Creating Emotion-Evoking Music to Communicate Wellness for Users with Diverse Musical Backgrounds

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ABSTRACT

Chord progressions influence the emotional response a song evokes, suggesting altering a song's chords can help a system control the emotions that a user experiences when listening to sonified data. In this paper, we explore how chord progressions could be used to musically communicate wellness information that invokes specific emotions, and whether a person's musical background affects their perception of emotions in music. We conducted two studies where participants provided structured or open-ended perceptions of emotions in harmonies. Our findings suggest that the emotional impact of a chord progression can be changed by various factors, including the chord transitions, the type of chords, and the chord's mode. Additionally, we found that a person's musical background may influence nuances in their perception of emotions conveyed through chords. This implies that future systems may need to consider individual musical preferences to function effectively. These results will allow for more accurate and effective emotional sonification-based communication with the user.

CCS CONCEPTS

• **Human-centered computing** → **Auditory feedback**; **User studies**; **Interaction design theory, concepts and paradigms**.

KEYWORDS

Music, Harmony, Chords, Personalization, Sonification, Emotions, Affective Computing, Wellness Communication

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1 INTRODUCTION

Sonification researchers have developed techniques to represent data through sound. These techniques have been applied to a range of fields, such as crime statistics [25], mindfulness [34], navigation assistance for visually impaired individuals [20], and the representation of biosignals [17, 32]. It has recently been demonstrated that sonified music can communicate wellness information [5]. Study participants have also been found to be more active after hearing musical feedback than receiving textual feedback, or no feedback at all [6]. While musical feedback appears to effectively communicate wellness information and promoting physical activity, participants misinterpreted the music in nearly 75% of samples [6]. To ensure wellness information is properly communicated through music, more intuitive approaches must be developed to meaningfully embed wellness information into music.

A benefit of musical feedback is that music excels at communicating emotions [14, 35, 36], which can be leveraged by attaching emotional messages to the data. Embedding sad motifs into negative feedback could help users internalize their lack of wellness, while happy messages attached to positive feedback could make users feel happier about their wellness. However, to achieve this, we must understand how music can communicate specific emotions. Studies show that the emotion of a song is heavily influenced by the chord progressions [4, 13] (background on chords is provided in section 2.1). According to research, several chord elements influence the perceived emotion: the resolution of chord progressions (how much the listener is left "wanting more") [4, 38], the number of notes in each chord [38] and whether the chord progression is getting higher or lower [22].These findings could be integrated into existing music generation systems [7–9, 11, 18, 37, 40–42], allowing seamless presentation of data with clear emotional connotations.

While these findings are relatively straightforward, music theory is a highly nuanced field. No study has explicitly explored whether a listener's background knowledge of music affects their perception of music's emotional content. We focus specifically on chord progressions, as they are associated with the valence of music, but require an in-depth background in music theory to understand fully. Few studies have investigated the differences in perceived emotionality of music between individuals with varying levels of musical background [2, 3]. These studies, however, do not explicitly study chord progressions, despite their clear connection to emotionality. However, the connection between musical background and generalized emotions in chords has not yet been explored.

To effectively connect wellness feedback to specific emotions, we investigate whether an individual's musical education affects their perception of the emotions conveyed by music. To achieve this, we conducted two separate user studies. In the first study, participants listened to highly structured, pre-created chord progressions and rated them based on four adjectives using a 7-point Likert scale. In the second study, participants were asked to create chord progressions that sounded "happy" and "sad." Our results

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showed slight differences in how chord progressions are perceived, indicating that individuals with musical backgrounds may be more attuned to subtle changes within the harmony. To effectively embed emotionality within musical feedback, wellness systems must consider these individual nuances.

2 BACKGROUND & RELATED WORK

2.1 What is a Chord Progression?

Music theory is a complex field. In this subsection, we will briefly explain chords and their nuances to help readers better understand our work, regardless of their music theory background.

