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Spark Care+: Personalized Music Therapy for Relaxation and Energizing Using a Mobile and AI Approach

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ABSTRACT

Worldwide 1 in 8 people live with a mental illness (WHO, 2022). Music releases neurotransmitters, including dopamine, but without the side effects of medications (Schriewer, Bulaj, 2016). This study aims to test the effectiveness of personalized music therapy to relax or energize participants using a machine learning model (ML) connected to a mobile app created by the researcher, using information from the Galvanic Skin Response and Heart Rate sensors. In order to provide a more personalized therapy experience, an option to change pieces was given if biometrics did not align with session goals after 15 seconds. Sixty sessions of 15 minutes each took place, 25 at home and 35 in school settings. Participants had higher variance in the energizing session compared to the relaxation. However, significantly more participants across both sessions had a decrease in biometrics rather than an increase or no change, indicating that both music sessions helped the participants relieve stress. The number of interventions for all pieces statistically decreased while the average ratings from 1-5 statistically increased from the first to the last piece indicating the effectiveness of the machine learning model for both sessions selecting the pieces that fit the participant's preferences while helping to lower stress and obtain the session's optimal physiological and emotional responses. The data suggests that the personalized music selection for both relaxation and energizing by the Spark Care+ app can lead to participants feeling more relaxed or energized depending on their musical choices.

Introduction

Emotional well-being is crucial not only for one's emotional health but also for physical and overall health, despite being intangible and invisible. According to the World Health Organization (WHO), by the end of 2021, many individuals are still facing difficulties in accessing mental health resources, following a 25% increase in anxiety and depression disorders during the pandemic. Geographical location and cost are among the primary barriers to receiving treatment for emotional well-being. Countries with limited resources struggle to provide adequate mental health care (WHO, 2022). People with depression, anxiety, or other mental health illnesses all have unique needs- to relax or become more energized.

Spark Care+ is a mobile-based app connected to a wristband model that utilizes the healing power of music to assist with relaxation and energization created by the researcher. Through user feedback, and biofeedback from sensors, this app uses a machine learning model created by the researcher to offer accessible mental health support. Music has the ability to activate positive emotions by triggering the release of dopamine, a feel-good hormone ("The Impact of Music on Neurochemistry", 2013) and modulating emotions through various neurotransmitters and brain structures, including the reward and dopaminergic systems (Schriewer & Grzegorz, 2016). Personalized music therapy facilitated by Artificial Intelligence through Spark Care+ can aid in self-relaxation, monitored by Galvanic Skin Response (GSR) and Photoplethysmography sensors.

Relaxation and Energizing sessions will be offered to the participants within the Spark Care+ app. Energizing music, defined as exciting music, has been found to reduce heart rate variability compared to relaxing music (Koelsch

& Jancke, 2015). In addition, the brain's aesthetic judgment of music, whether positive or negative, influences emotions (Juslin, 2013). The physiological response to the music will be measured by the Heart Rate (HR) sensor through the photoplethysmography mechanism and the Galvanic Skin Response (GSR) sensor. The Galvanic Skin Response and Photoplethysmography are two of the main sensors that correlate with the chills while listening to music, showing a connection between listening to music and one's emotions (Salimpoor, 2009). The HR sensor measures cardiovascular measurements, which, when measured with the mean, serves as an accurate screening system for patients diagnosed with Major Depressive Disorder (Dagdanpurev & Sumiyakhand, 2018). The other sensor used is the Galvanic Skin Response (GSR) sensor, which measures skin conductance level by employing two low, constant voltage electrodes. The GSR sensor is considered the most sensitive physiological indicator of physiological events available to psychologists (Montagu & Coles, 1966). As eccrine glands, also known as sweat glands, begin to activate, moisture comes towards the skin surface and there are changes to the skin conductance which can be measured through the GSR sensor. ("Galvanic Skin Response (GSR): The Complete Pocket Guide", 2020).

Methods

Research Question

Can mobile-based personalized music therapy, utilizing Artificial Intelligence models and offering both energizing or relaxation sessions of music, improve the emotional well-being of participants across different gender, age groups, and settings?

