Investigating the Physiological and Psychological Effect of an Interactive Musical Interface for Stress and Anxiety Reduction

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ABSTRACT

Music is a powerful tool for managing negative affect, due to its portability, accessibility, and unique ability to impact mood. In an effort to explore uses of personalized music as an anxiety management intervention, we designed an interface featuring 14 novel musical fragments with adjusted tempo, instrumentation, and rhythm and allowed users to navigate freely. We conducted a pilot study to test the efficacy of this approach for reducing stress and anxiety. Through survey and biometric data, we found that our approach can effectively reduce stress when enabling participants to personalize their musical stimuli. This suggests significant value for conducting larger-scale studies, prompting us to present our findings to support future work toward building personalized musical interventions that alleviate symptoms of stress and anxiety.

CCS CONCEPTS

• **Applied computing → Sound and music computing**; • **Human-centered computing** → *Laboratory experiments.*

KEYWORDS

mental health, stress, anxiety, music, interface, affective computing, physiology

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1 INTRODUCTION

As of 2020, approximately 19% of adults in the United States (about 40 million people) suffer from diagnosed anxiety disorders, making them the most common mental illnesses in the country [15]. However, only about 37% of this population is receiving treatment [2]. Anxiety and stress can threaten the stability of an individual's physiological and psychological regulation and are linked to harmful health events, such as immunosuppression and the development of asthma, hypertension, ulcers, and acne [2, 16, 18]. This is not to say that all stress must be eradicated — limited amounts of acute stress may be adaptively beneficial [44]. However, when stressors become chronic, the likelihood of long-term damage increases dramatically [44, 58]. As such, it is vitally important to reduce excess stress and anxiety [58].

Given the growing mental health crisis, especially in light of the COVID-19 pandemic, there has been a push for improved anxiety management interventions, including prescribed medication, meditation, biofeedback, and automated behavior recognition [21, 42, 54, 59]. In this space, music has emerged as a powerful tool due to its portability, accessibility, and unique ability to impact mood [58]. Clinical observations of music therapy show that music noticeably helps patients with a variety of illnesses and disorders, including but not limited to cardiac conditions, depression, Autism Spectrum Disorder, substance abuse, and Alzheimer's disease [25]. In fact, healing music in Western society is found as far back as Aristotle's *De Anima* [33], though the first formal discussion of "music therapy" dates to an unsigned article in a 1789 issue of *Columbian Magazine* titled "Music Physically Considered" [3]. Despite observed positive clinical outcomes, there is still much to be explored in the realm of music-centered anxiety research with specific regards to effectiveness, efficacy, and practical application [20, 25].

In this work, we are interested in the concept of *relaxing* music, defined here as music that reduces listeners' stress and anxiety. Creating a treatment plan around one-size-fits-all "prescription music" fails to consider the impact that cultural background [24], age [9, 10], social identity [39, 40, 52], personality [24, 40], lifestyle [32], musical training and ability [19], emotional state [19], sex [35], and prior exposure [32, 43] have on music preference. We propose to mitigate this through personalized music listening approaches that give listeners increased agency and flexibility to improve their own health. Our research questions were (RQ1) "Can we shift users' affective state from anxious and aroused to calm and relaxed by allowing participants to adjust musical parameters of a piece, including tempo, rhythm, and instrumentation?" [25, 59] and (RQ2) "If so, which specific musical parameters lead to the largest physiological indicators of relaxation?" As a first step towards fully investigating this, we conducted a pilot study (*N*=8) structured around allowing participants to control and navigate through a custom musical interface. The interface features 14 novel musical fragments with adjusted tempo, instrumentation, and rhythm, in order to assess whether we can effectively reduce physiological and psychological indicators of stress and anxiety. We hypothesized that this intervention would more successfully reduce stress and anxiety than when at rest without musical stimulation. We also expected that the impact of the music would differ depending on the musical and cultural background of the listener, which is a part of ongoing work. At the conclusion of this pilot, we collected feedback from our participants and revised our protocol based on our results and feedback. We present our findings to support future work toward building personalized musical interventions that alleviate symptoms of chronic stress and anxiety.