In music, a note is the most basic element, which consists of a sound at a specified tone held for a specified length of time. A chord, on the other hand, is a group of multiple notes played simultaneously. The triad is the most common type of chord, consisting of three notes, each a small step above the previous. The chord is named after its root, which is the lowest tone. For instance, a chord with the root of C would be called a C-chord.

Although triads are the most common, composers can modify triads to produce different sounds. There are many ways to alter a chord, but for this discussion, we will focus on two: tetrads and changing the mode of chords to major or minor. Tetrads are chords with four stacked notes rather than three, while changing the mode of a chord alters its notes, making minor chords sound sadder.

A series of chords played in sequence is called a chord progression. Typically, chord progressions comprise the harmony of the song, which serves as the supporting musical voice within a song, complementing and adding to the main voice, called the melody. Throughout this work, we will interchangeably use the terms chord progression and harmony.

Progressions are influenced by the key, which specifies the exact notes to be played in each chord. Like chords, keys are named after notes. When the root of a chord is the same as the name of the key, the chord called the tonic. For instance, in the key of C, the tonic is the C-chord. Chords within a key have specific relationships with each other. These relationships are denoted using Roman numerals representing the number of notes away from the chord's tonic root. In the key of C, the chords are represented as follows: C=I, D=ii, E=iii, F=IV, G=V, A=vi, B=vii. Capitalized Roman numerals indicates that the chord will sound major in this key, while lowercase numerals indicate that the chord will sound minor.

Regardless of the key, the chords in positions I, IV, and V will always sound major, while the others will sound minor. These chords have special names and properties when transitioning between them. The chord in position IV is called the "sub-dominant," and a transition from I to IV is considered weakly resolved, which means that the listener may feel like the progression could continue or end. On the other hand, the chord in the V position is called the "dominant," and a transition from I to V is considered strongly resolved, allowing the listener to feel like the progression has concluded.

2.2 Music in Emotions and Healthcare

Studies have found that chord progressions impact a song's valence and arousal, with a stronger association with valence [4]. Arousal levels vary with less resolved chords, major keys, higher pitch, and tetrads [38]. Moreover, major keys [13] and higher pitches [4] are linked to higher valence, whereas tetrads are associated with lower valence [38]. It has also been found that ascending chord progressions have positive valence, while descending progressions have negative valence [22]. Nevertheless, previous studies have not adequately considered the influence of an individual's musical background. One study discovered that musical novices and experts differ in their perceptions of meta-features such as tension and interest [15]. However, another study showed that most musical features are perceived similarly by individuals with and without musical backgrounds [16]. Although these studies suggest that individuals with varying levels of musical background may perceive emotions differently, they do not focus on the emotional tone of the music, such as whether it sounds happy or sad. Some studies investigate connections between musical background and the perceived emotionality of music, although they focus on music as a whole, rather than chord progressions [2, 3]. There is a lack of research exploring how musical harmony can be used to communicate specific emotions. Properly understanding the connection between emotions and music will enable systems to communicate wellness information while evoking specific emotions.

This unique connection to emotions led to the creation of music-based healthcare treatments, primarily demonstrated by the field of music therapy. In music therapy, a certified therapist works with patients to perform, compose, and listen to music, often focusing on helping patients express themselves [26]. Music therapy has successfully helped patients manage anxiety [39], depression [23], and provide relief during palliative care [24]. While effective in addressing wellness concerns, few digital systems take inspiration from these musical therapies to use music to promote wellness.

2.3 Sonification

Sonification refers to the process of converting data into sound. Although it sounds similar to music, sonification is a distinct concept [27]. The objective of music is to create pleasing sounds, while sonification aims to represent data through sound. Sonification often uses sounds other than music,such as mapping seismic activity to auditory frequencies [31]. Researchers have also used other types of sounds like pings, beeps, changing auditory frequency, and musical scales to sonify spatial data and assist the visually impaired [1]. In another study, bird calls were employed to communicate electricity usage [19]. These systems combine sounds and data creatively, but they do not compose music.

