include into our design, we spoke to jazz musicians in Braun Music Center at Stanford University. This brought us to the conclusion to include functionality for the standard 'smallest version of the jazz combo', specifically, a chordal instrument, drums, and bass. Our chordal instrument in this case is the keyboard, and the bass is the backing tracks in three different scales. To enhance the hardware usability, we discussed the design with hardware professors and lecturers from the Electrical Engineering and Physics Department at Stanford University. It was over the discussions with the professors that we decided to replace buttons for key notes with limit switches.

Additionally, our original design plan was to provide guidance from the backing track to the keyboard and vice versa. The former, forward case, would look like so: By choosing a backing track of a particular key, the primary components of the key would light up on the keyboard as tasteful options for playing. On the other hand, for the backwards case, if one plays a particular note on the keyboard, it would light up the backing track button that the key falls into. However, through the interviews with music professionals, we learned that the latter could result in information overload, particularly if the backing track button keeps blinking while a user is attempting to explore different keys or happens to hit a key that works for other tracks. Thus, we decided to keep things simple by only implementing the forward case such that the user has freedom to explore without constant redundant distraction.

5.2 Quantitative User Study

For this early stage of project development, we focused on the user experience of the system. Thus, for quantitative user study, we created a survey in Likert scale to get an overview of how well the system align with our initial goal. The survey was taken by 20 university students of both genders, and the survey included but not limited to the following questions:

- Confidence level in playing improvisation alone before and after use
- Confidence level in playing main improvisation in a band setting before and after use
- Confidence level in playing the backing bass in a band setting before and after use
- Interest to learn about musical theory before and after use
- Interest to learn about improvisation before and after use
- A task to identify the notes corresponding to a chord before and after use

Their interactions with the system were also recorded in the process. We found from the survey that 100% after use as opposed to 40% before use felt comfortable in playing improvisation alone. 80% of the participants increased their confidence level to play the backing bass in a band after using the system. However, only 25% of the participants increased their confidence level in playing main improvisation in a band after use. 80% of the novice particpants expressed interest in learning more about musical theory after use, and 85% of them increased interest ni learning about improvisation after use. Looking at their interaction with the system, we also found that 70% of the participants begin exploring outside the recommended patterns after 3 minutes of playing. Additionally, 80% of participants found it more enjoyable to play with multiple players instead of playing alone.

5.3 Qualitative User Study

In the preliminary round of user studies, we invited three close friends to test out the system. Two of the friends have no prior musical education, and do not play any instrument. The third friend plays the guitar and has just started to learn the piano. All participants are females. All three of them had much fun with the system, but with varying learning results. For the two friends without musical backgrounds, they learned the concepts about what scales and chords are, and the relation between the two. The illuminated keys helped them greatly in identifying which notes align with the current chords playing, and through experimenting different notes that were not lit up, they discovered the constrasting effect of playing ntoes out of chord. One participant remarked, "I was surprised that playing the notes lit up by the chord could sound so differently than the ones that were not lit. Also, I felt the different emotions in scales, like the major and minor scales, that I had not noticed before." For novices, ChordKeys served the purpose of introducing them to musical concepts such as chord progressions while experimenting with improvisation. However, the novices noted that it was still difficult for them to improvise a melodic line just based on the chord guidelines provided. They suggested it would be helpful if the system could generate sample rhythms and melodic lines with the chord composition.

As for the participant who plays instrument, she found the system helpful in a different way. Since she already had knowledge about the chordal concept, she focused on the ability of the system to help create original music. She agreed that the physical interface and the illumination of chordal keys encouraged musicians to create within the scale without imposing hard limits. She expressed that ChordKeys helped her feel confident in playing the backing bass in a jazz jam session. However, due to the limited number of keys the system offered, it was difficult to compose beyond one octave.

In our second round of user studies, we interviewed 20 participants of both genders and varying musical background. All of the participants without prior musical background were surprised at how they could easily create music that consisted of a simple yet complete jazz set of chords, notes and percussion with clear guidance. Some participants suggested that although the function to change different scales did convey the message of how scales affect emotions, it was not immediately clear to users. Instead, it would be helpful if the interface also displayed different colors to intensify the emotions. On the improvisation aspect, the novices mostly viewed this as a good first step to attempt improvisation and playing backing tracks in the band, but were still a little confused as of how to compose a complete music line just with the chord progressions.