2 BACKGROUND

Physiological Measurements. Before delving further into the relationship between music and mental health, it is important to first understand the physiological origins of stress and Generalized Anxiety Disorder (GAD), referred to in this paper as "anxiety." According to the National Institute of Mental Health, GAD is defined as "persistent feelings of anxiety or dread, which can interfere with daily life [and are] not the same as occasionally worrying about things or experiencing anxiety due to stressful life events" [1]. Common symptoms include restlessness, fatigue, irritability, difficulty concentrating, headaches, muscle aches, and difficulty controlling worry [1]. Stress causes similar symptoms, though stress generally alleviates with the absence of a stressor [4].

The autonomic nervous system (ANS) provides interesting and thorough opportunities to study the physiology of anxiety and stress. The ANS is responsible for controlling unconscious bodily function, including organ and gland activity [28, 31, 36]. More specifically, the ANS plays a major role in regulating rest, relaxation, and the body's fight or flight and stress responses, which include sweat secretion/electrodermal activity (EDA) and heart rate (HR) [28, 31, 36]. Anxiety often manifests as notable change in ANS functions, including increased HR, shortness of breath, "hypersensitivity to adrenergic stimulation", increased interoceptive sensation, and increased sweating [47, 53]. We elected to measure the activity of the ANS through the collection of EDA, defined as "the variation of the electrical properties of the skin in response to sweat secretion" [5] and HR, defined as the number of heartbeats per minute [46], due to the noted relationship between these biometrics and the body's physical manifestations of stress and anxiety [5, 28, 31].

Music, Mood, and Physiology. Anxiety disorders significantly impact both human physiology and psychology, motivating our focus on both. In laboratory settings, evaluations of neuroendocrine [55], autonomic [55], cardiovascular [8, 29], and cognitive [45] indicators of human stress, showed that baseline values were reached considerably faster in participants who listened to relaxing music, defined in one instance as "Miserere" by Gregorio Allegri (1582 - 1652) [55], than when at rest without musical stimulation. However, it is important to note that the breathing rate of individuals with musical training has been shown to increase with faster tempi [8]. Exposure to music, both prior to and during stressor scenarios, such as VR-stimulated fear of heights or mock interviews, has been shown to significantly reduce self-reported levels of anxiety [45, 55]. In other studies, participants allowed to listen to music post-stressor, instead of sitting in silence or completing breathing exercises, showed the largest overall reduction in blood pressure, HR, and EDA, indicating stress reduction and suggesting the utility of these measures in our own personalization-focused study [37]. Additionally, there is significant evidence supporting the use of music as a non-pharmacological alternative to conventional intravenous anxiolytics in high-stress settings, such as preoperative holding areas (waiting rooms), to reduce self-reported anxiety [21]. Benefits of music-centered mental health work have also been shown in mothers suffering from postnatal depression [38], men suffering from prostate cancer [57], and surgical patients [27].

Personalized Music for Affect. Su *et al.*'s Adaptive Music for Affect Improvement (AMAI) [49] uses game music techniques and music generation to promote positive affect by adapting music based on facial emotion recognition. Similarly to our context, this proposes an adaptive paradigm for music for affect improvement. However, this study automatically adjusted music based on a limited set of initial stimuli that were controlled automatically, whereas we place control in the hands of users to positively impact their own affect. This work also points to the potential value of using physiological measures in this area, which we do in our study.

Grimaud and Eerola's series of experiments [22], conducted concurrently with our work, assess the impact of expressive cues (called "musical elements" in our study) on perceived emotional expression. The researchers employed a system of real-time musical change while avoiding familiarity bias, and emphasized the importance of giving participants the freedom to explore emotive music without constraints. In all, this work supports the idea that musical elements can have a direct impact on listeners' perceptions of emotions and demonstrates the value of using an interactive interface in music-and-emotion-centered contexts. In our work, we target the real-world use case of reducing anxiety and stress, and specifically evaluate the impact of music on human physiology and psychology. Additionally, we focused on elicited emotion (how the music makes the listener feel) rather than perceived emotion (the emotion the composer was trying to express), to further emphasize the goal of anxiety and stress reduction.