Musical sonification has been primarily used to convey emotions or data that is more meaningful when the user is experiencing a particular emotion. Many of these techniques involve converting real-time data into music for healthcare and wellness purposes. Researchers have transformed physical therapy movements into music, motivating users to perform better during exercises [10, 28–30]. Music has also been used to represent physiological signals, especially EEG, to assist users in better understanding their bodily functions [17, 32]. Additionally, it has been demonstrated that general wellness information, such as wellness states, can be incorporated into music [5], and then be used to promote physical activity in participants [6]. While these applications are promising, a better understanding of how songs convey emotions may enable researchers to improve the effectiveness of their systems.

3 STUDY 1: EMOTIONS IN PRE-DESIGNED HARMONIES

The first study utilized a structured survey to examine the influence of different progressions on participants' emotional perceptions of harmony. A total of 40 individuals were recruited through word of mouth, and 35 of them successfully completed the survey. All participants who completed the survey were included in our analysis. When asked "do you have any formal music education," 11 participants self-reported that they did not, while the other 24 had experience playing an instrument, could read music, received voice training, or knew music theory. 25 participants were between 18 and 22 years old, 5 were between 22 and 26, and the remaining 5 were over 40 years old.

In this initial study, our aim was to investigate how different types of chord progressions influence perceived emotions and whether these perceptions differ based on a participant's musical background. Specifically, we sought to answer two research questions:

RQ1: Do participants with different musical backgrounds perceive the progressions differently?

RQ2: Are participants with more musical backgrounds' perceptions of musical emotionality more consistently positive or negative?

We first analyze differences between the progressions at the population level and then whether musical and non-musical participants differ from population trends or each other.

3.1 Methodology

We designed a set of four-chord progressions for participants to listen to and rate the perceived emotionality of the harmony. Our first progression consists of a change from tonic to dominant (I-V), which is considered strongly resolved and should sound pleasing to the listener. Consequently, this transition also moves the chords around the Circle of Fifths [12], a musical tool for cyclically changing keys. Since this progression rotates clockwise around the Circle of Fifths, we refer to it as the "Clockwise" condition. Our second progression shifts between the tonic and the sub-dominant (I-IV), which still sounds resolved albeit not as concluded as the transition from tonic to dominant. This transition is equivalent to traversing the Circle of Fifths counter-clockwise and is called our "Counter-Clockwise" condition. These conditions are shown in figure 1A.

Our remaining progressions do not follow a pattern as structured as the Circle of Fifths. Rather, they are both deliberately designed to sound unresolved ensuring that the chord does not transition to its sub-dominant or dominant. To create a sequence of chords, we assigned random numbers to each of the twelve chords and used a random number generator to generate the progression. The first progression, which we call the "Limited Random" condition, was restricted to only major triads, despite the sequence being random. Since the Circle of Fifths displays all 12 major triads, this progression is also shown in figure 1A. The final progression was also randomly generated, although it was not limited to major triads, allowing for a wider range of harmonies. This was identified as the "Fully Random" condition.

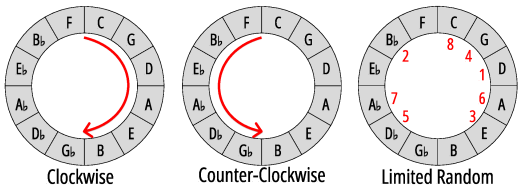

Figure 1: The "clockwise," "counter-clockwise," and "limited random" conditions from our first study, shown on the Circle of Fifths.

To keep the harmony short, each progression was limited to 8 chords, exported to an mp3 file, and placed into a Qualtrics Survey.The survey commenced by asking the participants about their music education level, through the same question as previous work investigating using music for wellness feedback [5, 6]. Then, the participants listened to each of the four progressions in a random order. After listening to each harmony, they were asked to how well four terms apply to the harmony on a scale of 1 (strongly disagree) to 7 (strongly agree).

