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Relax App: Designing Mobile Brain-Computer Interface App to Reduce Stress among Students

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***Abstract*—Students especially at universities undergo a lot of pressure and stress, and mental health is something that must not be taken lightly, especially at the time of pandemic as we are experiencing now. The need for us to look into the mental health is constantly reminded everywhere. There are a lot of ways to reduce stress such as meditation, getting involved in sports and one of the most practiced methods is by listening to music. Music has been indeed proved to have positive effects on humans and that it aids healing process such as binaural beats and Solfeggio frequency. These frequencies of music have impact towards the brainwave. This study reports on how the design thinking process was used to better identify the most suitable means on integrating mobile Brain-Computer Interface (BCI) as an application to know the impacts of different type of frequencies of music on the human brain to reduce stress. Besides suggesting a generic guideline to develop an application for mobile BCI, this study also provides us insights into the readiness of mobile BCI as an application for common usage.**

***Keywords*—Mobile application, Brain Computer Interface, Design Thinking**

I. INTRODUCTION

The stress level among students is in alarming state. A recent study by [1] has shown an increased stress and anxiety due to the COVID-19 outbreak. Even before the time of pandemic, in dealing with stress, listening to music has always been seen as a great way to reduce stress as it is proven by neuroscience that it calms nervous system up to 65% [2]. Brain Computer Interface (BCI) is widely known as a technology that is able to detect the electroencephalogram (EEG) signal of one's brain. With the advent of mobile BCI, there is yet an application that could measure the stress level of a person. The closest applications that are available in the market right now which come with Neurosky Mindwave Mobile 2 are those that measure the focus level and meditation level of a person, brainwave visualizer, study trainer, etc. [3]. There is a need to understand how much stress impacts an individual's person and how they think which could aid the designers to come up with a proper guideline to build an application. At the same time, there is no one specific music that could satisfy and help all users to reduce stress, which is why there will be a few suggestions available in the application, which are Solfeggio frequencies [4, 5] and binaural beats [6]. Detecting stress using methods like Stress Test is also time consuming and requires individual's stress level. Currently, the studies regarding Solfeggio frequencies and binaural beats and their capability to reduce stress among students are limited, let alone the compatibility of Solfeggio frequency music alongside of BCI. But at the moment, there is not many applications on mobile smartphone are able to track stress using BCI. Therefore, it is imperative to use a proper approach in designing this kind of application. For this to be done, the involvement of students in the design process is vital.

In this paper, we report on how we applied the design thinking process to create a user-centred mobile BCI application to reduce stress by incorporating music, known as Relax app. This study contributes to the use of wearable BCI for the masses, i.e. paving ways for BCI to become accessible for everyone. The proposed design model would also benefit the BCI community (designers and developers) with the same interests. The following section describes the method applied with respect to each phase in the design thinking process. Section 3 reports the results of usability testing. Finally, Section 4 describes the discussion and Section 5 is the conclusion and future work.

II. METHOD

Design Thinking is deemed to be the most suitable method that could be used for this study as the design is human-centered approach [7]. The design approach allows designers to work closely with users and also focuses on designing an application with iterative design process. The four main phase is empathy, define, ideate, prototype.

A.Empathy

As a preliminary step to understand the potential users, we conducted a survey with suitable and eligible participants. The survey was conducted using an online platform via Google form as at the time we were advised to take precautions due to the outbreak. Topics covered in this questionnaire are relating to background users, how frequent stress occurs and stress-management among students. The survey was conducted targeting students at the School of Computing, at our university and carried out anonymously. The inclusion criteria were individuals who: 1) are students in their 20s, 2) are able to understand and answer in English, 3) are without any disabilities, 4) owns a smartphone or computer with Internet to be able to questions online. The following are a few example questions that were asked in the survey:

1. What are the causes of your stress? (Options provided are: expectation to ace, peer pressure, and etc.)
2. What is your stress-relieving method? (Options provided are: sleeping, listening to music, watching Netflix or state an option.)
3. What are your stress symptoms? (Options provided are headaches, insomnia, easily agitated)

There were 11 respondents to this survey (3 male and 8 female) and aged between 21 to 22. 36.4% of them underwent stress because of the expectation to ace their grades in the current semester. The symptom of stress that has been voted most by the students was moody. Most of the students have heard about BCI as it was introduced in their Human-Computer Interaction (HCI) classes. When questioned further, none of the students have used a BCI headgear before. The data are categorized into frequency of feeling stress, period of time that students felt stress, stress symptoms, stress management method, etc. The users are then categorized into gender, age groups and expertise by using Google Forms data analyzer.

To further emphasized with the users, personas were created by using empathy map. There were two personas identified based on the survey; Chloe and Kate. Both personas often find themselves stressed because of the expectation to ace this semester and dealing with the deadlines of their assignments. Persona 1, Chloe, is an auditory learner and always find for music to listen to relax. Unfortunately, at times the search exhausts her and she is not able to find the suitable music to listen. Persona II, Kate, attends Yoga class weekly which is very expensive and she is not able to afford it. Kate and Chloe are looking for a right outlet that is able to reduce their stresses in an inexpensive way which could make them more productive. Refer to Table 1. User scenarios are also used in this phase. User scenarios details out the flow of tasks that might be performed by user and it is vital to know the order of tasks. The user's goals are put into context and the steps are walked through to perform scenario analysis. The combination of the answers is used to inform the design and indirectly to construct the guidelines to design the application.

TABLE I. USER PERSONA I AND II

User Persona 1	
[SAY] " I am so stressed up" "I want to listen to some free stress-relieving music, but I cannot find for anything that is suitable"	**[DO]** Assignments, Group project, Revision for tests, Lists things to do
[THINK] "So many things to do, so little time" "Will I be able to survive this semester?" "What else should I do to save this semester?"	**[FEEL]** Stressed, Tired, Headaches
User Persona 2	
[SAY] "I have got so much things to do." "I don't have time to sleep at night and I am so tired in the morning"	**[DO]** Yoga, procrastinates work, Final Year Project work, Joins University programs as organizing committee
[THINK] "Should I go out or finish this up?" "Will I be able to get proper sleep?" "Will I be able to graduate on time?"	**[FEEL]** Stressed, Tired, Agitated

B. Define

In further defining the suitable design for mobile BCI application for this context, this study looks into the mapping between BCI, music and stress, so it would provide a clear sequence of information that is connected logically. The mapping paths way to a design guideline for the development of the prototype. Music is used as one of the many ways to reduce stress based on the survey and it is proven to have a positive effect on brainwave of an individual [8, 9, 10, 11, 12]. Fig. 1 shows the information that was deduced from the literature review to comprehend the relationship between BCI, stress and music.

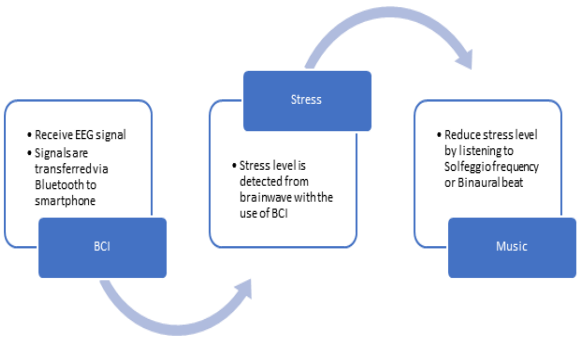

Fig. 1. Relationship between BCI, Music and Stress

From the identified relationship, the information was further extracted to a lower level, where we identified and mapped the brainwaves against frequency range and stress level. As previously mentioned, we considered two types of music in the effort of reducing stress; Solfeggio frequency and binaural beat. Solfeggio frequency is a music track of one frequency which can be 396 Hz, 417 Hz, 528 Hz, 639 Hz, 741 Hz or 852 Hz, while the binaural beat, is one generic music that is suggested to all stress levels, as proven by studies [13]. With this information, we were able to also map the Solfeggio frequency of music for each of the stress level (See Table II). The application was built in reference to these guidelines.