Characteristics of Anxiety- and Stress-Reducing Music. The search for the general properties of anxiety-reducing music has been ongoing since at least the 1950s, where "sedative music" was said to require sustained and less percussive "melodic passages", "slow attacks, low dynamic level, simple rhythms," and repetition [17, 56]. This characterization has remained relatively constant: recent work indicates that specific musical factors, like slower tempos (60-100 beats per minute) and simpler rhythms, are often marked as relaxing [7, 11, 13, 14]. Ventilation, blood pressure, and heart rate have been shown to increase with faster tempi and rhythms regardless of genre, while pulse rate and blood pressure reduce while listening to slow-beat music [8, 41]. However, it is important to note that self-reported perception of the relaxation potential of music is suggested to be highly correlated with the listeners' preference and that definitions of an ideal, reduced-anxiety state are personal [51].

The potential person-to-person variety found in classifications of anxiety-reducing music highlights the limitations of the current standards in the field, though the classical definition of relaxing, sedative music provides a useful and important baseline. Current definitions are susceptible to sample bias based on experimenter music selection in protocols where participants are required to listen to static, predefined pieces. Overemphasizing WEIRD participant populations [23], which we observe in such studies, may exacerbate this problem by promoting the selection of traditional music from these communities, such as Western classical music. Our approach provides an intervention that may be useful to a wider population through the introduction of personalization. After all, even though the relationship between *preference* and *relaxation* has been established and discussed widely, there is limited work available interrogating the practical applications of music as an anxiolytic. Although our pilot study reflects a small sample, this is an important motivation for the design of our approach to personalizable musical interventions for stress and anxiety management.

3 METHODS

Participants. In our pilot study, we recruited graduate students, undergraduate students, and university staff via email lists and class bulletins. We screened out potential participants who had (1) been diagnosed with ADHD and were not currently taking medication, (2) were currently taking anxiolytics, (3) were suffering from severe depression, (4) had hearing impairments and did not have an assistive device, or (5) did not enjoy listening to music. Nine participants who met the criteria, aged 18-75, were randomly assigned to either the control or intervention groups. Due to a technical malfunction, one participant's results were excluded, resulting in N=8 participants (four control and four intervention).

Our protocol, which was approved by our institution's IRB, took 30-45 minutes per session. Four of the eight participants identified as male and four as female. Participant ethnicities included South and East Asian, Eastern European, Hispanic/Latino, Caucasian, and African American. Five of the eight participants had received prior music training, and all used music as a tool to relax. All used music other than Western classical music as their preferred genre for relaxation, with selections ranging from Metal Core to jazz to "anything except rap or country." Participants were compensated with a $15 cheque for their participation, regardless of whether their data was included in the final analysis.

Study Design. Participants initially reviewed the consent form with experimenters and were then instructed to sit in front of a monitor with their hands on a desk while experimenters attached one Empatica E4 [1] sensor to each wrist [30]. Our protocol involved deception: participants were initially informed that the purpose of the experiment was to investigate the impact of competition on mathematical performance, to establish the validity of our data by working to ensure the intended effect of the stressor task. Participants were debriefed at the end of the study. Following the stressor task, participants completed a brief pre-study questionnaire, providing basic demographic data as well as information regarding their affective state via (1) a modified GAD-7 [48] survey meant to track recent anxiety (we focused on the prior three days as opposed to two weeks) and (2) two five-point Likert-type items, one each for current stress and anxiety levels, henceforth referred to as the Current Affective State (CAS) survey. Following this, we collected five minutes of physiological data to ensure that we would be able to identify trends that deviated from each participant's baseline [48].

After this, participants underwent a stress-inducing math task (stressor task), where they were given five seconds per question to verbally respond to 60 multiplication problems that appeared on the screen in front of them. Following this, participants completed the CAS survey. Control participants were then instructed to sit in silence and "think relaxing thoughts" to supposedly collect additional baseline data, while experimental participants were told that one of the experimenters was conducting secondary, unrelated tests of the usability of a new musical interface.

At the conclusion of the study, all participants completed the CAS survey again, were debriefed, and provided feedback. Each participant consented to be video recorded for the duration of the study as well, which allowed us to compare their time-stamped biometric data, the annotated recordings, and our noted observations during data analysis.

Musical Interface. We composed unique pieces for our interface, to present all participants with novel music, ranging from electronic to pop-rock to ballads, in an effort to avoid bias. We elected to compose using popular styles, in order to try and replicate some aspects of music present in participants' daily environments while avoiding familiarity bias. The choice to place the musical fragments along a slider bar (Fig. 1) was to limit the motion of the participants' wrists to a mild left-and-right cadence to mitigate motion artifacts. The graphics of the interface were purposefully made to be stark, in order to avoid any confounding influence from added visuals. This interface was designed to be as user friendly and self-explanatory as possible: since we were collecting EDA and HR data, which we knew would be impacted by the addition of novel stimuli, we wanted to minimize our interactions with the participants as much as possible during the intervention portion of the protocol.