We collected ratings for the words "happy," "tiring," "satisfying," and "pleasing." While most terms were chosen using Russell's circumplex model of affect [33] (better known as the valence-arousal scale), we use emotional terms rather than valence-arousal scales to better study how specific emotions can be invoked. Although we analyzed each term, our main focus was on "happy," due to the aforementioned concept of playing happy music to reward users for positive wellness. Happiness is considered high valence but relatively neutral arousal. We then added the term "tired," a term with very low arousal but neutral valence, to our study in order to better observe the differences between arousal and valence. Using the circumplex model, we then identified the term "satisfying" as falling halfway between "happy" and "tired," and included it to study terms with more ambiguous meanings. Lastly, we added the term "pleasant," which is considered to have very similar valence and arousal to "happiness" allowing us to gauge whether ratings remained consistent across different emotional terms, where the valence and arousal only slightly change. Table 1 summarizes the responses.

3.2 Results

We analyzed how different resolution levels affect perception in clockwise, counter-clockwise, and limited random conditions. The study found that the counter-clockwise condition was perceived as the happiest among the participants, with a mean of 4.629 and a standard deviation of 1.513. The clockwise condition was the second happiest, with a mean of 4.314 and a standard deviation of 1.469. However, the difference in happiness levels between the clockwise and counter-clockwise conditions was not statistically significant according to the Kruskal-Wallis test ($p = 0.404$). The limited random condition was perceived as sadder than both conditions, with a mean of 4.176 and a standard deviation of 1.200. This condition, however, was not significantly sadder than the clockwise ($p = 0.510$) or counter-clockwise ($p = 0.125$) conditions. These results suggest that progressions with some level of resolution may sound happier to users, although the difference is relatively minor.

Table 1: The average and standard deviation of emotion ratings for each chord progression and music background.

	Novice	Experienced	Novice	Experienced	Novice	Experienced	Novice	Experienced
Progression	Happy		Pleasant		Satisfying		Tiring	
Clockwise	4.09 ± 1.78	4.42 ± 1.29	4.18 ± 1.70	4.67 ± 1.28	4.36 ± 1.92	4.83 ± 1.21	3.90 ± 1.50	2.83 ± 1.28
Counter-Clockwise	4.82 ± 1.53	4.54 ± 1.50	5.18 ± 1.19	4.67 ± 1.57	5.0 ± 1.54	4.75 ± 1.51	2.64 ± 1.07	3.08 ± 1.32
Limited Random	3.8 ± 1.54	4.33 ± 0.99	4.0 ± 1.61	3.46 ± 1.41	4.3 ± 1.74	3.83 ± 1.55	2.7 ± 1.1	3.33 ± 1.49
Fully Random	2.5 ± 1.43	3.25 ± 1.30	3.4 ± 2.00	3.29 ± 0.92	3.7 ± 2.1	3.29 ± 1.54	2.9 ± 1.3	3.71 ± 1.54

Next, we investigated how the inclusion of chords beyond major triads affects perceived happiness. To do this, we compared the limited random to the fully random condition. We found that the limited random condition sounds significantly happier than the fully random condition ($p = 0.002$). This indicates that limiting chord progressions to major triads can make a song sound happier. However, it is important to note that some changes in perceptions may sound sad due to their random nature being less intuitive for listeners to follow. To investigate this confound, we explore this question further in our next study (section 4).

We then analyzed whether a participant's music education background influenced how they perceived the harmonies. There was no significant difference between how happy participants with and without music education perceived a harmony to be across all four types of progressions according to a Kruskal-Wallis test (Clockwise: $p = 0.623$, Counter-Clockwise: $p = 0.496$, Limited Random: $p = 0.224$, Fully Random: $p = 0.164$). While these tests indicate musical background does not affect how the progressions were perceived, an interesting trend exists within the data. For all progressions other than the counter-clockwise condition, participants with musical experience rated the progression as sounding happier than non-musical participants. This indicates, although not significantly, that participants with less music education were more affected by the weakly resolved chord progressions, perceiving their open-ended resolution positively. It is also possible that participants with musical backgrounds tend to focus less on the resolution of the chord progression, which we investigate in our next study.