Hypothesis

The implementation of personalized music therapy on mobile devices will result in a significant decrease in biometric measurements during relaxation sessions, while an increase in biometric measurements will be observed during energizing sessions, across various age and gender groups. Additionally, participants in the home setting will demonstrate greater responsiveness to relaxation sessions than those at the school setting; participants in both settings will have an increase in ratings as the session progresses.

Procedure

A. Preparation

1. I have classified a total of 45 musical pieces based on two factors: Genre (Classical, Slow Pop, Rock) and Tempo (Slow, Medium, Fast). Each Genre/Tempo combination consists of 5 music pieces, resulting in a total of 15 unique combinations. To ensure consistency, all music pieces have been shortened to a duration of 2 minutes and 30 seconds, allowing each participant to listen to exactly 4 music pieces during the Spark Care+ session. It's important to note that the Classical music pieces are instrumental, while all other music selections contain lyrics. For a comprehensive list of the music selections, including those with lyrics, please refer to Appendix A.

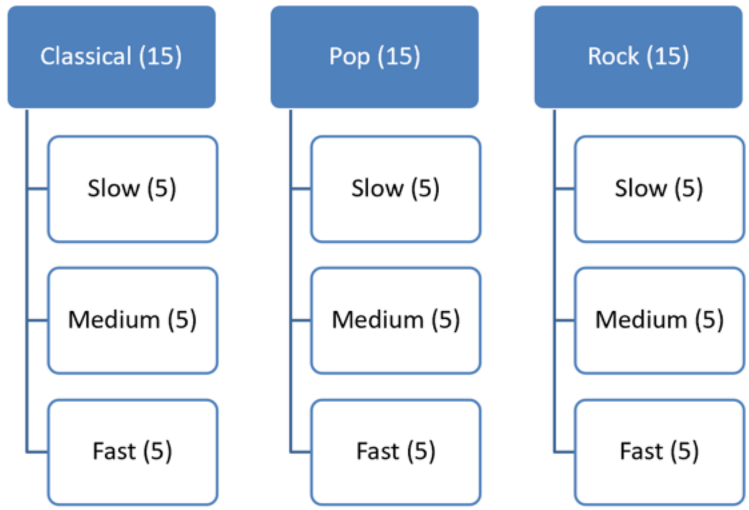


Figure 1. Music Genre/Tempo Coding indicating the genres and tempos along with the number of music pieces under each category used as factors for the machine learning model.

2. I have connected the sensors, including Galvanic Skin Response and Heart Rate, to the Arduino microcontroller. The Arduino microcontroller is then attached to the wristband base, ensuring proper integration. To establish a connection with the Android device, the USB cable is connected to both the Arduino microcontroller and the USB to USB-C adapter, which allows compatibility with the Android device.

3. The Python ML model programmed by the researcher will generate outputs using Flask, allowing seamless communication of data with the Flutter application through HTTP. Utilizing Python, the user's physiological sensor in addition to their preferences and ratings of each piece will be used as inputs. This model recommends the genre and tempo for the next piece of music based on individual participant inputs. Subsequently, a randomly selected music piece that aligns with the recommended genre and tempo is chosen. To streamline the functionality, the Relaxation and Energizing functions have been nested under a single overarching function. This function is designed to interpret the input retrieved from the Firebase database and determine the appropriate course of action. The implementation of this system requires various libraries, including but not limited to numpy, statsmodel.api, statistics, sklearn, and flask.

4. I have developed a mobile application for Spark Care+ and utilized ADB (Android Debug Bridge) for debugging purposes. The mobile app is connected in the backend to the machine learning model as well as a secure cloud database. The application has been successfully downloaded onto an Android tablet. It comprises multiple screens, including a login/registration screen, a screen to establish a connection with the wristband device via a USB cord connected to the Android device, and a screen where music is played using data retrieved from the Python program via HTTP. To ensure efficient data management, each new participant is automatically assigned a new database within the cloud-based Firebase database. This database serves as a repository for storing all relevant participant data. It is important to note that user emails and passwords remain confidential and are not linked to any of the data present in the databases. Survey questions are included in Appendix B.

