Effects of virtual reality and music therapy on academic stress reduction using a mobile application

Arcos Gómez Alexander Rafael y Cabezas Fernández Cristian Alexis

Departamento de Ciencias de la Computación

Carrera de Ingeniería en Software

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Dr. Carrillo Medina, José Luis

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Cristian A. Cabezas, Alexander R. Arcos, José L. Carrillo-Medina and Gloria I. Arias-Almeida
Universidad de las Fuerzas Armadas ESPE, Sangolquí, Ecuador
{cacabezas5, ararcos1, jlcarrillo, giarias}@espe.edu.ec

Abstract. In recent years, music therapy has proven to be an effective strategy to reduce stress. This research examines the effects of applying a social support strategy to reduce stress levels in students of higher education students, by combining music therapy with the use of immersive virtual reality, making use of a mobile application. This proposal implements a system that performs the following tasks: i) collects information on the emotions of the participants through a facial recognition module, ii) provides a relaxation experience within an animated and musicalized virtual environment, iii) measures stress levels, through the application of a psychology stress questionnaire, and iv) evaluates the effects produced on the user. Experiments were carried out with the participation of several students from Universidad de las Fuerzas Armadas-ESPE. Results show that the use of music therapy, combined with virtual reality, could be a powerful strategy to decrease stress by up to 50%.

Keywords: Virtual Reality, Music Therapy, Mobile Application, Reduce stress, Academic.

1 Introduction

The COVID-19 pandemic has created a worldwide state of emergency and more than a year after its onset, we continue with biosecurity measures, according to the policies implemented in each country that has forced men and women to adapt and seek new ways to cope with their daily reality [1]. One of the strategies to mitigate the spread of this disease is isolation, which has led people to carry out their activities such as work and studies virtually. Social distancing and change of lifestyle have affected people's emotional and psychological health, which in the long run can produce depression, anxiety and especially stress [2,3]. The latter can be one of the main generators of pathologies and chronic diseases such as irritability, decreased self-esteem, insomnia, asthma, hypertension, ulcers, etc. [4]. Under these circumstances, it becomes necessary to implement early strategies for the prevention and treatment of psychological effects that can be caused by multiple factors [5]. According to some studies, it turns out that young people show greater stress than older people [1,6], and even more so when they are pursuing an academic education [7].

Academic stress is a common pathology that appears when a student faces a set of situations and/or academic demands, such as: assignments, homeworks, scholar projects, test or quizzes. This problem can affect the well-being and emotional stability of people. Many studies conclude that the performance and development of competencies of higher education students appear altered due to the influence of stressful academic situations and/or circumstances combined with personal, family and the pandemic situations [8, 9]. For this reason, it is necessary to seek a set of strategies to address these problems in order to achieve a stable psychological condition and have a quality mental health [10]. In this scenery, many studies have proposed methods to reduce stress levels, among these are physiological, natural, and technological. They aim to relax and provide peace of mind, relieving the patient's stress symptoms [11,12]. Music is related to the emotions of a person, a song can cause happiness or sadness having the ability to impact on their mentality [13], it can also be used to improve the physiological state [14], since the words and harmonic rhythm that conform it provide a relaxing and positive stimulus for mood change and stress reduction [15] due to the use of sounds, melodies, relaxing harmonies that when listened to satisfy physical, emotional, mental, social and cognitive needs [16], through listening to relaxing sounds or musical pieces [8,15]. Recent studies report that music therapy helps to balance a person's emotional state [17], to achieve a better intrapersonal and interpersonal integration and therefore a better quality of life [18].

In recent years virtual reality has gained much attention among developers. This technology allows the immersion of a person in a computer-created environment [19], giving a sense of presence and interaction that can take place depending on the level of immersion [20]. For the development of this type of applications, it is necessary to acquire devices for the visualization and manipulation of virtual reality environments.

