Evaluating an LED-based Interface for Lumanote Composition Creation Tool

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ABSTRACT

Composing music typically requires years of music theory experience and knowledge that includes but is not limited to chord progression, melody composition theory, and an understanding of whole-step/half-step passing tones among others. For that reason, certain songwriters such as singers may find a necessity to hire experienced pianists to help compose their music. In order to facilitate the process for beginner and aspiring musicians, we have developed Lumanote, a music composition tool that aids songwriters by presenting real-time suggestions on appropriate melody notes and chord progression. While a preliminary evaluation yielded favorable results for beginners, many commented on the difficulty of having to map the note suggestions displayed on the on-screen interface to the physical keyboard they were playing on. This paper presents the resulting solution: an LED-based feedback system that is designed to be directly attached to any standard MIDI keyboard. This peripheral aims to help map note suggestions directly to the physical keys of a musical keyboard. A study consisting of 22 individuals was conducted to compare the effectiveness of the new LED-based system with the existing computer interface, finding that the vast majority of users preferred the LED system. Three experienced musicians also judged and ranked the compositions, noting significant improvement in song quality when using either system, and citing comparable quality between compositions that used either interface.

Author Keywords

music composition, music teaching and improvisation tools, real-time adaptive user interfaces, light-based feedback systems

CCS Concepts

•**Human-centered computing** → **Graphical user interfaces; Sound-based input / output;** *User centered design;* •**Applied computing** → **Performing arts; Sound and music computing;** *Media arts;*

Figure 1: The Lumanote LED interface under dim lighting conditions.

1. INTRODUCTION

The creation of modern music has relied increasingly on the assistance of computer systems, and the composition process itself has been largely enhanced by digital musical creation tools. Current technologies tend to either focus on analyzing existing music to extract meaningful metadata, or assisting authors in creating automatically or semi-automatically generated music. Though this may greatly facilitate the songwriting process, this risks a composition losing the personality and identity of its creator. This motivated the creation of Lumanote, an interactive real-time digital composition aid that suggests chords and melody notes based on music theory concepts. The most common feedback from a preliminary user study showed us a beginner's difficulty with mapping the interface suggestions with the keys of the MIDI keyboard that they used. This motivated the creation of an LED-based interface, designed to be directly attached to the keyboard itself, as a way to provide more immediate feedback that directly maps to the keys themselves. This paper summarizes related works in this domain, the existing Lumanote system, and the introduction of the new LED-based interface. We also describe a new user study consisting of 22 participants that analyzes the user experience of both the existing Lumanote monitor-based interface and the new LED system. Additionally, we use three experienced musicians to judge and rank the user compositions.

2. BACKGROUND AND RELATED WORKS

2.1 Musical Analysis Tools

Some computer-based musical applications focus on employing algorithms to analyze and generate metadata about music. One such system, detailed by Bello et al., extracts rhythmic and harmonic information about a song without attempting to transcribe said song in its entirety [2]. Ab-

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dallah et al. introduces a model for extracting structural components such as a verse, the chorus, and the introduction of a piece of music for the purposes of cataloging, music summarizing, and song identification [1]. More recent developments have focused on automating harmonic analysis using theories of tonal harmony as its backbone, such as the work of De Haas et al. [9]. While these technologies employ music theory to existing pieces, they are only analytic in purpose and do not play an active role in the creation new music. Leveraging the same basic principles for the composition of music is a significant motivator for the creation of Lumanote and its different interfaces.