Participants were asked to explore our interface (Fig. 1) and find a tick mark, which represented a set of musical parameters in the composition, that best described their initial affective state (Table 1). After identifying this location, they were asked to slowly navigate the interface over the remaining eight to nine minutes, to find a tick mark that best represented what they would listen to in an *ideally calm* state. When one minute was left in the 10-minute duration, a reminder pop-up window appeared at the top

[1] More information about the Empatica E4 wristband, used to measure both HR and EDA, can be found in Empatica's online documentation: https://www.empatica.com/research/e4/

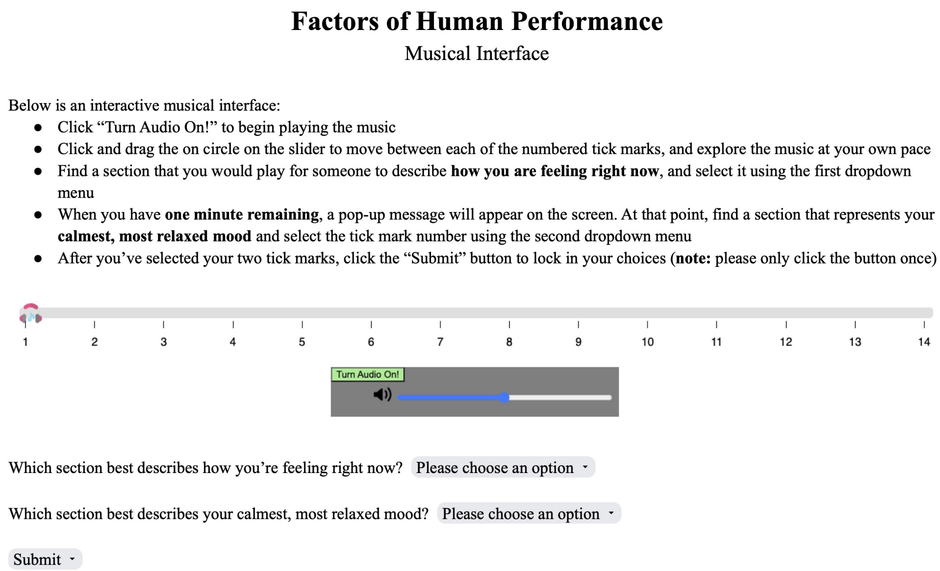

Figure 1: Experimental musical interface. In our study, participants used the pictured interface to explore the 14 segments of music, shown in Table 1, and indicate (1) which segment corresponded to their current mood and (2) which segment corresponded to their ideally relaxed mood.

Table 1: Description of the musical intervention compositions. Numbers on the left correspond to a tick mark on the interface shown in Fig. 1. A summary of the musical elements changed from fragment to fragment is included below, as well as a one word classification of the overarching musical element that was modified, either rhythm, instrumentation, or tempo. We have also provided the style/genre that we believe classifies each piece.

Tick #	Summary	Element	Style/Genre
1	150 BPM. Staccato synthetic strings and bass. Focus on rhythmic development. Deliberately harsh guitar and trumpet. Synthetic drum pad used to create beats with unfamiliar noise. Music builds to a crescendo for suspense.	N/A	Electronic
2	150 BPM. Staccato strings. Less spatially compressed drum track and bass. Same harsh guitar and trumpet, as well as synthetic drum pad.	Rhythm	Electronic
3	150 BPM. More legato strings, guitar, and bass. Synthetic drum pad is still used. Music is rhythmic, but lacks the urgency found in 1 and 2.	Rhythm	Pop-Rock
4	150 BPM. Exclusion of guitar and synthetic strings. Inclusion of legato flute and LoFi piano. Staccato bass and synthetic drum pad are still in use.	Instrumentation	Pop-Rock
5	150 BPM. Addition of acoustic bass to flute and staccato LoFi piano. Acoustic drum pad used instead of synthetic	Instrumentation	Pop
6	150 BPM. Acoustic strings added to #5	Instrumentation	
7	150 BPM. Twang guitar riff added in place of acoustic strings found in #6.	Instrumentation	Pop
8	150 BPM. Drums and guitar removed. Electric piano riff made up of single, held notes added to #7.	Rhythm	Lo-Fi
9	150 BPM. Extended, soothing synth strings single note added to #8.	Instrumentation	Lo-Fi
10	120 BPM. Tempo of #9 reduced by 30 BPM.	Tempo	Lo-Fi
11	100 BPM. Tempo of #10 reduced by 20 BPM.	Tempo	Ballad
12	100 BPM. Second layer of extended, soothing synth strings added. LoFi piano and flute duet composed of sustained notes replace staccato piano/flute combination.	Instrumentation, Rhythm	Ballad
13	100 BPM. Piano and flute duet shifted into a minor key.	Instrumentation	Dark Ambient
14	80 BPM. Tempo of #13 reduced by 20 BPM. Piano and flute duet replaced by single notes of piano and flute in a minor key.	Tempo, Rhythm	Dark Ambient

