Assistive technology to monitor and reduce anxiety levels among college students throughout the analysis of heartbeat frecuency

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Abstract– ***We developed a smart wearable system to identify, monitor and reduce levels of anxiety of college students by using a wearable device and a mobile application. Anxiety is one of the most frequent mental health problems of college students. Prior studies suggest that anxiety is related with low study performance, college attrition, heart-related condition, and depression. Despite the availability of college resources offered to assist students (e.g., counselling services), only 1 in 5 students with anxiety issues receives an adequate treatment. Two highlighted reasons for this gap are stigma and preference for self-mutual help. The proposed wearable system includes a wearable device and a mobile application with embedded recommended activities to reduce anxiety levels of college student. The solution has 5 components: 1) Gathering of physiological variables though the wearable, 2) Integrating the wearable and the mobile application, 3) Storing data, 4) Integrating the solution and web application and 5) Monitoring, treatment and identification of anxiety levels. The system was validated at a University in Lima, Peru with 10 students between 18 and 23 years old. The preliminary results indicated that the system could identify and help in reducing effectively the level of anxiety in 80% of the cases students.***

Keywords-- Wearable; Technology; Mobile Health Application; Anxiety Detection; Cloud technology;

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Abstract*– We developed a smart wearable system to identify, monitor and reduce levels of anxiety of college students by using a wearable device and a mobile application. Anxiety is one of the most frequent mental health problems of college students. Prior studies suggest that anxiety is related with low study performance, college attrition, heart-related condition, and depression. Despite the availability of college resources offered to assist students (e.g., counselling services), only 1 in 5 students with anxiety issues receives an adequate treatment. Two highlighted reasons for this gap are stigma and preference for self-mutual help. The proposed wearable system includes a wearable device and a mobile application with embedded recommended activities to reduce anxiety levels of college student. The solution has 5 components: 1) Gathering of physiological variables though the wearable, 2) Integrating the wearable and the mobile application, 3) Storing data, 4) Integrating the solution and web application and 5) Monitoring, treatment and identification of anxiety levels. The system was validated at a University in Lima, Peru with 10 students between 18 and 23 years old. The preliminary results indicated that the system could identify and help in reducing effectively the level of anxiety in 80% of the cases students.

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I. INTRODUCTION

During college life, students are exposed to different situations such as academic, social and work situations that may trigger anxiety.

A study conducted by the World Health Organization reports anxiety as the second most common disorder in the world; however, it is important to clarify that anxiety is a normal response to a stimulus, but when it exceeds the acceptable levels, it can become a barrier for correctly performing activities, it can foster detriment of social and labor abilities; besides in extreme cases and concurrence of depression causes development of suicidal ideation and behaviors. [1][2] Moreover, anxiety is strongly related with the development and progression of illnesses (heart, circulatory system o degenerative nerve diseases) and its symptoms include headache, high blood pressure, extreme lumbar pain and gastrointestinal problems. [3][4]. In Canada, an evaluation of anxiety disorders using portable devices identified that around 264 million people in the world suffer from anxiety, this number has increased 14.9% each 10 years. Furthermore, a study done in Peru by San Marcos National University shows that 9 out of 10 students have problems related with anxiety and it is categorized as one of the main causes of student desertion (30%).

The last technological advances in the health field have promoted the use of wearable tools to detect and monitor mental health problems such stress and anxiety via physiological variable collection. For instance, a technological solution based on the use wearable devices, mobile phones and computers allows the identification and decrease of the levels of stress. This technological solution identifies the physiological variable of the heart rhythm by integrating a mobile application and a wearable device; using text recognition to determine the level of anxiety; also provides recommendations to decrease the level of stress obtained. This proposal states recommendations based on breathing, muscular and mental exercises to care for mental health [5].

Regarding investigations about the identification of anxiety, an article is found that compiles and explores the use of wearables and ECG (Electrocardiogram) readings in order to determine several anxiety disorders among individuals. This investigation promotes the use of wearables because their portability with ease and their use as smartwatches and electrocardiogram belts [4].