TABLE II. RELATIONSHIP BETWEEN BRAINWAVES AND STRESS LEVELS

Brainwave	Frequency Range (Hz)	Stress level	Suggested Solfeggio Frequency of Music
Alpha	8-12	Low	396
Low Level of Beta	12-15	Moderately Medium	396, 417
Medium Level of Beta	16-20	Medium	528
High Level of Beta	21-30	Moderately High	528, 639
Gamma	31-1	High	741, 852

C. Ideate

This phase is largely driven by the previous input, where it started with the design of the application's wireframe. The Fig. 2 below shows the steps taken to design the prototype.

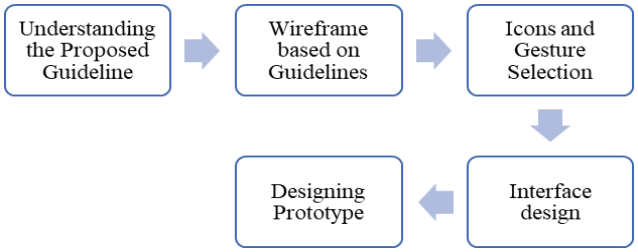

Fig. 2. Process of Designing Prototype

Wireframe is able to provide a natural next step where a few interactions are designed on a screen to easily navigate an individual to the next screen [8] (see Fig. 3). Emphasis is given on tasks to connect to the headgear via Bluetooth connection, as most of the users are not that familiar with device yet, as well as to detect stress level, and to choose music from the suggested songs to listen to depending on the stress level. Suitable gesture and icons are also considered in this phase. Tap is chosen to be the gesture type for this application. It would detect one or more finger to touch the icon on the screen briefly. The tap on the screen has an approximate around 0.1 second to detect. Tap will be used for:

- the "Next" button to move from the homepage to the next page
- the status of connection to the interface to detect the stress level of an individual
- the stress level to interface of suggested music

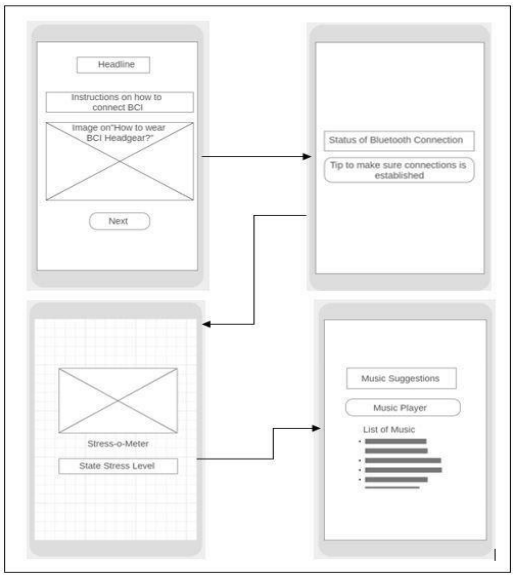

Fig. 3. Wireframe of application

The selected icons that are deemed to be able to convey the meaning metaphorically are as per illustrated in Fig. 3. A meter with a dial will show the stress level of the individual. Green symbolizes low stress level, light green shows moderately medium stress level, yellow indicates medium stress level, orange is moderately high stress level and red is where an individual faces high level of stress. While a music player icon will allow user to play, pauses, forward and rewind song. It also displays the length of music played.

Fig. 4. Icons considered for the application

D. Prototype

A series of prototypes was then developed to realize the initial design idea. The first prototype (Prototype I) is a low-fidelity prototype, which was developed using prototyping software named MockingBot. The purpose of this first prototype was to further understand the interaction and the flow of the application to fulfill the tasks by incorporating the chosen icons and gesture in the interface.