of the screen that prompted participants to make their selection of the fragment that described this ideally calm state. Each musical fragment lasted 30-45 seconds on a constant loop for as long as the participant remained on the corresponding tick mark — each time the fragment was played in full is defined here as one *cycle*.

It has been shown that allowing individuals to have some sort of control over their situation, known as a "locus of control," leads to decreased stress regardless of the scenario [6, 12, 26, 50]. As such, we allowed participants to control how and when they progressed through the musical composition.

Stressor Task. Our experiment required all participants to feel some level of stress, leading us to develop a broadly applicable stressor task informed by Talevich et al.'s taxonomy of human motivation [34]. We (1) stationed an experimenter next to each participant as they were answering the questions, (2) informed them that they were being compared to their peers and coworkers at their home institution and at a rival school, (3) called the multiplication problems "basic" when introducing them, (4) required participants to think more carefully about their answers by requiring them to say "the answer is…" before responding, and (5) promised and provided an additional $30 reward to the participant with the highest score.

In the pre-study questionnaire, six of the eight participants reported enjoying mathematics, with an even split of preference for written or mental calculations. All participants had studied mathematics at or above Calculus-level difficulty. Since all of our participants had high-level mathematical experience and many of them had either completed or were in the process of completing engineering degrees, it was vitally important to target as many facets of motivation as possible. This, we believe, helped to ensure the success of our stressor task, by avoiding the assumption that all of our participants would find the same aspects of the task to be equally impactful.

4 RESULTS

4.1 Questionnaire Data

GAD-7 Scores. Though participants were randomly assigned to control and intervention groups, all control participants had significantly higher GAD-7 scores (6.8 ± 2.8) than our intervention group (2.5 ± 1), scoring mild-to-moderate and minimal self-reported anxiety respectively (Two-tailed t-test, t=-2.90, p=0.02). Since this provides a baseline of longer term anxiety, we report this result to provide more context on our participant pool.

Self-Reported Stress and Anxiety. Despite pre-study stress being significantly higher in the control group compared to the intervention group (Wilcoxon-Mann-Whitney, U=0, p=0.02), there was no significant difference in reported stress between both groups after the stressor task (Wilcoxon-Mann-Whitney, U=5, p=0.38). Ultimately, at the end of the experiment, participants in the intervention group reported significantly less stress than participants in the control group (Wilcoxon-Mann-Whitney, U=1, p=0.04). Despite these self-reported fluctuations in *stress*, there was not a significant difference between the two groups' self-reported *anxiety*, as seen in Fig. 2.

4.2 Physiological Data

The physiological data (shown in Fig. 3 for two participants) can be grouped into seven main periods, described from first to last as (1) the sensor application and pre-study questionnaire, (2) the five-minute-long **baseline**, (3) the stressor task instructions, (4) the **stressor** task, (5) the completion of the first CAS survey followed by control/intervention instructions, (6) the control/intervention task (**condition**), and (7) the final CAS survey and participant debrief. For the control participant, the largest spike in both EDA and HR occurred either just after or during the math task respectively, highlighted by Circles 2 and 4. Circle 5 highlights a major spike