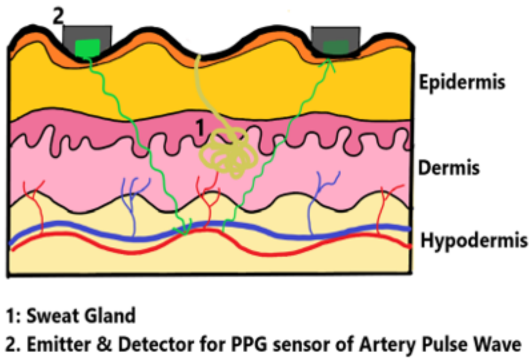


Figure 2. Sensor Diagram

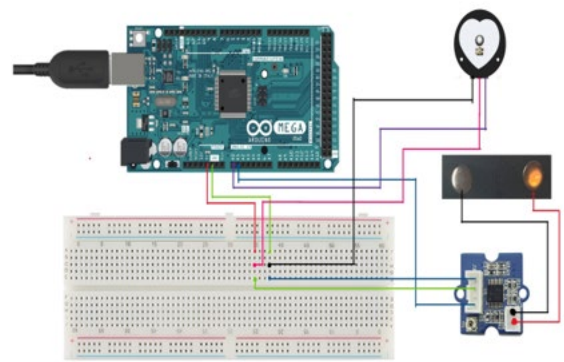


Figure 3. Arduino Circuit

Figure 4. Mobile App Connected with Wristband Model

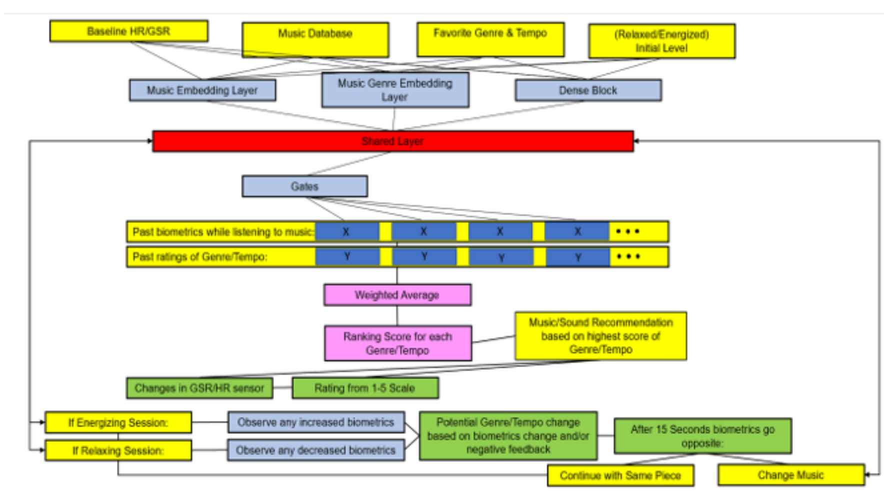


Figure 5. Machine Learning Model Framework

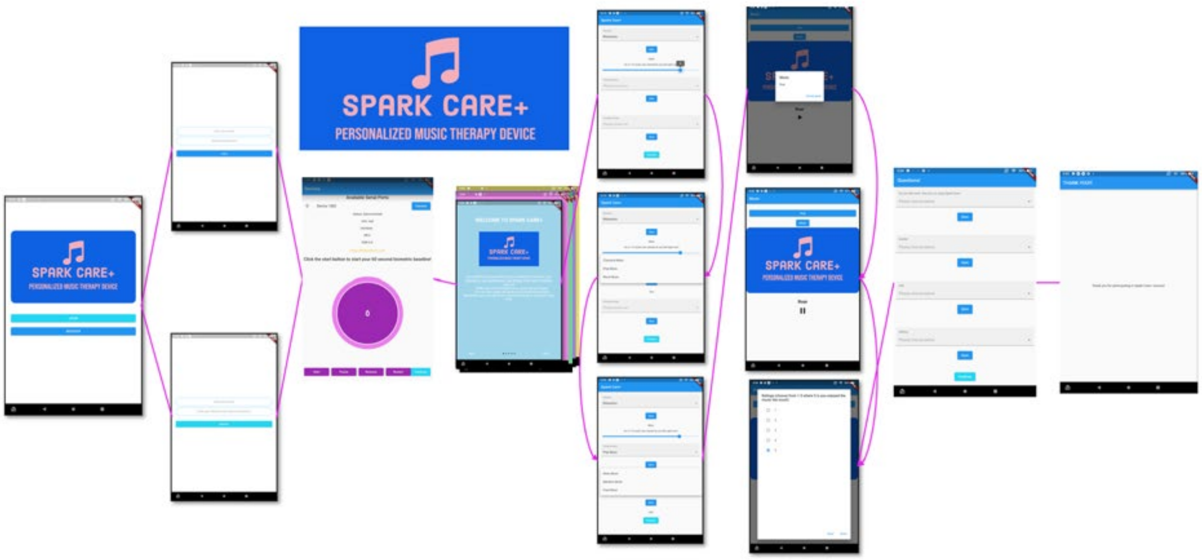


Figure 6. Flowchart of Spark Care+ Mobile App

B. Data Collection

I conducted data collection for Spark Care+ through various channels, including sharing flyers with a QR code with study information and Informed Consent form. and via email. To ensure a diverse sample, I utilized a snowball sampling technique. In total, 55 participants responded and engaged in 60 sessions, which took place both at home (N=25) and in school settings (N=35). Prior to data collection, all participants signed an Informed Consent form, and during the process, I ensured the presence of an adult, either a school teacher or parent. The following steps outline the procedure I followed for data collection:

1. Participants were told that they could adjust the volume to their preferred level and they could stop at any period by exiting the app.
2. Participants logged in if they already had an account or registered to create a new account. They entered their email addresses and entered/created passwords. The email addresses were stored in the database, which was not connected with any of the following data collection, and the passwords were not accessible by anyone, including the researcher.
3. The participants inputted their preferred session type (Relaxation, Energizing), their (Relaxation/Energizing) current level from a 1-10 scale where 10 indicated feeling the most Relaxed/Energized, favorite genre of music (Classical, Pop, Rock), and favorite tempo of music (Slow, Medium, Fast) on the mobile app screen, which was stored as data anonymously.
4. Prior to putting on the wristband, participants were strongly advised to wash or use their own hand sanitizer on their hands and wrists before and after their participation. The participants put on the wristband and adjusted it to fit. Then, on the tablet screen, they clicked the Connect button for the Android device to connect with the wristband via a USB cord. Participants clicked Next for the proceeding steps.