To better understand whether music's happiness is perceived differently, we analyzed the correlation between happiness and satisfaction, pleasantness, and tiredness for both novice and experienced participants. According to Pearson R tests, we observe that experienced participants' ratings have happiness positively correlated with pleasant ($p = 2.098 * 10^{-5}$) and satisfying ($p = 0.002$), and negatively correlated with tiring ($p = 0.001$). Ratings from the novice participants revealed no significant correlation between happiness and satisfaction ($p = 0.086$), or tiredness ($p = 0.123$). There was, however, a positive correlation between pleasantness and happiness ($p = 0.026$) for these participants. These results appear to emphasize that participants with a musical background are more consistent with their perceptions of music emotionality than novice participants.

4 STUDY 2: EMOTIONS IN PARTICIPANT-DESIGNED HARMONIES

While our initial study identified that altering the resolution of a chord progression may change how happy the harmony is perceived, it also identified several possible confounding variables. Our second study strives to provide participants with more freedom to associate harmonies with emotions, better removing these confounds. Specifically, this study investigates the two findings from study 1 that could be the result of confounding variables.

RQ1: Are chords other than major triads used to make a harmony sound sadder?

RQ2: Do participants with varying music backgrounds use different musical elements to express specific emotions?

We investigated these questions in an interactive session where participants composed chord progressions to sound either happy or sad. Eight college-aged participants were recruited for our study. P2 identified as female, while the other 7 identified as male.

We ensured our recruited participants had varying music backgrounds. P1 and P2 had no music education. P3 and P4 both played musical instruments growing up. P3 played for only a year while P4 played for multiple years. P5 no longer played instruments but remained confident in their ability to read music. P6 and P7 both played instruments at the time of this study and could read music. P7 was highly confident in their musical background, which was consequently entirely self-taught. P8 was an award-winning pianist and a member of local music ensembles. Participants' numbers were assigned such that participants with her numbers had more musical backgrounds. P1 and P4 were new participants, while the rest were re-recruited from study 1.

4.1 Methodology

The participants were given a task to generate two chord progressions, one that sounded "happy" and another that sounded "sad." To accomplish this, they utilized a web application called ChordChord [21], which is displayed in figure 2. We chose this particular application due to its user-friendly interface and the diverse range of options it provides. Users can also decide the length of their chord progressions and design a supporting drum track.

Participants were first given a brief tutorial on how to use ChordChord. After learning the software, participants were instructed to create a chord progression that reflected a particular emotion. They then used ChordChord to create a drum track that complemented the harmony. After creating both the chord progression and drum track, participants were asked which of the two influenced the song's valence more. A member of the research team remained in the room and monitored the participants to ensure they properly followed the procedure.

4.2 Results

In comparing the chord progressions designed to evoke emotions of happiness and sadness, we noticed a stark difference in the usage

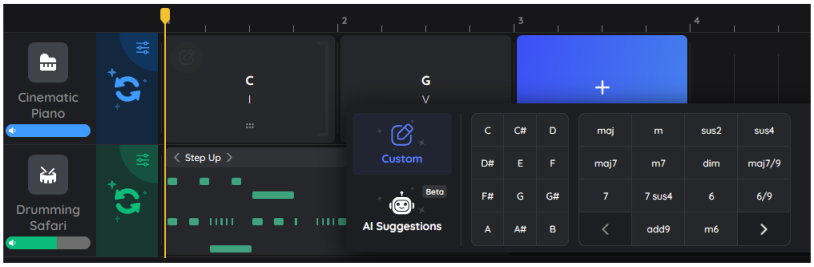

Figure 2: The ChordChord web application. The tool allows users to intuitively create chord progressions and drum tracks with a variety of options while hearing how every change sounds in real-time.