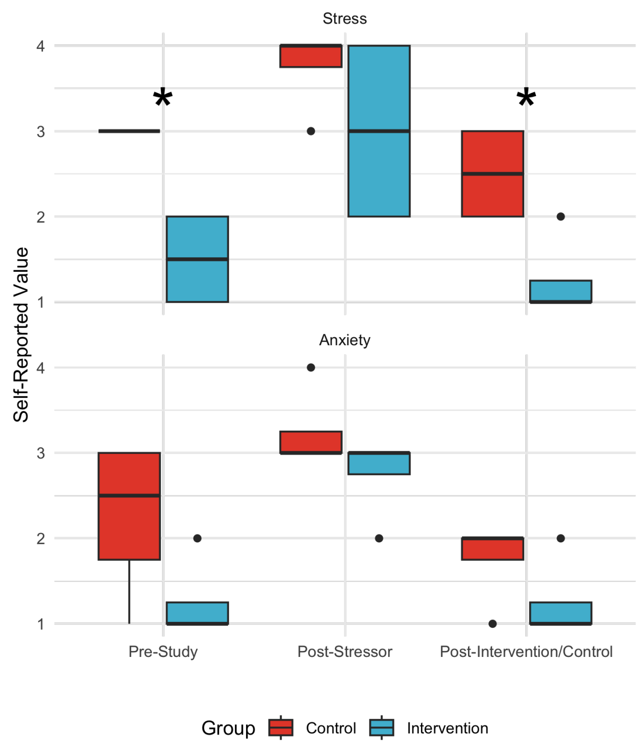

Figure 2: Participants' self-reported stress and anxiety pre-study, after the stressor task, and after the study. (Left) Self-reported stress – in accordance with the adapted GAD-7 results, control participants initially had significantly higher self-reported stress than the intervention group participants (Wilcoxon-Mann-Whitney, U=0, p=0.02). After the stressor task, there was no significant difference between the two groups' self-reported stress (Wilcoxon-Mann-Whitney, U=5, p=0.38). However, after the intervention/control period, the intervention group reported significantly less stress than the control group (Wilcoxon-Mann-Whitney, U=1, p=0.04). (Right) Self-reported anxiety – there was no significant difference between control and intervention group anxiety pre-study (Wilcoxon-Mann-Whitney, U=3, p=0.15), post-stressor (Wilcoxon-Mann-Whitney, U=4.5, p=0.31), or post-study (Wilcoxon-Mann-Whitney, U=4, p=0.24).

in EDA in the intervention participant at a moment when they forgot to state "The answer is…" before providing the answer to the arithmetic question. When the experimenter corrected them, the participant responded with verbal, facial, and body posture indicators of surprise. We show these as examples of the overall physiological data we analyzed for differences.

Through careful analysis of this data and accounting for events such as those we annotated, we observed that the intervention may result in higher arousal levels than the control condition. This was a surprising finding that we will discuss in more detail, but may reflect difficulties in disentangling stress and anxiety from other high arousal affective states, such as excitement and interest.