5. Using the wristband, the device measured their baseline GSR and HR measurements for 60 seconds with data recorded every 1-2 seconds, as the timer and instructions were shown on the app screen to find the baseline measurement for the participants.
6. Participants were guided through a set of screens to show them how Spark Care+ worked and showed instructions for the Spark Care+ session.

7. Once the participants arrived on the music screen, they clicked the Start button to start measuring biometrics again, then pressed the Music button for the first piece selection. A pop-up let them know the piece of music selected, then when participants pressed the play button, they listened to the piece of music.
8. If, after 15 seconds, their biometrics went the opposite direction than that predicted for their session type (either Relaxation or Energizing), a pop-up dialog appeared to give them a choice to continue listening to the same piece or switch to another piece of music.
9. After playing the music, participants rated the piece of music on a 1-5 scale where 5 indicated feeling the most (Relaxed/Energized). Once they clicked Save! and Done! buttons, the rating was saved on the cloud database and connected with HTTP, which gave the Machine Learning output Python gave using all the data collected from the cloud database. The user preferences, rating scores, and GSR/HR measurement averages all became independent variables in the Python Machine Learning program. The next piece appeared and started playing.
10. It repeated steps 11-13 until the 15-minute timer was up for the participants. Participants had listened to 6 pieces by the end of the session.
11. Participants were prompted to rate how they felt on a 1-10 scale on the mobile app where 5 indicated no change, 1 was less relaxed/energized compared to prior to the session, and 10 indicated feeling much more relaxed/energized. They were also asked if they were above 18 or under 18, if they were participating from school or home, gender, and if they felt more (Relaxed/Energized) than they did prior to the session as written in Appendix B with the survey questions at the end of the session.
12. The final screen was a Thank You screen for the end of the Spark Care+ session.