2.2 Tools for Musical Composition

Several technologies have been developed to help musical composition through procedural generation, with increasingly more complex methods of input and parameters that affect the resulting output for more musically interesting material. Diaz-Jerez leveraged his previous technology of FractMus into a project called Melomics in order to assist in the procedural creation of music based on biologically inspired musical evolution [7]. While this produces interesting musical material, it takes considerable creative input away from the composer. Hookpad is a composition tool that utilizes music theory concepts to help composers construct melodies and chord progressions that are known to work well together in specific keys [1]. The software, however, relies on a more thorough understanding of musical composition theory with an interface that is not particularly intuitive for beginners. Biles presented the GenJam project, a real-time interactive improvisation tool for Jazz music [4]. Its intent is to serve as a companion for existing Jazz musicians, requiring considerable expertise in the genre. It is also restricted to the Jazz genre only. Levitin et al. proposes alternative forms of creative input through gestures, although we maintain that hardware accessibility, ease of use, and familiarity with the piano format will be more improtant for aspiring composers [14]. Kitahara et al. developed a system that automatically "finishes" an existing composition when a user makes edits [12]. This system relies mostly on editing an existing piece and, unlike Lumanote, does not focus on the process of writing a song from scratch. Chuan et al., similarly, identified chord progression of songs and suggests new chords to complete the composition, but relies on an existing piece and does not function in real-time [6]. Similar technologies, with similar caveats, have also been applied for a composition's melody such as Tsuchiya et al.'s work that extracts a melody and assists users in finishing edited melodies [18].

There also exist several digital chord suggestion systems. Huang et al. present their ChordRipple interface, a system that suggests a wide variety of appropriate chords to assist novices in chord progression composition[11]. This system, while useful, relies on a menu interface rather than allowing users to receive suggestions as they play a keyboard in real-time. Additionally, the system is built for chord progression suggestions but does not combine this with melody note suggestions. Simon describes a musical accompaniment system, MySong, that suggests chords based on notes that users sing into a microphone [17]. Users adjust parameters such as whether they wish to compose a "sad" or "happy" song, and receive various chord suggestions for them to include in their music. Like ChordRipple, however, MySong does not provide suggestions in real-time nor does it provide an instrument-based interface through which a user can input notes. Additionally, its heavy reliance on sliders to determine genre and mood might be considered to be taking too much agency away from aspiring musicians. Hardware LEDs on individual keys are a prominent feature in products like Native Instruments' Komplete Kontrol keyboards,[2], although the LEDs in this context are not used to make any real-time note suggestions for composers.

2.3 Teaching Systems

Computerized interactive teaching tools have promisingly emerged as low-cost, convenient solutions for learning about music theory and instrument playing. Nilsson et al. has explored the integration of professional computer musical sequencing programs with the creative composition process of children, and found that students were successful in developing music of sound form and structure [16]. Hickey employed the researcher-designed "Music Mania" digital composition tool and found that unobtrusive recording sessions for children resulted in more successful inspiration for students over more closely guided tasks [10]. Burnard explores the impact of digital composition tools and online teaching courses on the existing pedagogy of instrument and music theory teachings [5]. Burnard emphasizes the promise of the viability of utilizing digital composition software for teaching purposes, encouraging both teachers and pupils to remain engaged and communicate both of their needs as research in this field continues. Klemenc et al. describes the principles of color visualization of music that connects musical tones to shared and related colors in the color spectrum [13]. This builds off of existing work from Bergstrom et al. that explores alternative forms of visualizing chords [3]. Although this research also uses colors to identify harmonious notes, its emphasis in teaching music theory produces far more complex color schemes likely to be intimidating to beginners without a teacher or music learning resource.

Xiao et al. presents MirrorFugue, a mirror-like interface that displays the keyboard being played by an instructor for students to imitate [19]. Teaching systems like Synthesia[3] use a scrolling-note interface to teach timing and notes of existing songs, but also does not provide features to aid in musical composition. This system largerly relies on an instructor's input and does not support composition features. These tools offer a glimpse on the potential that interactive digital composition tools might have on the learning process. A digital composition tool that offers teaching opportunities on the basics of authoring music could prove invaluable.