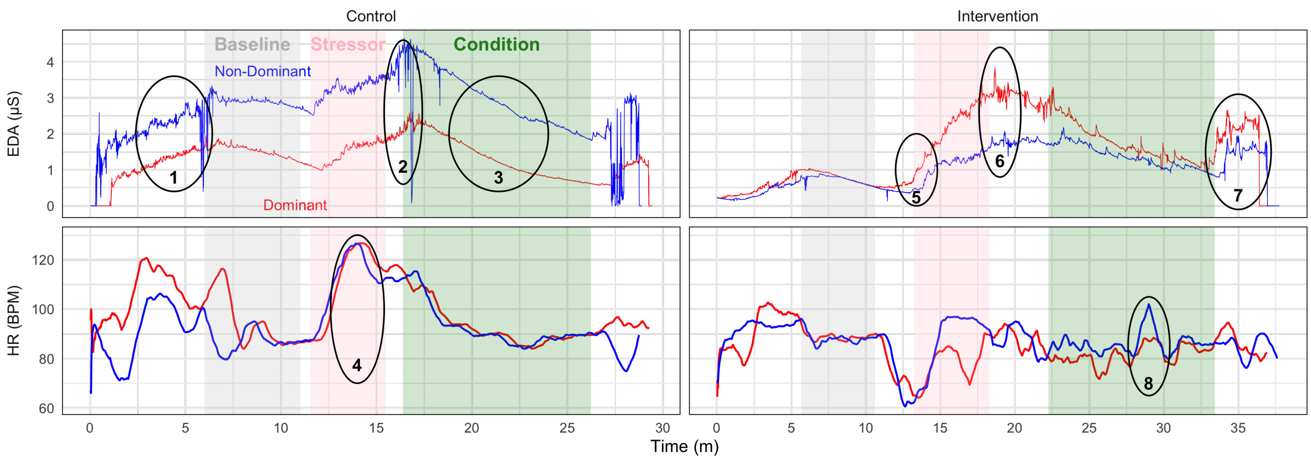

Figure 3: Comparison of electrodermal activity (EDA) in microsiemens and heart rate (HR) in beats per minute from representative intervention and control participants. Red lines indicate dominant hand readings, while blue lines indicate non-dominant hand readings. Black circles indicate significant events observed by the experimenters, which were confirmed via video data. Circles 1-4 annotate control data. 1 indicates a spike in EDA during the pre-study questionnaire. 2 indicates the largest spike in EDA during the protocol. 3 indicates a decrease in EDA consistent with relaxation that occurred when the participant was reportedly "listening to music in [their] head." 4 indicates the highest spike in HR during the protocol. Circles 5-8 annotate intervention data. 5 indicates an initial spike in EDA that occurred when the participant was corrected during the math task. 6 indicates the largest spike in EDA during the protocol. 7 indicates the moment where the participant was debriefed on the true purpose of the experiment. 8 indicates the moment where the participant believed that the interface had broken due to forgetting usage instructions. We provide these annotations to show how we identified events and patterns in the physiological data.

4.3 Interface Data Collection

We used participants' interaction data to compute the average frequency of visits and duration of time spent on each tick mark, shown in Fig. 4. Tick marks 11 and 12 show particularly high levels of engagement, averaging around 1.5 minutes each of total time spent during the intervention. We also recorded the tick mark number corresponding with submitted initial and ideal calm state fragments. *Current* states diverged from one another (P1: 4, P2: 9, P3: 3, and P4: 6), whereas *ideal calm* states were more similar, despite still exhibiting some variation (P1: 12, P2: 12, P3: 9, and P4: 11).

5 DISCUSSION

Musical Elements. Participants' self-reported data supports our overall approach, since the intervention group reported significantly more stress-reduction than the control group and EDA generally decreased during the musical intervention. However, it was difficult to determine the impact of specific musical elements in our pilot study, which suggests a needed refinement to the interface to more readily identify such factors. The control group's EDA was overall lower than the intervention group, as compared to their individual baselines, suggesting lower arousal. Note that this does not necessarily indicate less stress; it is possible that the use of this musical interface results in high arousal, high valence affect, such as excitement and pleasure. The self-report data indicates higher valence, supporting this interpretation.

Study Sample. Our work presents a small-sample pilot study to address this challenging problem. As such, we were unable to obtain significant conclusions in some aspects of our evaluation. This is, however, a first step, supported by self-report data, physiological data, and our observations, that validates the goal of this work: to design user-controlled music interfaces as a viable anxiolytic intervention. In future studies, it is essential to recruit a larger, more diverse sample, composed of a variety of social, cultural, and ethnic backgrounds, to reach grounded conclusions about the impact of personalized user-controlled musical interfaces on anxiety reduction accounting differences in background.

Data Collection. By extracting a greater range of possible anxiety markers from measures such as EEG, fMRI, and video analytics (e.g. detecting posture, fidgeting, etc.), this work could more robustly assess the impact of our approach on participants who exhibit diverse symptoms. We also note the importance of capturing more detailed demographic data, with respect to native languages, cultural backgrounds, and musical exposures. For instance, our pilot emphasized English-speaking participants in a way we did not anticipate. All participants who were not native English speakers mentioned that the stressor task was especially difficult since they learned arithmetic and performed calculations in their native languages. The added effort of conducting translations may have led to unaccounted-for differences in induced stress. Finally, we observed that some participants exhibited higher arousal during the pre-study questionnaire than during the stressor task. As