Note: Participants were told that they were able to leave at any point of the data collection if they wished to. Their email and identity were stored solely for authentication and were not correlated with any participant database. Each database was named with a number, so all data remained confidential.

60 Total Participants							
Home 25				School 35			
Relaxation 14		Energizing 11		Relaxation 21		Energizing 14	
Males 4	Females 10	Males 5	Females 6	Males 8	Females 13	Males 6	Females 8

Figure 7. Participant Breakdown

Results

A total of 60 participants participated in a 15-minute session, with 25 in a home setting and 35 in a school setting, as shown in Figure 7. When both settings were combined, there were 35 participants who chose relaxation (21 of them at the school setting) and 25 participants who chose energizing (14 of them at the school setting). Out of the total participants, 23 were male (14 of them in the school setting) and 37 were female (21 of them in the school setting). Each participant listened to four complete music pieces during the 15-minute session.

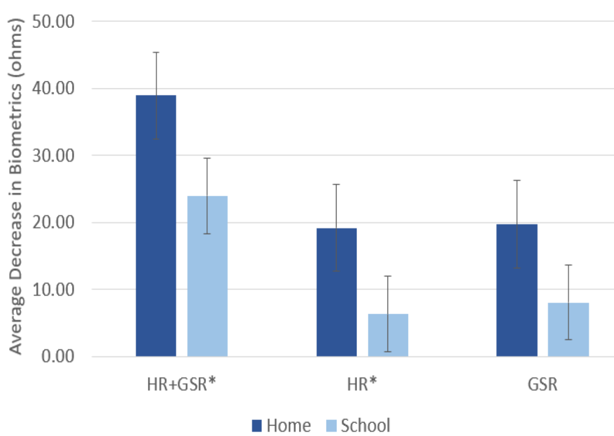
As shown in Graph 1, participants in the home setting experienced a larger average decrease in all three biometric measurements (HR, GSR, and HR+GSR combined) compared to participants in the school setting. The difference was statistically significant for HR and HR+GSR ($p<0.05$). Regardless of the session type, both the home and school settings showed an average decrease in all biometric measurements, indicating that the selected music was effective in reducing stress. However, the decrease was larger for participants in the home setting. For both relaxing and energizing sessions, there were statistically significantly more participants who experienced a decrease in biometrics (HR+GSR and HR) compared to those who showed no change or an increase in biometrics (Chi-square, 3 d.f. N=60, $p<0.05$). Furthermore, Graph 2 illustrates that the average variance over four pieces in biometric measurements was higher for the energizing session compared to the relaxation sessions. When considering age, participants aged 18 or above demonstrated statistically higher variance in HR+GSR and GSR biometrics compared to participants younger than 18, as indicated by the non-overlapping error bars in Graph 3 ($p<0.05$). Similarly, as shown in Graph 4, males exhibited a statistically higher average variance in HR+GSR and GSR biometrics compared to females ($p<0.05$).

Graph 5 illustrates that the average number of interventions for each music piece significantly decreased from Piece 1 to Piece 4. This suggests that as the Machine Learning model accumulated biometric and rating data, it was able to select music pieces that better matched the participant's preferred style. The decrease in interventions was statistically significant (Chi-square, 3 d.f. N=104 interventions, $p<0.05$). When interventions did occur, the majority of participants chose to not change the music piece, as indicated by Graph 6. Participants were asked to rate each music piece on a scale of 1-5, with 5 indicating the highest level of enjoyment. The ratings showed a statistically significant increase from the first to the last piece, demonstrating an improvement in participants' perception of the music's quality. Additionally, participants were prompted to indicate their level of relaxation or energization on a scale of 1-10 after each session, depending on their chosen session type. Before the session, the average overall rating for relaxation/energization level was 4.87. However, after the session, the average rating increased to 8.97, indicating a positive change of 4.1 on the 1-10 scale. This increase suggests that the music had a beneficial impact on participants' relaxation or energization levels.