3. DESCRIPTION OF *LUMANOTE* SYSTEM

Lumanote is a real-time composition software tool that uses the basic concepts of harmonizing musical notes with chords and vice versa [8]. It is intended for use with any standard MIDI controller such as an electronic keyboard, but has also been programmed to take input from a mouse and/or computer keyboard. We target inexperienced-to-beginner piano players in order to best democratize the musical composition process. The system deliberately avoids providing templates and examples so as to avoid potential issues of comformity among aspiring musicians (as explored in the work of Marsh et al.[15]). Lumanote's web-based interface displays a standard piano layout with a vertical Split Point line that separates the left-hand "chord" side form the right-hand "melody" side. A songwriter can start the composition process by either inputting a base chord with their left hand, or inputting a single melody note with their right. Luman-

[1]Hookpad: https://www.hooktheory.com/hookpad/new

[2]Komplete, Keyboards: https://www.native-instruments.com/en/products/komplete/keyboards/

[3]Synthesia: http://www.synthesiagame.com/

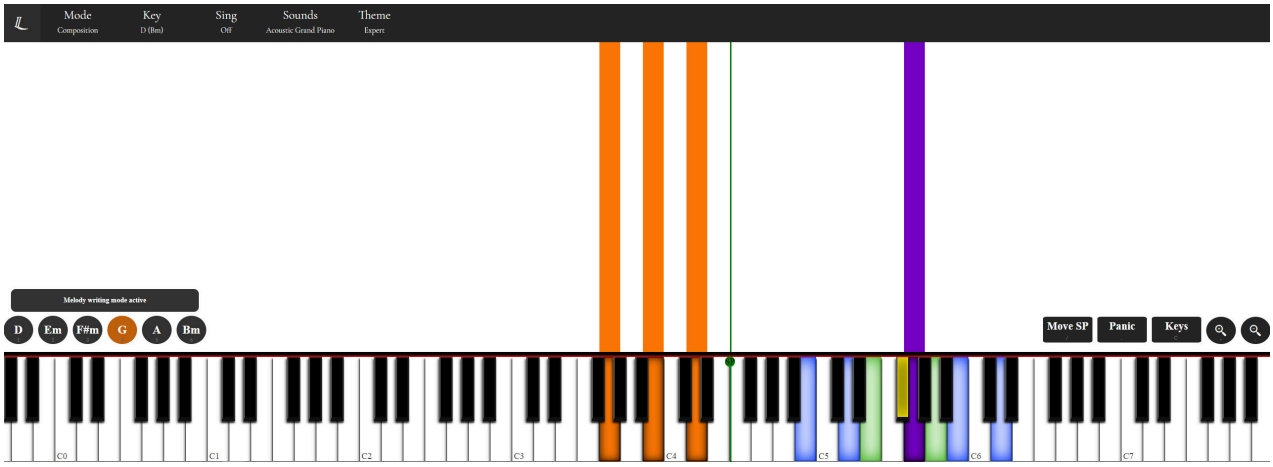

Figure 2: The Lumanote web-app interface. The chord to the left of the Split Point (green line) and the pressed melody note on the right yields various suggestions for new melody notes.

ote then suggests a range of appropriate melody notes if user input is a chord, or chord options if user input is a melody note. Chord and melody not suggestions are made according to basic music theory rules and the provided key signature. For chords, a user is presented not with a single chord, but rather a choice of various chords represented by their base note. To choose a chord, the user keeps the melody note pressed and presses one of the three suggested chord base notes. Lumanote then recognizes the chosen chord and expands the rest of the notes for that chord.

After having chosen both a base chord and the first melody note, the songwriter is presented with appropriate melody notes that he or she can use for their composition. The songwriter can, at any time, press a single melody note or chord note and receive further appropriate notes based on their input. Lumanote is intended to inspire composers by letting them move from chord to chord and melody note to melody note by constantly discovering new notes to play off their input notes. The result is a piano interface that always presents songwriters with a wide variety of options through which to take their composition.