The acquisition of virtual reality devices depends on their intended use, since they are expensive and represent a large investment. For this reason, this project has decided to use low-cost technologies, low-consumption energy and easy to transport. In this case, mobile devices are a good alternative. There are a number of successful cases where the use of this type of low-cost technology works properly and efficiently, which has led to its use in different fields such as education [21], entertainment [22], social media [23], health care [24], among others. In the health field, virtual reality has been used for therapeutic purposes to provide the patient with a simulated experience for the treatment of psychological conditions that cause difficulties to patients [2], reported studies indicate good results [11]. In the case of reducing stress levels, virtual reality can be applied with two approaches. The first employs relaxing generic environments, while the second requires people to interact with objects in the virtual environment [25].

In addition, this research examines the effects of applying a social support strategy to reduce stress levels in higher education students, by combining music therapy with the use of immersive virtual reality, making use of a mobile application. The proposed system allows collecting information about the emotions of the participants (facial recognition through convolutional neural networks), providing the participant with an experience within a virtual musical and animated environment as a relaxation tool, applying an academic stress questionnaire (self-perceived stress through the SISCO SV-

21 academic stress questionnaire) and with the results obtained to evaluate the effects produced by the pre-use and post-use of the mobile application.

2 Methods and Materials

Virtual reality is getting a lot of attention in the development of therapeutic applications for stress management [26]. On the other hand, music therapy is an intervention that is very commonly used in stress reduction. This paper proposes a mobile application that integrates these two approaches, with the aim of facilitating stress management.

2.1 System design

This application is intended to function as a tool for psychologists to reduce stress levels through the collection of data on emotions, self-perceived stress and its effects. SCRUM software development methodology was applied because of its high flexibility and adaptability [27]. The functional scheme of mobile application is shown in Fig. 1 which is composed of four modules: a) The emotion recognition module, which allows to know the visual emotional state of the participant, b) The stress assessment module, which allows to do a pre-test before using the application and a post-test at the end of the intervention according to an adaptation of the SISCO-SV-21 questionnaire (the description of this adaptation is in the metrics section) to obtain self-perceived stress information and its effects, c) The virtual reality interfaces, which generates an environment of a virtualized forest where the participant interacts with 3D objects such as percussion instruments, and d) The data reported by the application, on the analysis of emotions before and after using the application.

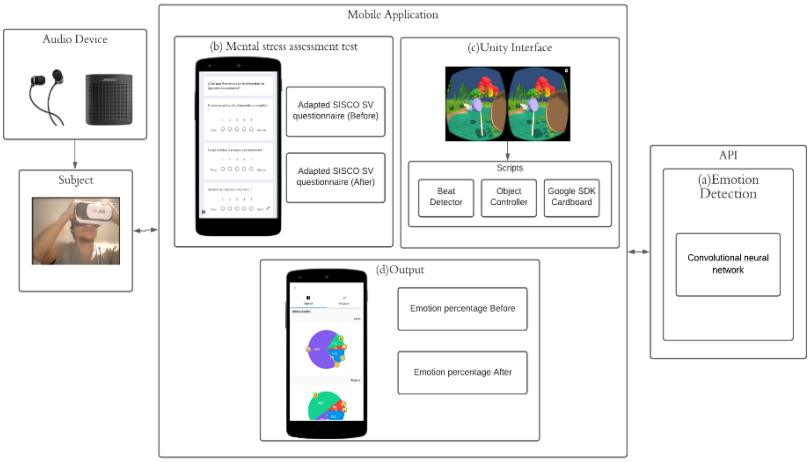

Fig. 1. Functional scheme of the proposed application: a) emotion recognition module, b) stress assessment module, c) virtual reality interfaces and d) reported data about emotions.