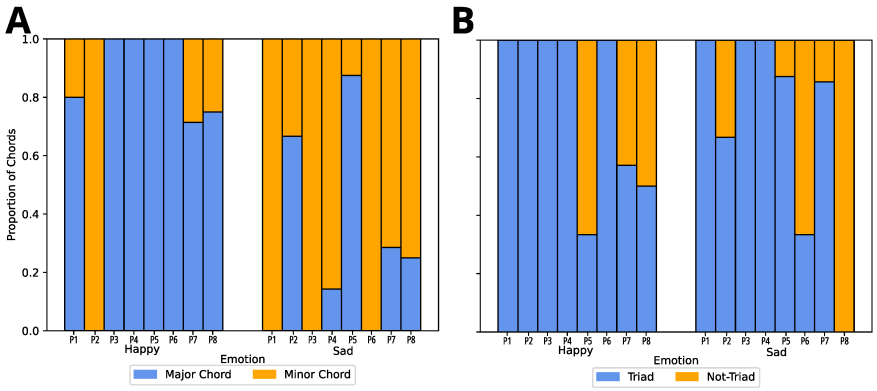

Figure 3: The proportion of chords in each participant's designed progression for happy and sad. Participants with higher numbers have more music experience. A) The proportion of major and minor chords. B) The proportion of chords that are triads, compared to those that are not triads.

of major and minor chords. 72% of chords used in the "happy" harmonies were in a major keywhile 70% of the chords used in "sad" harmonies were in a minor key. This difference is not unexpected, as major keys are generally considered to sound happier than minor keys, but it is still important to note. We then analyzed the use of major and minor chords on a per-participant level, shown in figure 3A. Interestingly, we notice differences in how various participants used major and minor chords. Most notably, the participants with the most and least music experience were the only four to use minor chords in a "happy" progression. P2 in particular, only used minor chords to sound "happy." Participants' "sad" harmonies also used different rates of minor chords. P2 and P5 used more major than minor chords. Our two highly musical participants, P7 and P8, used very similar rates of major chords in this sad "melody," while the other 6 participants were far more variable. This may indicate that participants with varying levels of music background perceive the "happiness" and "sadness" of major and minor chords differently.

We also explored if participants used resolved chord progressions (I-V or I-IV) to express emotions, without being instructed to do so, based on a vague finding in our previous study. We found that only the highly-resolved transition from root to dominant (I-V) was used in three "happy" progressions. This finding supports our earlier conclusion that resolved progressions sound happier. However, our first study suggested that this transition would be used by less musical participants, which contradicts our current findings. We observed that P3, P4, and P6, three participants with some musical background used this transition. The transition from root to subdominant (I-IV) was only used in P7's "happy" progression. This supports our conclusion that resolved chord progressions may sound different based on a participant's musical background, but it does not clarify whether they follow a predictable trend.

Expanding on study 1, we further aimed to better understand how chords other than traditional triads affect the perceived emotional response to a harmony. We analyzed the progressions created by participants to determine whether they used any chords other than a major or minor triad, such as a tetrad. Figure 3B shows the usage rates for triads and other types of chords. Interestingly, non-triads were primarily used by participants with some level of music experience. P2, however, served as an exception, using non-triads with no music experience. Non-triads were used more frequently in "sad" harmonies. This further supports the idea that these chords make a song sound sadder. The increased usage by musical participants is also noteworthy, suggesting that these changes may be more noticeable to individuals with more musical training.

Finally, we wanted to investigate whether a participant's musical background affects their emotional response to musical elements other than a harmony. Specifically, we asked participants to identify which musical voice - harmony or another - they found to

be more emotional. In the context of our study, participants used drums to provide an additional voice, albeit simplified compared to a traditional melody to ensure their focus during design remained on the chord progression. P1, P2, P4, P5 and P7 believed that the emotional message of a song is influenced more by the chords than the designed drum track. P3 thought that the chords and drums had an equal influence on the conveyed emotion. Overall, these responses suggest that participants with less musical experience tend to find the harmony of a song to be more emotional. However, P6 and P8 disagreed. P8 argued that a drum track with high velocity could make almost any chord progression sound happy, while P6 indicated that he would normally find chords to influence emotions more, but in this specific composition, the drums held a greater influence. These responses contradict the views of less musical participants and suggest that participants with more musical experience may be more likely to focus on different elements within the music to understand the conveyed emotion.