Lumanote color-codes the "appropriateness" of these notes and chords. Chord tones share the first "tier" of color labeling, whole-step passing tones the second "tier" of labeling, half-step passing tones the third, and 7th and 9th degrees the final tier. The actual colors displayed depend on which color palette is chosen in the application setting. For example, the "Beginner" theme changes the color-coding so that all in-scale notes of a chord are labeled the same shade of blue. By contrast, the "Expert" theme uses the full gamut of "tier" labeling, utilizing the rainbow color spectrum to progressively label suggested notes from blue (most harmonious) to red (least harmonious). Other coloring schemes perform the same function but utilize shades of narrower color gradients (such as from green to blue for the "Rainforest" theme). The different themes both accommodate differing user skill levels as well as a songwriter's personal taste.

It is important to emphasize that Lumanote does not present a user with instructions. Rather, the system provides **suggestions**. Once the user chooses the notes and chords of their choosing, the user is free to follow, disregard, or alter the highlighted notes. For instance, all chords of a note do not need to be pressed at once, or at all. A composer might choose to only play two notes from a four-note chord, or play three of them in an arpeggio pattern. Lumanote will recognize even individual notes to the left-hand side of the Split Point as a chord, and still suggest harmonious melody notes. Similarly, while Lumanote will never suggest a completely out-of-scale melody note, if the user inputs one the system will suggest the closest note that will allow the composer to resolve the tension created by said note. This would be useful for music in the Jazz or Blues genre.

Lumanote also includes a wide variety of features including changing piano key widths, identifying scale notes in each key signature and enabling microphone input that identifies the note being sung as the "melody" note and suggesting appropriate chords among others.

4. LED-BASED INTERFACE

A preliminary user study with inexperienced piano players yielded valuable feedback on Lumanote's interface, with one of the most common points of critique being the difficulty in mapping the suggested piano keys on the interface with the electric keyboard they were playing. Although Lumanote has a feature to change key widths, computer monitors are manufactured with very high variations in sizes and resolutions, and very rarely are wide enough to directly map the keys of an 88-key or even 61-key piano keyboard with a 1:1 width ratio. However, we recognized Lumanote's advantage of requiring no custom hardware for its use, and wished to preserve the spirit of the system's design in its adaptability to various MIDI controller inputs. This motivated us to create a different way of interfacing with the Lumanote system with the following design requirements.

- Create a **low-cost, adaptable peripheral** that can be physically attached to an electronic keyboard.
- **Preserve Lumanote**'s intuitive note-suggestion system without using a high-resolution computer monitor.
- Choose a physical interface that **does not interfere with the pressing of keys**, both in terms of the keyboard mechanism and the user's finger movement.

To that end, we have created a light-based interface that utilizes a strip of LEDs that is attached directly above the top of the keyboard keys and aligned to the keyboard notes.

4.1 System Description

The LED interface for Lumanote is controlled by an Arduino Uno, which houses code that controls LED colors,

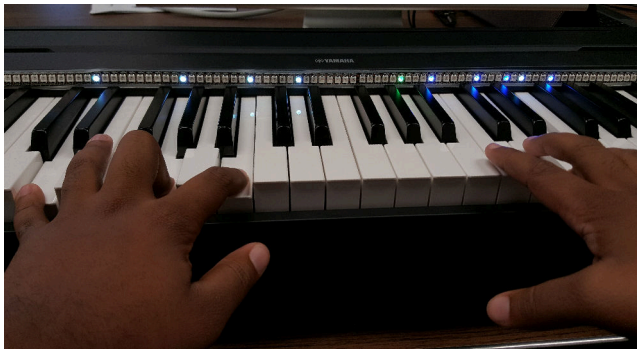

Figure 3: A composer using the LED interface in normal lighting conditions.

mapping of suggestions from the traditional Lumanote interface, and LED-to-note assignments. We chose to use an off-the-shelf LED strip to reduce the amount of required custom or expensive hardware. The Arduino Uno's code maps the keyboard notes to the corresponding light that is vertically closest to a note. Mapping lights to a specific spacing pattern (e.g., every third LED), would misalign notes with lights and would essentially present the same interface-to-keyboard mapping issue that is present in the original computer screen interface. Our priority was mapping the lights to the keys that were directly below them, which we believed to be the more intuitive mapping scheme for users.