2.2 Emotion Recognition

Emotion recognition represents a very important function in many fields such as forensic crime detection, psychologically affected patients, tutoring students in academia, observing victims in court, etc. [28]. The aim of this module is to recognize facial emotions, for this purpose we make use of the well-known convolutional neural networks (CNN), which detects in an image (human face) 6 emotions: anger, fear, happy, sad, surprise, disgust. The CNN network proposed in the paper "Real-time Convolutional Neural Networks for Emotion and Gender Classification" [29] was used as a basis for its development, since the proposed network architecture is small and reduces the number of parameters to be used in training at the same time improving performance, which makes it possible to detect faces, identify gender and, in our case in particular, classify emotions in a fast and efficient way. Based on this premise, the CNN network was deployed as a cloud service (Digital Ocean - jukeapi.ml) and through an API (application program interface). The image of the face of an application user is analyzed, classifying the emotions detected, entries that are stored in a database and can be consulted through the mobile application. To create the API, the Flask framework was chosen because of the several advantages it provides in the creation of these services [30]. The structure of this module is shown in Fig. 2.

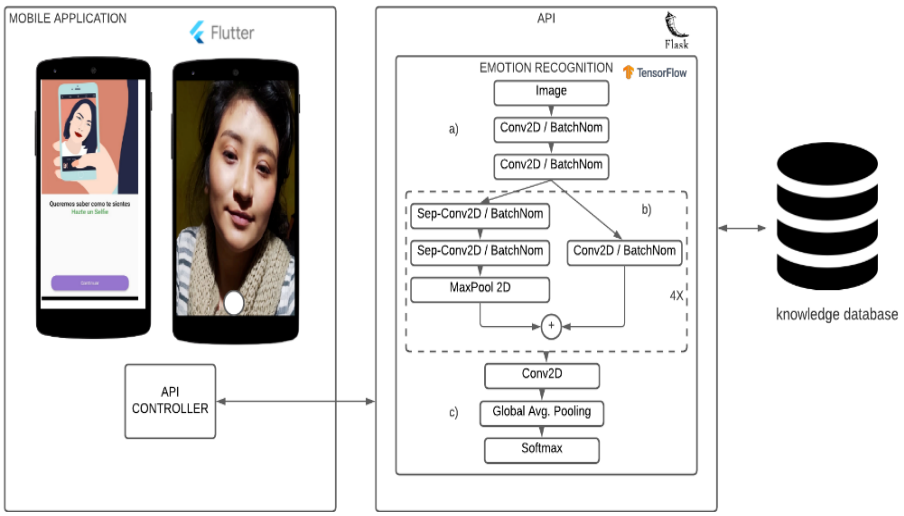

Fig. 2. Emotion recognition implementation architecture a) Batch normalization for image processing b) Residual convolutions a) Batch normalization and the ReLU trigger function c) Combination of global averages, softmax trigger for prediction.

The mobile application sends an image containing the face of the user to the API in which each of the 6 emotions is analyzed using the CNN network. The model for emotion recognition is formed by a) a batch normalization for image processing prior to analysis b) four separate residual convolutions, in which each convolution is formed by a batch normalization and the activation function ReLU. Finally, c) a combination of

global averages, plus a softmax activation for prediction based on a percentage of the emotions reflected by the user's face. The API returns a percentage for each of the 6 emotions indicated above, which are stored in a knowledge database for further analysis. The interest of knowing the emotions through this module is to be able to compare each of the emotions recorded at the beginning and end of the use of the application and thus have an objective comparison of the change in the participant's emotions [29].

2.3 Virtual Environment and Music Therapy

Virtual reality (VR) is increasingly and more frequently used in the construction of interactive 3D environments in different research fields, due to its great flexibility, through game engines [24]. The Unity 3D graphics engine was used to build the virtual environments of the application (Unity SDK for Google CardBoard, due to its ease of implementation). This type of virtual reality applications can be visualized using viewers for mobile devices.

Fifty two students were surveyed in order to collect information about their preferences about the relaxing environment with respect to their favorite music and choose between "rainforest", "beach", "riverbank", "home" and "anywhere". This task is based on previous studies [31,32]. After that, this information was used to design the virtual environments. The relaxing environment preferred by most of the students surveyed was the rainforest, according to the results obtained, and was selected for implementation due to its therapeutic and relaxing effect [32]. A 3D modeling of this environment was performed to provide the user with a realistic experience of being surrounded by nature with a 360° perspective [31]. A VR viewer for mobile devices was used for the visualization of the constructed virtual environment as well as for testing and validation of the application due to its easy accessibility and affordability.