Due to the nature of this application, which requires connection between the BCI head gear to a mobile device, the prototype was further developed in a high-fidelity prototype (HFP), which emphasized on the functionality dimension. There are two versions to these high-fidelity prototypes as they had gone through an iteration, HFP1 and HFP2. Android Studio software was used in the development. Fig. 4 illustrates the first working prototype (HFP1) of Relax app. HFP2 was further enhanced where the enhancement was mostly done in the main activity screen to ensure the clarity of the flow of the application (See Fig. 5).

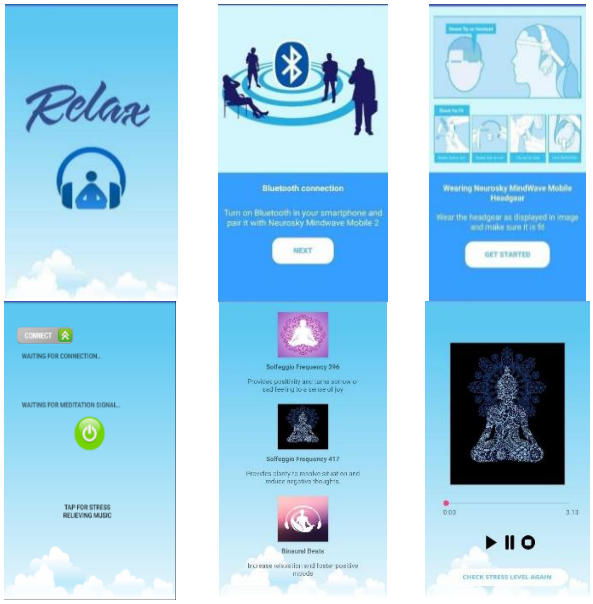

Fig. 5. Image Interface of First Working Prototype (HFP 1) of Relax app

Fig. 6. Image Interface of First Working Prototype (HFP 2) of Relax app

E. Test

There are three tests taken place in this study (see Fig. 6). The first test was conducted on Prototype 1 which was the low-fidelity prototype by using the System Usability Scale (SUS) as the instrument, which consists of 10 question with five response option ranging from strongly agree to strongly disagree. This test was participated by 6 students from different degree courses from the School of Computing. The aim of this test was to discover how well the users can wear the BCI headgear, apart from to validate how they perform the navigation of the screens. Each participant was given a task to read the instruction and wear the BCI headgear accordingly and to navigate through the application. The session lasted approximately for 10 minutes for each participant. At the end of the session, the participants were given the SUS form to complete. Based on the results, it was found that the participants were still a bit unfamiliar with the device, as they have never used a BCI headgear before. The users felt a little awkward trying the BCI headgear, which they may require some time and a quick assistance to learn how to use it. Other than that, most of them agree that they felt confident using the prototype application, as the interface and instructions are clear and 3 out of 6 participants suggested a more minimalist design that might make the application more attractive. These feedbacks are considered into the modification of the HPF 2, by adding a next button to prompt to the next screen for each screen interface.

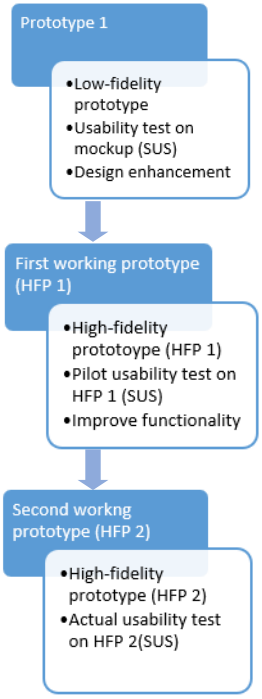

Fig. 7. The flow of tests conducted on Relax Prototypes

Before a usability test can be conducted, a pilot study was conducted on HFP 1. The purpose of the pilot study was to examine the feasibility of the actual test. Three participants involved to test the Relax application and were asked to complete the SUS and a feedback form. From the pilot test, it was found that they faced some difficulties as they used the app. One of it was, when the user checked the stress level again, the Solfeggio frequency music kept on playing in the background because music was set on a loop. Hence, the correction was made to play the song only once. Apart from that, the smartphone device went to sleep every 2 minutes, which kept interrupting the process. Some users also needed assistance to make sure the headgear was worn properly.