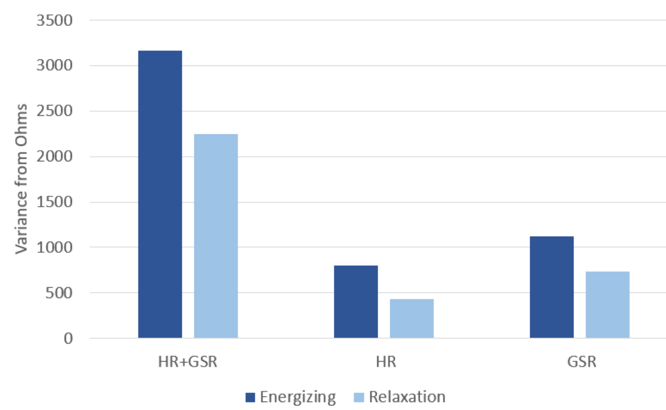
Graphs

*Indicates significant results ($p<0.05$).

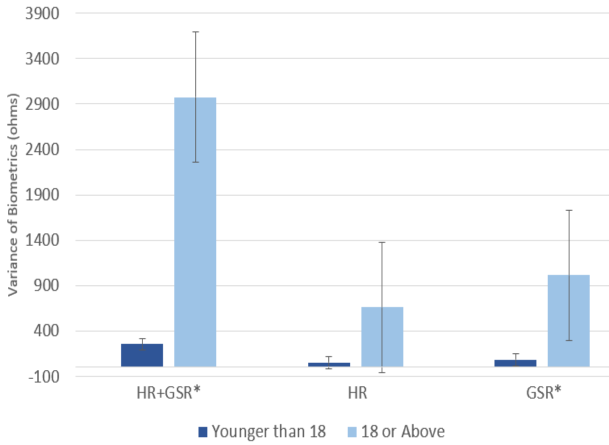
Graph 1. Average Biometrics Decrease based on Setting Home vs. School*



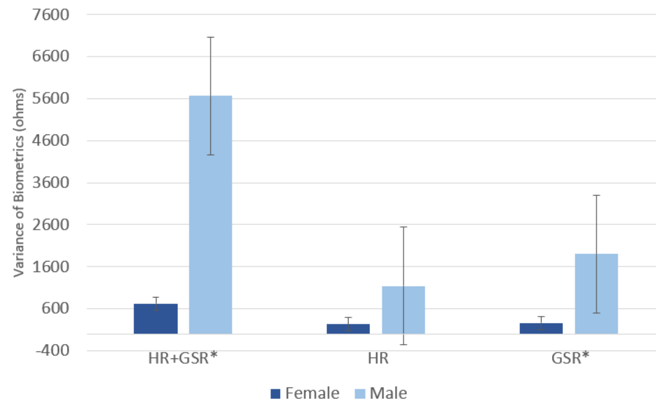
Graph 2. Average Variance over Four Music Pieces based on Type of Session



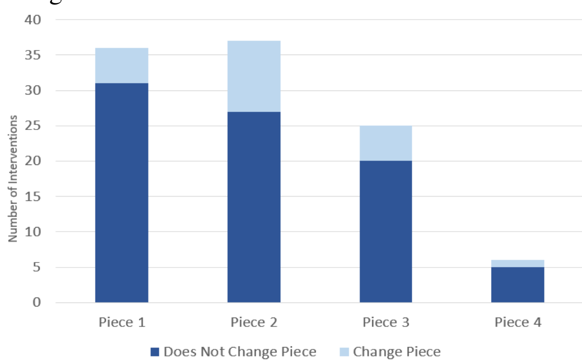
Graph 3. Average Variance over Four Music Pieces by Age*