Additionally, music is used as therapy while navigating through the virtual environment, the user's favorite music will be played at the same time. Several studies [27,33] have shown the effectiveness of using music therapy, as it awakens in the participant different feelings and emotions, such as joy and tranquility, this would positively stimulate the participant's emotional state.

The experience within the virtual environment is not limited to listening, an interactive activity has been created to accommodate the rhythm of the song. A bass drum, and a snare drum (3D objects) are modeled as percussion instruments as they are more common to carry the rhythm of the songs [34]. These objects are generated according to the rhythmic pattern of the musical piece the participant has selected (see Fig. 3a) and can be destroyed with a drumstick whose movement is linked to that of his head (see Fig. 3b-c). When the bass drum and the snare are destroyed, an animation and a sound that simulates the sound of the percussion instrument is played (see Fig. 3d) [35] which allows to make the user's experience more dynamic and satisfying, increasing its relaxation state [36].

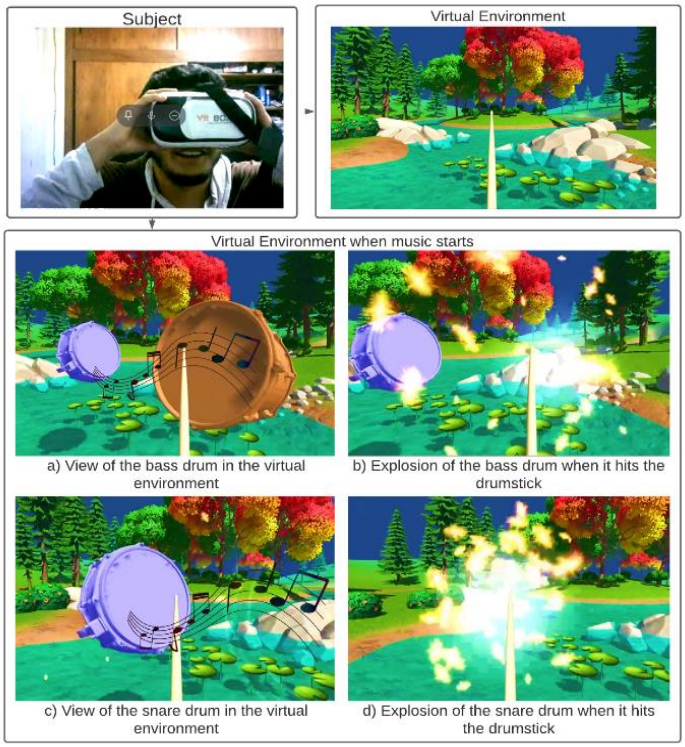

Fig. 3. View of the virtual environment through a virtual reality device. a) view of the bass drum and snare drum b) explosion of the bass drum when it hits the drumstick c) view of the snare drum d) explosion of the snare drum when it hits the drumstick

Beat Detection Algorithm. The beat detection algorithm is based on the search for a rhythmic pattern from an audio. The rhythm was used to synchronize certain effects such as the generation of 3D objects as percussion instruments when the user interacts, objects that will make the experience more vivid and dynamic within the virtual environment [35]. For the implementation of the algorithm, the best balance between accuracy and processing speed has been used, considering that it should be as optimal as possible because it will be executed on a mobile device, which is why the method used in this study is based on one of the pulse detection algorithms of Frédéric Patín [37].

The algorithm suggests the use of a statistical model based on the amplitude or energy of sound, the average value of this energy in an interval of a couple of seconds is calculated and compared with the current energy of sound, if the difference between the two exceeds a previously determined threshold, it is considered that a pulse has been generated. The objective is to capture the lowest frequencies in a range between 60hz-180hz for the bass threshold in which we find the sound of a bass drum, and a mid/bass range 500hz-2000hz in which it is considered, are most of the snare drums [38]. A window of 1024hz is used as samples and a sampling rate of 44100hz, obtaining a buffer of 43 elements to store in 1 second of audio. It is worth noting that the values of the samples can be obtained from the analysis of the fast Fourier transform (FFT).