5 DISCUSSION & FUTURE WORK

We conducted two studies to identify factors that can influence how happy harmonies are perceived, supporting existing literature. Both studies indicate chord progressions that resolve better sound happier. Additionally, we found that harmony sounds happier when it uses exclusively triads. However, study 2 provides strong evidence that the most significant difference between happy and sad-sounding harmonies is whether the chords are played in a major or minor key. Our studies expand existing findings, demonstrating that despite variations, these trends appear to be generally followed regardless of a participants' musical background. Future systems can use these results to design harmonies that communicate wellness information while evoking specific emotions.

While our studies showed that perceptions of musical emotions generally abide by the aforementioned trends, we observe slight variations between participants with different musical backgrounds. In study 1, we observed that participants may perceive harmonies as equally happy or sad, but novice participants may be less consistent with their interpretations. Study 2 revealed several potential differences in emotional musical preferences. Interestingly, participants with the most and least musical experience used minor chords in their "happy" chord progressions. In contrast, participants with some (but not a lot) of music experience exclusively used major chords in the "happy" progression. This could indicate that participants without music experience are less sensitive to traditional music-emotion rules, and participants with much experience are willing to deviate from these rules. However, participants with some music experience but not much may know the association between major chords and happiness and are unwilling to deviate from it. Study 2 reveals another, more straightforward trend that participants with higher levels of music experience appear to be more likely to use non-triads to express emotions. These findings indicate that while participants' perceptions of emotional harmonies follow the general trends, there may be minor differences in how participants of varying levels of musical background perceive the emotions of harmonies. To better understand these apparent nuances, we need to expand our analysis to highlight how small changes to chords alter the perceived emotions. Our analysis uses features similar to those from previous studies; however, analyzing the differences between different types of chords, such as inversions, might help to better communicate emotions.

Our work is inspired by the recent finding that musical feedback of wellness is challenging for users to interpret [6]. We specifically investigate how to improve the emotional messaging contained within a harmony. We do not investigate new methods to explicitly communicate wellness information but rather how to embed specific emotions in the music. Musical feedback's strength lies within music's unique connection to emotional processing, meaning our findings may enable systems to deliver feedback in more meaningful ways by evoking specific emotions. But, future research must still investigate how wellness data can be more intuitively embedded within music. It is possible that systems could represent wellness feedback directly in the emotionality, building relatively simple models such as playing happy songs when the feedback is positive. However, this approach would require accurate awareness of the user's context and emotional state, meaning controlling the wellness data and emotions separately may result in more accurate models.

Although our studies have produced interesting findings, they are not without limitations and provide direction for future research. Firstly, the two studies differ in how they approach emotionality. The first study measures emotions on a scale of 1 to 7, while the second study only allows participants to choose between "happy" or "sad." To better understand how emotions can be communicated on a continuous scale, the second study could be rerun with participants creating more than two progressions that can be ranked. Our studies could also benefit from larger samples, specifically recruiting more participants who are musically novices. While we ensured these participants were recruited, both of our studies contain fewer musical novices than individuals with music experience. Additionally, our first study relies on participant's self-reports to determine their musical background. Requiring participants to complete a music-based questionnaire in future work may provide better insights into a participant's musical background than a simple binary survey question.

6 CONCLUSION

We investigate how specific emotions can more intuitively be attached to musical feedback of wellness information. We conducted two user studies to explore how emotions can be incorporated into the harmony of a song, considering the differences in participants' musical backgrounds. In the first study, we asked users to listen to a set of chord progressions and rate the emotions they felt. In the second study, participants designed chord progressions themselves to represent specific emotions. We discovered that a chord progression that sounds happier is better resolved, uses triads, and primarily uses chords in a major key. Additionally, we found that participants' musical backgrounds influenced their perceptions of the music. Building on these results, future studies can test new ways to integrate these harmonies into musical feedback.

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