Our mapping conforms to full-sized keyboard keys, so the same LED strip can be used on any keyboard with full-sized keys once the strip is aligned properly. Alignment only requires that a single note be properly aligned to its corresponding light, and all LEDs and notes to the right and left of it will be aligned as well. The note suggestion system present in the original Lumanote interface remains virtually the same; the process of finding melody and chord notes, as well as the actual note suggestions, are identical across both interfaces.

4.2 Hardware Composition

The hardware layout of the LED interface is presented in Figure 4. A USB-A cable is plugged into the Arduino Uno for powering the Arduino, with pin 6 being used for the transfer of data from a computer that runs the Lumanote interface. Data transfer has been set at a baud rate of 4800, allowing real-time note input and output with no additional delay between the original monitor interface and the new LED strip. A +5V DC power supply connects directly to the LED strip for power to the lights. A 1000 uF capacitor is added between the power supply and LED strip to prevent the initial burst of current from damaging the lights, and a 470 ohm resistor is added between the Arduino's data pin and the LED strip to prevent data spikes from damaging the first LED in the strip.

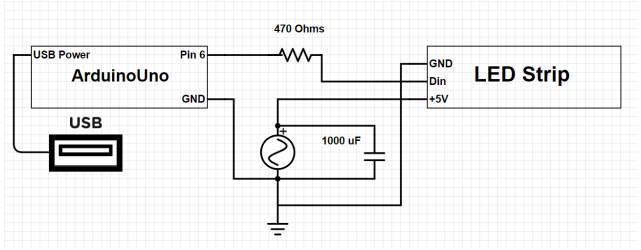

Figure 4: Hardware schematic of the LED interface.

5. EVALUATION

We believe that the note suggestion system has the most potential for improvement among users who have little to no piano-playing experience, and those consider themselves beginner-to-intermediate musicians of other instruments. For that reason, we sought to analyze the usage experience in a 22-person user study with participants inexperienced with playing the piano, but who may have some musical background.

5.1 Study Description

We conducted a within-subjects user study that tested each user under three different scenarios: a composition with **no assistance** from any note-suggestion interface, a composition with the assistance of the original **computer monitor interface**, and a composition with the assistance of the new **LED-based interface**. In order to counteract a potential learning effect, we asked half the participants to use the monitor-based interface first, and half the participants to use the LED-based interface first. For the second and third scenarios, participants were given 4 minutes to compose an original piece that lasted around 10 seconds. At the end of the 4 minutes, the composition was recorded. Participants were given as many times as they wished to record their composition, since we did not intend to capture their live music-playing skills but rather the composition itself. However, the song was not allowed to change in between recording attempts.

A post-study questionnaire was distributed to participants, asking about any prior musical experience, a series of Likert-scale questions about their opinion on the usefulness of the interfaces and the note-suggestion system, as well as which interface they preferred.

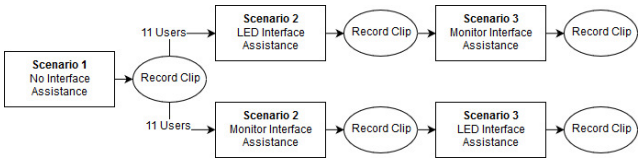

Figure 5: Study order and distribution of participants.

We recruited 3 experienced musicians to judge the user compositions without knowledge of which interface the participants utilized.

- **Judge 1** has 15 years experience of playing electric and acoustic guitar, and 2 years of playing drums. This judge has been composing songs for around 5 years, and improvising music for around 3 years. They have thorough understanding of scales, (minor, major, pentatonic minor/major, blues), modes, ideal chord progressions for various genres, extension chords, and modulation between key signatures among other concepts

- **Judge 2** has played percussion instruments for 11 years, including keyboards and drums. This judge's composition expertise is mostly rhythmic, creating several original ensembles for drums and arranged several for mallets and keyboards. They have 7 years of formal education in music and has judged auditions for a university music group for 4 years.