The equation for the energy calculation (equation 1) is constructed assuming that k and k+n are the limits of the current range being processed and FFT[i] is the amplitude of the frequency for position i.

$$E = \frac{1}{n}\sum_{i=k}^{k+n} FFT[i] \tag{1}$$

It is necessary to store the resulting value with the 42 remaining samples over 1 second to establish the historical record (equation 2).

$$H = [E_{t0}, E_{t1}, \dots, E_{t42}] \tag{2}$$

The arithmetic average is then calculated (equation 3).

$$avg(H) = \frac{1}{43}\sum_{i=0}^{42} H[i] \tag{3}$$

If the energy at the current time is higher than the calculated average (equation 4), a pulse is considered to have been detected, which depending on the defined thresholds for bass and mid/bass, generates a bass drum or snare drum within the virtual environment.

$$E > avg(H) \tag{4}$$

2.4 Evaluation Metrics

Qualitative and quantitative data collection was performed by analyzing emotions through a percentage measure for each of the 6 emotions analyzed. Through this metric the change or not of the emotional state that the user experiences when using the application is reported and if there is a change, how this can influence their self-perceived stress level, these values were analyzed at the beginning and end of the use of the application.

An adaptation of the SISCO SV-21 academic stress questionnaire [39] was used, a questionnaire that allows collecting information regarding academic stress (stressors, symptoms and coping strategies) of the respondents (participants). This adaptation was made with the advice of an expert in psychology to obtain indicators related to symptoms of stress. Out of the original 21 items, seven were eliminated from the stressors dimension and seven from the coping strategies dimension because they were not related to the object of study, leaving seven items (see Table 1: Items 1-7) that have allowed us to measure the most common stress symptoms (reactions) of the participants. In addition, eight items were taken from the first version of the SISCO SV questionnaire [40] and were not taken in the second version because they allowed us to obtain indicators relating to other uncommon stress symptoms (see Table 1: items 8-15), obtaining at the end fifteen items that are evaluated on a Likert scale of five numerical values, where 1 means a little and 5 means a lot (scale used throughout this study).

In addition, the survey asked participants to enter demographic data (name, age, academic level, place of residence). The first two questions of the questionnaire were not

modified because the first one serves as a filter to find out if the participant has experienced stress during the course of an academic period (Question 1. During the course of this semester, have you had moments of worry or nervousness/stress?) and the second one provides information about the level of self-perceived stress (Question 2: in order to obtain greater precision, indicate your level of stress, using the Likert scale). At the end of the study, a short questionnaire was given to the participants to find out their appraisals about the mobile application, each question is evaluated on a 5-point Likert scale, the questions asked were: 1) How likely is it that you would recommend the application to a friend or member of your family? 2) From your point of view, how easy was it to use? 3) How likely is it for you that you would use the application again?

Table 1. Items about SISCO SV-21 Symptom dimension (Reactions)

Items	Reaction
Item 1	Chronic fatigue (permanent tiredness).
Item 2	Feelings of depression and sadness (feeling down).
Item 3	Anxiety (nervousness), anguish or despair.
Item 4	Difficulty concentrating.
Item 5	Feelings of aggressiveness or increased irritability.
Item 6	Conflicts or tendency to argue, contradict, argue or fight.
Item 7	Unwillingness to do academic work.
Item 8	Sleep disorders (insomnia or nightmares).
Item 9	Headaches or migraines.
Item 10	Digestion problems, stomach pain or diarrhea.
Item 11	Scratching, nail-biting, rubbing, etc.
Item 12	Drowsiness or increased need for sleep.
Item 13	Restlessness (inability to relax and be calm).
Item 14	Isolation from others.
Item 15	Increased or decreased food consumption.