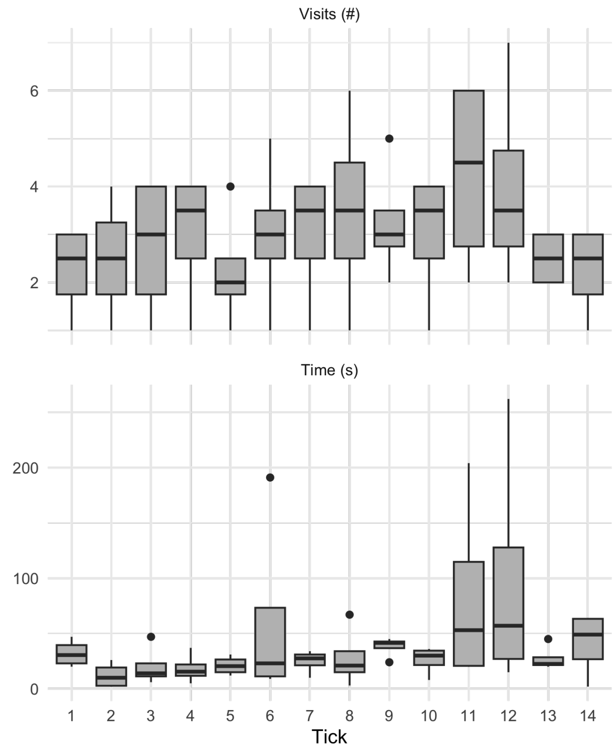

Figure 4: Participant interface interactions. (Left) Number of times intervention group participants visited or re-visited each of the musical fragments during the intervention. (Right) Time participants spent on each musical fragment. On average, participants spent the majority of time on tick marks 11 and 12, which were characterized by slightly slower tempos, more soothing instrumentation, and slower rhythms (Table 1).

such, we must collect baseline data before conducting the pre-study questionnaires, to keep the impact of introducing novel stimuli on physiology from influencing this measure.

Cognitive Load. Control participants sat in silence for the same time that intervention participants interacted with the interface. The collected EDA shows that intervention participants had higher arousal than control participants. However, the self-reported survey data shows that, after the study, intervention participants were actually *less* stressed than control participants. HR data supports this – the HR of intervention participants either remained the same or decreased during the intervention, despite the spike in EDA. This suggests that participants were *stimulated by* or *interested in* the interface, but not necessarily stressed. As such, creating a control condition that matches the cognitive load of the intervention condition is important when trying to control for the arousal spikes derived from interacting with novel stimuli, to be able to make clearer conclusions about the impact of the musical interface.

Exploration Time. Relatedly, it would be useful to allow participants to explore the interface for one to three minutes. We noticed several spikes in EDA in our participants that did not correspond to elevated heart rate, which suggests arousal caused by exposure to novel stimuli rather than stress. We expect that giving participants time to explore the interface beforehand would control for these anomalies, to ultimately allow us to clearly observe the impact of the music on the participants' biometric data.

Music Length and Composition. Currently, each musical fragment is approximately 30-45 seconds long and plays in a loop until the participant switches to another tick mark. Though some participants elected to linger on fragments for upwards of five cycles of the piece, others would remain for one to two cycles and move onto a different tick mark. In the future, it is important to compose longer pieces of music to allow participants to spend more time with the piece without the possibility of repetition fatigue causing participants to navigate away. We also believe that it is important to dig deeper into investigations of the impact of musical elements, by using more varied tempi and rhythms, for example. Relatedly, in this study, we elected to compose using features from popular genres in order to try and replicate some aspects of music present in participants' daily environments while avoiding familiarity bias. In future studies, we would like to branch out and explore additional genres, to get a better understanding of the impact of musical preference on user interactions with this interface. There is also notable potential in emerging work for the use of a generative approach for personalized music for affect change, which could be further supported by considerations and analyses of physiological data such as what we have discussed here [49].

6 CONCLUSION

We reported on a study centered around a personalized musical intervention for anxiety and stress reduction. The intervention was deployed through an interface containing 14 novel musical excerpts which we composed to vary along musical dimensions of rhythm, instrumentation, and tempo to positively impact affect. We used a combination of self-report and physiological data to assess the effect of this interface, with initial results suggesting benefits of our approach for reducing anxiety and stress. This study serves as proof of concept that musical interventions can reduce stress effectively when delivered through an interface which allows participants to personalize their musical stimuli. Our results suggest significant value for conducting a larger-scale study that may reveal the impact of changing key musical elements for making personalized music-therapeutic interventions accessible to a broad population of users in ways that they can control.

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