- **Judge 3** has has 15 years of playing the piano and has experience with guitar chords. Throughout those 15 years, this judge has composed short melodies, has

been learning music theory, and can comfortably sight-read sheet music. They also frequently improvise with other musicians for recreation.

All judges were asked to rank the compositions individually: all compositions from the no-interface scenario, all compositions with the assistance of the monitor-based interface, and all compositions of the LED-based interface. They were also asked to rank the composition of each user across every scenario. Judges were not told which scenario pertained to which, if any, interface assistance the users had.

Judge ranking was based on a broad definition of quality. A presence of rhythm, harmonious notes/chords, and a general sense of musicality were the main components of judging quality. We avoided strict measures like "notes per minute" to avoid favoritism to faster songs over slower ones, or giving preference to certain musical styles and genres.

5.2 Results

5.2.1 User Responses

The user questionnaire and its responses are summarized in Figures 6 and 7, and Table 1. The post-study questionnaire consisted of two parts: questions on the user's experience with playing and composing music, and questions based on their experiences with both interfaces. Although 36% of users had 4 years or more of instrument-playing experience, only 9% had any experience at all in composing songs. Only 6 participants had ever played a piano and characterized themselves as inexperienced, and those with previous musical experience noted that their skill in their respective instrument did not transfer to their piano playing during the study.

Responses to interface questions were on a 5-point Likert scale, with 1 being "Very Difficult" or "No Help at All", and 5 being "Very Easy" or "Very Helpful". Finally, we asked which of the two presented interfaces they preferred. 86% of users preferred the LED strip over the monitor-based interface, noting that they vastly preferred the lights marking the suggested notes more directly onto the physical keys. They expressed more difficulty in having to "count" keys in the original monitor interface.

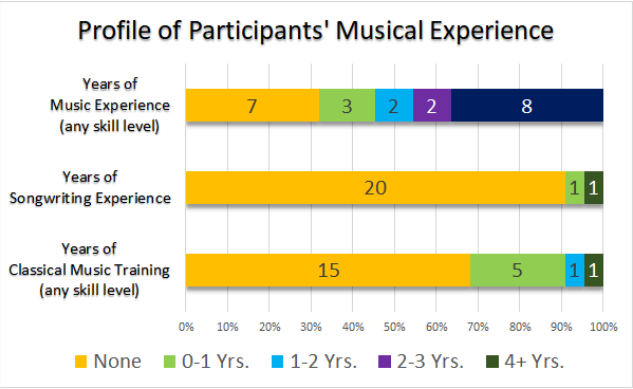

Figure 6: Information on musical experience of user study participants.

This demonstrates a clear preference for the LED-based interface. 2 of the 3 participants who preferred the monitor-based interface had previous experience with playing a piano, and cited the monitor interface's depiction of piano keys as the main reason for their preference. These participants noted having little issue with mapping the keys depicted in the monitor to the keys on the musical keyboard. The 19 participants who preferred the LED interface, however, reported trouble with the same task of mapping the notes suggested on the monitor with the keys in front of them. They preferred the close proximity of the LEDs clearly labeling the actual key that should be pressed, and they did not mind the irregular spacing between LEDs for key suggestions. Some users expressed preference for LED interface's potential portability, since it only requires a small strip that can be attached to any standard-sized keyboard rather than a computer monitor.

Table 1: Participants' Interface Preference (Number of Users)

Monitor Interface	LED Strip
3 (14%)	**19 (86%)**

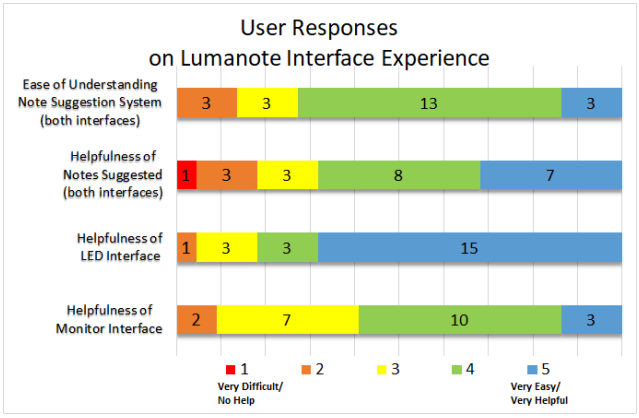

Figure 7: Post-study questionnaire responses of system and interface experience.