3 Results and discussion

Sampling was used to create groups of the target population, students of the last levels of Software Engineering at the Universidad de las Fuerzas Armadas ESPE - Ecuador, due to the availability of time and technological resources to which the students had access. The selection of participants was carried out under the supervision of an expert in psychology related to the research. The number of participants selected was 6 students in an age range between 21 and 25 years, 3 men and 3 women, who were subjected to the application of music therapy with virtual reality. The participants used the application during five sessions, each session was carried out in a time interval of between 10 and 15 minutes, this depending on the duration of the musical piece selected by each participant and the time taken for the data collection process.

The analysis of the results was also conducted with the advice of a psychologist. The percentage values stored in the database of the emotion recognition module for the evaluation of positive and negative emotions were obtained; in the same way, for the evaluation of the effects of stress, as well as the self-perceived stress level, the values of the forms completed by the participants were obtained, averaged, and transformed into a percentage measure to facilitate their interpretation.

Fig. 4a shows the variations of positive emotions when using the application. The obtained average values of positive emotions of all participants at the beginning of each session are represented in red, and the average values obtained of positive emotions at the end of the sessions are represented in blue. The participants started with an average of 21.53% positive emotions and at the end, their average increased to 70.72%, showing an increase of 49.19% in the average of positive emotions with a standard deviation of 11.32 at the end of the five sessions. Based on the data related to the positive emotions of the 6 participants, a greater increase of 54.44% was found in female students, while in male participants there was an increase of 43.94%.

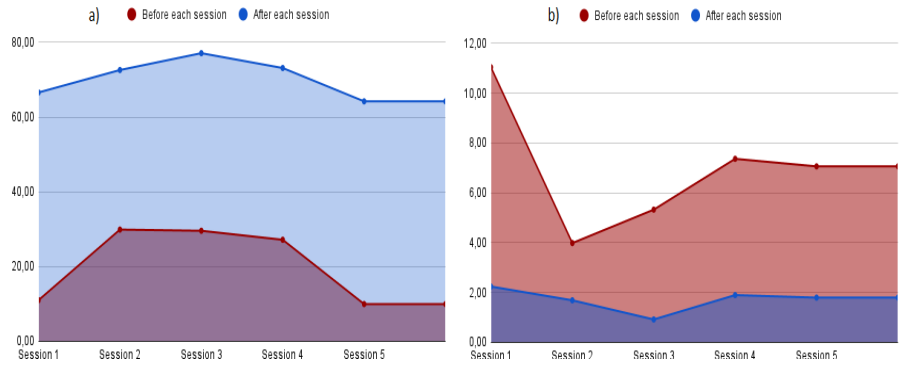

Fig. 4. Results from a) positive emotions analyzed b) negative emotions analyzed: Measurements before (Red color) and after each session (Blue color).

On the other hand, negative emotions had the opposite effect to positive emotions. As shown in Fig. 4b, the average of negative emotions of all participants at the beginning of each session is shown in red and the average of negative emotions at the end of the sessions is shown in blue. The participants started with an average of 6.96% and at the end of the application their average was reduced to 1.71%, establishing a decrease of 5.25% in the average of negative emotions with a standard deviation of 2.13 at the end of the five sessions.

The participants used the application during the entire study for an average of 1 hour 8 minutes and 36 seconds, it was evident that the female participants used the application for an average time of 1 hour 7 minutes 58 seconds while the male participants used it for an average of 1 hour 9 minutes 15 seconds, as shown in Table 2, which shows a summary of the characteristics of the students, including the change in their emotions and their level of self-perceived stress.

Table 2. Summary of participant characteristics: Gender, grade, change in their emotions, self-perceived stress, and stress level reduction.