As for the participants with previous musical knowledge, most felt excited to create music on a different interface. However, they felt limited by the single octave as mentioned previously. They also expressed difficulty to play multiple notes simultaneously because the keys are too big and too far apart. Also, some raised the point that arranging the keys in two rows representing the flat and natural notes might be more intuitive for that many people were accustomed to the actual piano setting.

6 DISCUSSION

As discussed above, ChordKeys was a hit. We see boosted confidence and interest in exploring music creation with the help of ChordKeys. Chordkeys also serves an educational purpose and was successful in helping novice users get a feel for the chords and tools that they can work with when creating music. The big keys are a great educational tool for multiple users, and teamwork became a large component for users playing ChordKeys, which bolstered the 'jamming' aspiration of the system.

From the results of our study, we also see that many improvements could be made for ChordKeys. It seems that more prototyping can be done to have a more compact design for single-user ease of use. In addition to this, the current state of the LEDs light up for each note that makes up the triad of the chord. However, we can extend this to hold Dominant 7th chords (4 notes), or harmonic tones that work for chord in order to give users more note options to guide them along for each chord. The sparsity of options given a simple 3-note triad were not quite enough of a robust guide for users. The users showed that they could use more variations in guidance to enable them to truly 'improvise' and create their own music.

For the backing track, we currently use a repetitive interstellar arpeggiation. This track has percussive tones in addition to the

arpeggiation. As the purpose of the backing track is to provide the basis for the key in which the user is playing, it would be helpful to have a simple walking bass that clearly signified which key the user is improvising in.

All in all, ChordKeys in moving towards its goal of enhancing musical creation and education for novice musicians, and with the analysis of the results of our study, we can discuss future work to enhance its usability and impact.

7 FUTURE WORK

Given the results of the user study in addition to the discussion and analysis of these results, there is a lot of potential for ChordKeys in the future.

7.1 Variations in Guidance Systems in Software Design

Within the discussion, we concluded that the current guidance system, in which we provide the 3-note triad chord as our main marker of improvisational guidance, could be bolstered. There are a few ideas that we would like to explore within this field of guidance.

All of the software guidance tools listed below provide a good basis for users to intuitively learn the chordal harmonies, styles, and moods that they can create when improvising. Every recommendation is a simple guide that starts the user off in their musical journey. The users would still have the option to veer off of what is recommended and play to their hearts content.

7.1.1 Static Guidance. We define static guidance as the practice of providing set recommendations based on the current chord of the key. These recommendations do not change based on the current note that the user is playing. For example, our 3-note triad chord recommendation is a static guidance system. We would like to extend our current static system by increasing the number of notes to recommend to the user. In particular, we would like to add 7th chords recommendations, in addition a options of the 9th, 11th, and 13th notes, often called extensions that harmonically extend the basic triad. This would provide more options for users, and would be a good static guiding tool.

7.1.2 Dynamic Guidance Using Artificial Intelligence. We would also like to explore dynamic guidance systems to dynamically guide users as they play by incorporating Artificial Intelligence (AI) and Reinforcement Learning (RL) into the guidance software. There are multiple variations of dynamic guidance systems that would be feasible.

One variation in particular would be to guide the user to play within the style of particular artists that they would like to take inspiration from. With RL, given the historical state of the notes they've played and the current state of the note, chord, and key that users are in, the software could generate a slew of 'next best' notes indicated through the LED lights that the users could play. This would provide a more masterful basis to guiding users to play like artists in industry and play more create more complex 'licks', and raising the ceiling of what they can be guided to create.

Another variation would be to create dynamic guidance would be to have the user choose a style that they are interested in playing in, and have the system suggest more rhythm and melodies instead of simple chord compositions. This would incorporate a more cohesive system, in which not only the keyboard note suggestions are dynamic, but also the chordal and percussive aspects are dynamic.