5.2.2 Judge Rankings

Judge rankings can be seen summarized in Tables 2 and 3. Because the LED and monitor interfaces present the same information to the user, we initially hypothesized that the actual quality of user compositions would not differ greatly regardless of which of the two interfaces users personally preferred. However, in practice we did notice a small increase in composition quality with creations assisted by the LED interface; Judge 1 ranked 12 of 22 (55%) of LED compositions as the "best" of the three for each user, and Judge 2 ranked 15 of 22 (68%) of LED compositions as the "best". Conversely, Judge 3 ranked 15 of 22 (68%) of monitor compositions as the "best". By contrast, all compositions with no interface assistance performed the worst across all judges: Judge 1 ranked all 22 no-interface compositions as the worst for each participant, Judge 2 ranked 21 of 22 as the worst, and Judge 3 ranked 18 of 22 as the worst.

We calculated the correlation coefficient averages of all three judges with respect to their rankings for Scenarios 2 (LED-assisted composition) and Scenario 3 (Monitor-assisted composition) and whether said interface was played first or second. We found no statistical correlation between how highly ranked the songs were and whether they played with an interface first or second. Average correlation coefficient for all three judges for Scenario 2 was 0.0407 and for Scenario 3 was -0.0454.

Although the LED compositions performed slightly better with the judges, we can confidently conclude that the Lumanote system yields considerably better musical compositions among users with little musical composition experience. The outcomes also suggests that using the LED

Table 2: Songs ranked as "Best" by judges, sorted by interface used (bolded best performing).

	None	Monitor Interface	LED Strip
Judge 1	0	7 (32%)	**15 (68%)**
Judge 2	1 (5%)	9 (41%)	**12 (54%)**
Judge 3	2 (9%)	**15 (68%)**	5 (23%)

Table 3: Songs ranked as "Worst" by judges, sorted by interface used (bolded worst performing).

	None	Monitor Int.	LED Strip
Judge 1	**22 (100%)**	0	0
Judge 2	**21 (95%)**	0	1 (5%)
Judge 3	**18 (82%)**	2 (9%)	2 (9%)

interface results in compositions of at least comparable quality with those composed from the monitor-based interface. Furthermore, we can identify participants' strong preference for the LED interface.

6. FUTURE WORK AND CONCLUSION

We intend to further iterate on this LED interface that will use an off-the-shelf strip of LEDs with adjustable spacing between them. This would allow every LED to be used and perfectly aligned to keys, even for keyboards with narrower or wider keys. We also intend to implement a note recording feature, since several users expressed a wish to be able to remember which notes and chords they chose as they composed. This would also allow them to compose a more complicated piece that they may not be able to play live due to their skill level.

Lumanote's note-suggestion system for both chords and melody note allows users of varying skill levels to produce musical compositions that follow music theory rules on tone harmony. Strong preliminary results yielded some insights on the shortcomings of the note-suggestion interface when displayed on a standard computer monitor, including multiple comments expressing difficulty in mapping the piano interface as shown on the monitor to the musical keyboard they were playing. This motivated the creation of an LED-based interface that preserves the note-suggestion system but communicates it through a physical peripheral designed to be attached to the keyboard itself. A more extensive user study followed, finding clear improvements with the note suggestion system over no assistance, and finding that users strongly preferred the LED interface. With a clear path for improvement, we believe that Lumanote can democratize the creation of musically sound songs without relying on minimal-input procedural generation. We believe Lumanote can help develop an aspiring musician's creative process and identity.

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