Students	Gender	Semester	Stress level	Application usage time	Increase positive emotions	Decrease negative emotions	Stress level reduction
Student 1	Male	9	4	1:09:12	47,19	4,69	2
Student 2	Female	9	4	1:08:57	43,59	6,96	2
Student 3	Male	9	4	1:10:44	50,97	6,49	3
Student 4	Female	6	4	1:06:45	68,02	6,46	3
Student 5	Male	7	4	1:07:48	33,66	1,21	2
Student 6	Female	4	5	1:08:11	51,73	5,68	3
Average				1:08:36	49,19±11,3	5,25±2,13	2,5±0,55

The results obtained from the application of the SISCO SV-21 questionnaire to confirm the change in the state of self-perceived stress and its symptoms (reactions) are shown in Fig. 5. These show that negative reactions were reduced with the use of the application. Participants started with an average score of 3.1 on the 15 test questions, evaluated on a 5-point Likert scale (see Table 1). At the end of the five sessions, participants experienced a reduction effect of their symptoms (reactions) that reached an average of 2 points.

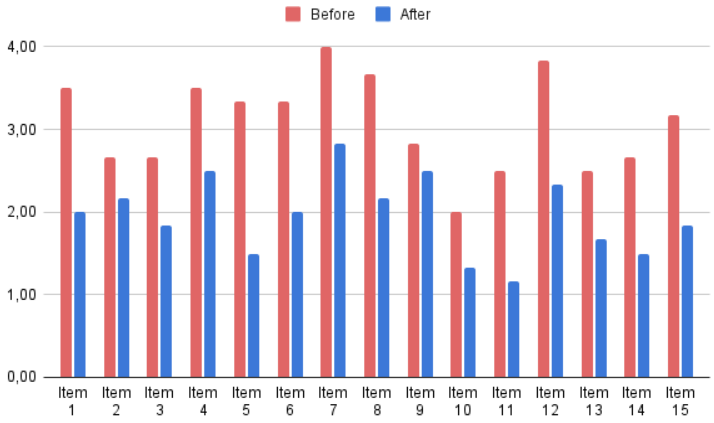

Fig. 5. Results from items about SISCO SV-21 Symptom dimension (Reactions) before (Red color) and after (Blue color) five sessions, each Item is specified in Table 1 and is evaluated on a 5-point Likert scale.

At the beginning of the application, the SISCO SV-21 questionnaire was used, a higher percentage of participants with sleep disorders, drowsiness and listlessness to perform their academic activities were reported, at the end of the five sessions it can be observed that there was a greater reduction in some stress reactions. According to the items of the questionnaire, the following results are reported 30% reduction in sleep disorder

(item 1), chronic fatigue (item 2) and drowsiness (item 6), 26% reduction in skin itching, nail-biting (item 5), tendency to get involved in conflicts (item 12) and increased or decreased food consumption (item 15), 36% reduction in irritability or aggressiveness (item 11) and 24% reduction in isolation with others (item 13) and reluctance to perform academic activities (item 14). The values of the items that were not specified obtained on average a decrease of one point or less.

The information related to the level of self-perceived stress for each participant can be seen in Fig. 6. At the beginning of the application, the participants presented an average of 4.2 in their level of self-perceived stress and at the end of the sessions there was a significant reduction in the average score of 2.5 with a standard deviation of 0.55. In addition, it was observed that female participants had a reduction of 53.3%, being higher than male participants whose reduction was 46.7%.

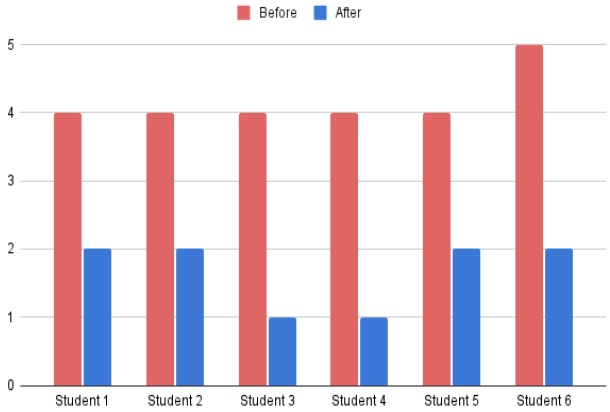

Fig. 6. Results from Self-perceived stress: Measurements before (Red color) and after (Blue color) five sessions.