The third test was the actual usability test on the working prototype 2 (HFP 2). The aim of this test was to measure the

performance and effectiveness of the Relax app and its usability. To measure the performance and effectiveness of the Relax app, a within subject design was applied, where the users will be needing to measure their stress level using (i) stress level assessment, and (ii) Relax app. Meanwhile, SUS instrument is used to measure the usability of the Relax app.

This session was participated by 10 new participants. They were first asked to answer online stress assessment that is available on the Be Mindful website (http://www.bemindful.com). This assessment required the participants to answer 10 multiple choice questions and at the end of the assessment, participant's stress level is stated.

The participants were then asked to test the usability of the prototype. The participants were first briefed about the Relax app prototype. The participant was equipped with the BCI headgear; NeuroSky Mindwave Mobile 2, with the Relax app prototype in Huawei Nova 3e smartphone. Each participant was given tasks that instructed them to wear the BCI headgear and navigate through the application to check their stress level and try to reduce it by selecting and listening to music. The session approximately lasted 10 minutes for each participant. At the end of the session, the participants were given the SUS form to review the prototype.

III. Results

A. Performance and Effectiveness

The performance and effectiveness of Relax app were measured against an online stress level self-assessment test. Out of the 10 participants, 60% stress levels were detected the same by using both methods, with 20% the Relax app detected one level higher, and another 20% the stress level self-assessment detected one level higher. See Fig. 7. The time to detect the stress using both methods was recorded for each participant. The time taken for the assessment is recorded from the second the participants start to read the first question and as for the Relax app, the time is recorded from the second the participant clicked on the start monitoring button (once the Bluetooth connection is established). Using the self-assessment test, the time taken was ranging from 1 to 3 minutes, while using the Relax app the time was constant at 5 seconds. See Fig. 8.

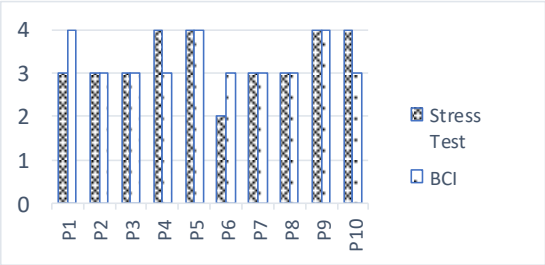

Fig. 8. Stress level using Stress Test and Relax app

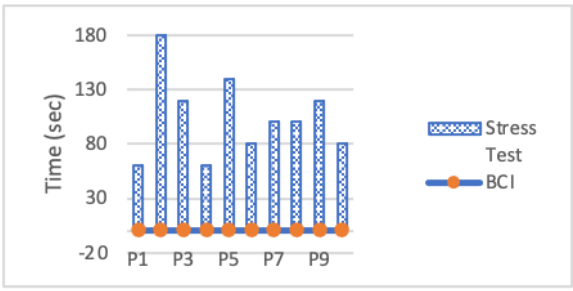

Fig. 9. Time Taken to Detect Stress Level

B. Usability

The SUS form consists of two sections which has the feedback of the application and the usability scale. Fig. 9 shows the SUS response using the average value. The highest rating by participants is confident of using the application which is 3.4 followed by the ability for participants to learn quickly at 3.3 and easy to use at 3.2. There is no factor below the average 2.00 and the lowest rating is at 2.2 which is on the inconsistency.