Finally, our last idea would be to guide on the basis of a mood that the user may like to play in. Perhaps the user is feeling a certain way and would like to play something that would resonate with this feeling. We can use AI to help guide melodies that evoke such emotions.

7.2 Interactivity and Hardware Design

There are a few hardware prototypes that we would like to explore within this project.

One in particular would be to incorporate mood into the hardware visually. To do so, we would use various LED colors to represent different emotions, allowing users to visually learn how different notes, styles, melodies within a key may evoke different emotions.

Other hardware ideas that we would like to explore would be the option of making the keys two rows of white and black keys rather than one row in order to have a more keyboard-like interface. This would be useful for those who would like to use ChordKeys as a educational precursor to the keyboard.

Finally, we would also like to explore variations in sizing. A more compact ChordKeys would serve single users better, as they would be able to easily create across the span of the system.

Another variation in sizing and design would be to simply abstract away the idea of the keyboard, instead replacing it with a 'stones on a wall' that users can press on interactively. This would take away from the visual intuition, but instead focus on gaining an auditory intuition for improvisations that can be played given the chord progression and keys.

8 CONCLUSION

ChordKeys is a musical device aimed at aiding improvisational education and musical enjoyment with the use of a tangible interface. Chordkeys aims to lower the threshold for beginners in musical improvisation by guiding users with lit-up chord progressions on a tangible interface. Through interacting with ChordKeys, users learn about improvisation on a foundation of chord progressions. With a simple visual interface displaying information of music theory in correspondence to their current backing track, chord, and note state, users can better understand what they are playing.

Our study found that ChordKeys was successful in enhancing musical creation and education for novice musicians, but also identified several areas for improvement. Therefore, we see a lot of potential with ChordKeys. Future work could focus on variations in guidance systems in software design, such as static and dynamic guidance using artificial intelligence, and another area of future work could be with fine-tuning the interactivity and hardware design, such as incorporating mood into the hardware visually.

Overall, ChordKeys provides an enjoyable and tangible way for beginners to learn and experiment with musical improvisation.

REFERENCES

[1] A. Esteves, F. Quintal, and I. Oakley. 2013. jamTable: Can Physical Interfaces Support the Collaboration between Novice and Experienced Musicians? *Lecture*

Notes in Computer Science 7989 (2013). https://link.springer.com/chapter/10.1007/978-3-642-41068-0_11

[2] C. Hu, K. Tung, and L. Lau. 2008. Music Wall: A Tangible User Interface Using Tapping as an Interactive Technique. *Lecture Notes in Computer Science* 5068 (2008). https://link.springer.com/chapter/10.1007/978-3-540-70585-7_32

[3] R.A. MacDonald and G.B. Wilson. 2014. Musical improvisation and health: a review. *Psych Well-Being* 4, 20 (2014). https://doi.org/10.1186/s13612-014-0020-9

[4] Biasutti Michele. 2017. Teaching Improvisation through Processes. Applications in Music Education and Implications for General Education. *Frontiers in Psychology* 8 (2017). https://www.frontiersin.org/articles/10.3389/fpsyg.2017.00911

[5] G. Palaigeorgiou and C. Pouloulis. 2018. Orchestrating tangible music interfaces for in-classroom music learning through a fairy tale: The case of ImproviSchool. *Education and Information Technologies* 23 (2018). https://doi.org/10.1007/s10639-017-9608-z

[6] Joseph A. Paradiso, Kay-yuh Hsiao, and Ari Benbasat. 2001. Tangible Music Interfaces Using Passive Magnetic Tags. (2001).

[7] Alfred Schütz. 1951. MAKING MUSIC TOGETHER: A Study in Social Relationship. *Social Research* 18, 1 (1951), 76–97. https://www.jstor.org/stable/40969255

[8] Paul T. Sowden, Lucie Clements, Chrishelle Redlich, and Carine Lewis. 2015. Improvisation Facilitates Divergent Thinking and Creativity: Realizing a Benefit of Primary School Arts Education. *Psychology of Aesthetics, Creativity, and the Arts* 9, 2 (2015). http://dx.doi.org/10.1037/aca0000018