The results of this study provide evidence on the feasibility and effectiveness of a mobile application that uses music therapy and virtual reality environments to improve users' emotions and decrease their self-perceived stress levels. The use of virtual reality technology as a technological tool for mental health support is important and useful since it helps users to change their mood positively, and to some extent improve their physiological state. There are two motivations for using mobile devices. First, using this type of device is more accessible for virtual reality technologies with certain limitations. Second, considering the repercussions of social isolation in the global context in which we live, it is more viable to provide people with a mobile application that can be used at any time and place without risking their health.

The results show that positive emotions increased significantly at the end of each session, which corroborates a positive experience that the participants had when using the application. With an average of 49.19%, emotions improved and at the same time their self-perceived stress levels decreased by 50%, demonstrating an inverse relationship between people's mood and their stress level. It could be observed that, despite the fact

that female participants used the application to a lesser extent, they obtained better results than male participants, both in the increase of positive emotions and in the reduction of their stress level, although it is true that the results reflect that there is no relationship between the time of use of the application and the levels of self-perceived stress reduction, However, there could be a direct relationship between the time of use of the application and the increase in indicators of positive emotions.

In the questionnaire regarding the participants' appraisals of the application, it was found that 100% of the participants would use the application again and would even recommend its use to others, 50% reported that it was easy to use, and 83% would use it again. According to these results, it can be indicated that there is a high level of acceptance by the participants.

In addition, it can be indicated that our study provides a different approach to similar studies since one of our indicators is based on the detection of the participant's emotions which, with the support of a psychology specialist, has been considered to have a close relationship with the levels of stress that they present [56,57].

It should be noted that this study has some limitations. First, the time of use of the application was very short; it would be interesting to test how the application affects longer periods of use and when it has better results. Second, to stimulate relaxation, positive emotions and reduce stress, only a relaxing environment was used. However, it would be possible to experiment with other environments and analyze how it affects the participant's emotions considering the duration or type of music selected.

4 Conclusions

This paper proposed a mobile application based on music therapy and virtual reality to manage and to reduce the stress. This application could be used directly by the end user or by a specialist, in both cases, as a support or complement to relaxation and stress management therapies.

This mobile application records information about the participant's emotions and applies the SISCO SV-21 academic stress questionnaire. After that, it selects a song based on the participant's preference. Immediately, the song is analyzed to identify the rhythmic pattern and generate three-dimensional objects (musical instruments). Within the virtual environment the participant destroys these objects and upon executing this action an animation and a sound associated with the instrument is played, which makes the user's experience more dynamic and satisfying, relaxing the participant. This therapy is performed during five sessions, to analyze and validate the stress levels and symptoms (reactions) of the participants.

The results show that the use of the mobile application can improve the positive emotions achieving a best of 49.19%. It also has promoted relaxation which has led to a reduction of self-perceived stress levels by 50%.

Now, the pandemic continues, therefore stress problems are active. Thus, this work could be a starting point for further studies related to stress-related emotion management using virtual reality-based technology.

Acknowledgments. This research was carried out with the cooperation of Ms. Gabriela Tualombo, a psychologist, for her valuable professional support that has allowed the application of the necessary knowledge on the analysis of self-perceived stress and its symptoms, through the adaptation and application of the SISCO SV-21 academic stress questionnaire and the interpretation of the results.

This study is part of the research project called "DEVELOPMENT OF A MOBILE-WEB SYSTEM AS A PREVENTIVE SOLUTION FOR THE REGISTRATION AND MONITORING OF PEOPLE WHO ARE IN DOMICULAR ISOLATION AND ARE POSSIBLE CASES OF CORONAVIRUS: Project "APP COVID-LIFE". And we would like to thank all the research assistants of the project, also the Universidad de las Fuerzas Armadas ESPE and the Research Group of Technology Applied to Biomedicine - GITbio, for the support to develop this work.

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