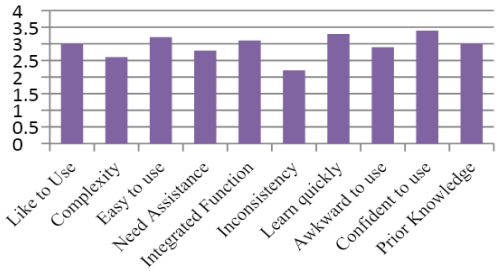

Fig. 10. SUS Average Score by participants

C. Comparison between Solfeggio frequency and Binaural Beats

As mentioned in the earlier, there is yet a study that considers which music type is more suitable in reducing stress level. This study offers two different music which are Solfeggio Frequency and Binaural Beats in the design of the Relax app. Table III below shows the stress level before and after listening to Solfeggio Frequency and Binaural beat. According to Table III, 6 participants were able to reduce their stress levels with Solfeggio frequency and as for the rest 4 participants, 1 participant's stress level is the same before and after, and the other 3 participants' stress level became higher. In comparison to binaural beats, 5 participants were able to relax themselves and for the other 5 participants the stress level increased after listening to the music.

TABLE III. STRESS LEVEL WITH SOLFEGGIO FREQUENCY AND BINAURAL BEAT

Music	**Solfeggio Frequency**		**Binaural Beats**	
Stress	***Before***	***After***	***Before***	***After***
P1	Moderately High	Moderately Low	High	Moderately High
P2	Moderate	Moderately High	High	Moderate
P3	Moderate	Low	Moderately High	Moderately High
P4	Moderate	Moderately Low	Moderate	Moderately Low
P5	Moderately High	Moderately Low	Moderately High	High
P6	Moderate	Moderate	Moderate	Moderately High
P7	Moderate	Moderately High	Moderately High	High
P8	Moderate	Moderately Low	Moderately Low	Moderate
P9	High	Moderately High	Moderately High	Low
P10	Moderate	Low	Moderate	Moderately Low

IV. DISCUSSION

Based on the findings from the usability test performed on the Relax app prototype, using the mobile BCI headgear is more effective as it is based on the brainwave frequency received from the participant at the current time. Thus, the time taken is constant as opposed to use the self-assessment test where the participants need to think of the answers first before the stress level is revealed. The detection of the stress levels nonetheless can be said to be neutral as the percentage between using Relax app and self-assessment is the same. This usability rating from the SUS had helped us to see how applicable and user-friendly the Relax application is. Overall, the Relax app has a good usability with no factor is below the average of 2.00. Inconsistency is something that the app needs to address. More than half of the subjects stated they like to use the application, and this can be translated into the acceptance of mobile BCI-based application for daily usage. Although 25% of participants feel like they need assistance, the majority have felt confident to use the application as it is very new to them. Between Solfeggio frequency against Binaural beats, for those participants who have listened to the former, their stress level has reduced drastically compared to the ones who heard the latter. From the feedback taken after the usability testing, 60% participants have preferred Solfeggio Frequency to Binaural beats.

V. CONCLUSION AND FUTURE WORK

From this study, we are able to see how the design thinking method could be used to develop a mobile BCI-based application to detect stress level. The prime factor that made this application development possible is one of the many advantages from design thinking process. This method provided an opportunity to support designers in every stage to meet the needs of potential users. Through the design thinking, designers would be able to best identify approaches to introduce an application that is a BCI-based since the idea of BCI headgear is still very new among students. However, the students who became the participants in the studies were able to adapt and learnt about BCI. The Relax application was developed offers two different music types; binaural beat and Solfeggio frequency, to reduce stress levels. Based on findings, it shows that the mobile-BCI has huge potentials in facilitating in reducing stress levels among students. Usability testing shows the application is user-friendly although it requires some update. The design of the application can be further expanded into other functionalities of smartphone such as connecting it with other music platforms such as Spotify. Overall, this study explores the potentials and readiness of BCI in everyday and common usages and contributes a guideline for the development of similar mobile BCI-related applications for future designers and developers.

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