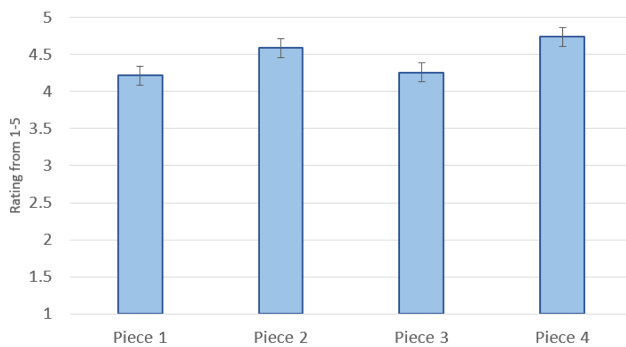
Graph 4. Average Variance over Four Music Pieces by Gender*



Graph 5. Average Interventions with an Option to Change Pieces*



Graph 6. Average Ratings from 1-5*



Conclusion

Spark Care+ is a personalized music therapy device designed to help individuals experience relaxation or increased energy levels through carefully selected music pieces generated by a unique machine learning model. The study aimed to test the hypothesis and evaluate the device's effectiveness by analyzing participants' biometric responses, ratings, and preferences.

The results partially supported the hypothesis, as biometric indicators decreased during the relaxation sessions. However, the biometrics also decreased on average during the energizing sessions, suggesting that music itself can help reduce physiological stress responses, as indicated by the declining biometrics. The difference in energizing and relaxing sessions were demonstrated through the variability in biometric responses between the two types of sessions, with the energizing sessions showing greater variability in heart rate (HR) and galvanic skin response (GSR). Additionally, the biometrics measured from the baseline biometrics significantly differed on average from the biometrics when participants were listening to the music.

The study found that the setting in which the sessions took place had a significant impact on the results. Participants in a home setting experienced a greater decrease in biometric measurements, specifically HR and HR+GSR, compared to those in a school setting. Gender and age also played a role, with males displaying higher variance than females, and participants aged 18 or older showing greater variability compared to those under 18. The average ratings for the music pieces increased from piece 1 to piece 4, highlighting the effectiveness of personalized song selection in reducing stress levels. Furthermore, participants' overall ratings of relaxation or energy levels increased for all participants, indicating the effectiveness of the music selected by the machine learning model for each respective session.

Limitation

Although the sensors undergo changes during the 15-minute session, a longer session time may be necessary, particularly for the GSR sensor, to observe significant variations in biometrics. Extending the session duration will also allow participants to listen to more than four pieces per session, enabling us to determine if the same patterns in biometrics and ratings persist and improve as the ML model gathers more biometrics and user feedback data from a larger set of music pieces. Furthermore, the inclusion of 45 pieces (5 for each genre/tempo combination) proved sufficient for this study, given that each participant only listened to four pieces per session. However, as the music database expands, we will have a greater variety of pieces to choose from, enhancing the diversity and richness of the study's music selection.

Extension and Future Study

The mobile app format of Spark Care+ enables wider accessibility and reach for users. The study's findings regarding the influence of setting, age group, and gender on participants can be incorporated to enhance the machine learning model's accuracy by considering these factors prior to the music session. Future studies could collect additional user information to further improve the model's precision, and interventions can be implemented when biometrics increase for both relaxation and energizing sessions.

Moreover, Spark Care+ has the potential to integrate with various physiological sensors and wristbands, expanding its accessibility and functionality. It can be utilized to support patients during hospitalization, allowing them to listen to music for relaxation or energy enhancement.

Furthermore, in addition to non-mental health applications, Spark Care+ can serve as an adjunct therapy for clinical anxiety and depression. When used in conjunction with the guidance of a psychologist, the device can incorporate the DSM-5 criteria to select appropriate music pieces to complement the therapeutic process.

Overall, Spark Care+ demonstrates great potential for a wide range of applications, both in non-clinical and clinical settings, offering personalized music therapy to enhance well-being and support individuals in managing their mental health.

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