Considering the importance of the physiological variables in identifying mental health problems in people, along with the recent advances the utilization of wearables in the healthcare field, it is necessary to develop and implement a technological solution in order to control and monitor the levels of anxiety in college students from Lima, Peru. This research article proposes a solution, a system that permits patients to perform activities that reduce their anxiety, and medical professionals to monitor people's medical condition. This solution includes a wearable device that collects the heart rhythm, a mobile application that gives recommendations to reduce the level of anxiety measured via heart rhythm; and

web application utilized by the specialist to monitor patients, schedule medical appointments or record treatments.

This article is organized in the following manner: we start by reviewing literature related with the use of wearable devices to monitor anxiety. Then, the proposal section presents the analysis and development of the assistive system. In the next section all preliminary results of the case study that validate the proposed solution are detailed, and in the last section, the conclusions are presented.

II. Reviewing literature: Anxiety and physiological variables

Anxiety is an emotional normal state that plays as defensive mechanism to alert people and prompt them to react when facing dangerous events or situations, pressure or fear. At low levels, anxiety works an impulse to perform activities and reach goals and objectives; however, at excessive levels, it is harmful because anxiety provokes low performance and interferes with social, work and student development in humans preventing to reach planned objectives. Moreover, anxiety can foster the development of physical problems like tachycardia, breathing issues, nausea and tingling. Now, a brief study of the physiological variables used in anxiety identification and employed monitored solutions is described. [6].

A. Physiological variables of anxiety

Researching literature has allowed to identify physiological variables that permit to determine the level of anxiety among people. Some of these articles consider the use of wearables due to their features and functions that aim to collect the variables listed in table I. Among the identified variables, the most used by the investigations are heart rhythm, facial recognition, electrodermal activity and electrical impulses in the brain.

TABLE I
Principal Physiological Variables of Anxiety

Nº	Principal physiological variables of anxiety	
	Variable	Reference
1	Heart activity, Electrocardiogram (ECG)	[3], [4], [7], [8], [9], [10], [11], [12], [13]
2	Electrodermal Activity	[7], [12]
3	Electromyogram	[12]
4	Cortisol	[14], [15]
5	Brain Activity, EEG	[2], [16]
6	Breathing	[12]

It is imperative to emphasize that the physiological variables listed above have limitations. The precision, the invasiveness of the method used for collecting the physiological variable and the difficulty in collecting the physiological variable are limitations that must be considered when being chosen for the solution. Examples of this are the investigations that measure cortisol to determine anxiety because collecting cortisol requires to conduct blood or saliva tests in people. [4][8]. As to the collection difficulty, there is a case study of a solution that proposes to collect EEG via a helmet to identify anxiety; however, this signal contains θ, β and α rhythms, which have to be analyzed through an algorithm to assess its efficiency [2]. Moreover, precision is required, according to the revised literature, collecting variables associated with anxiety depends on collecting multiple biological signals along with ECG; nonetheless, this causes both the solution and the extraction of these variables to be more intricate than what is required because they demand the use of more advanced and higher dimension technological devices. This is shown in an investigation, where in order to measure multiple biological signals for evaluating a mental health problem, it was necessary to use different tools as wearables; furthermore, it is necessary to state that when comparing these signals, it was found that the signals obtained via ECG were optimal [12].

Based on the previously stated, the project development of the present case chose the heart rhythm as the physiological variable. Nevertheless, it is necessary to state that the selected variable presents some limitations as the other ones listed in the table above. For example, the heart rhythm can be affected by doing physical activity or development of heart problems, such arrhythmia or tachycardia. For that reason, to do this investigation, students who did not have those heart conditions were selected.

B. Evaluation of the use of wearables

Wearable devices have a great advantage over specialized technological sensors or technological tools because they are easy to carry, portable; in other words, they are accessories like bracelets and smartwatches that can be daily worn without interfering with people's activities. In table II, technological tools such as sensors, electrodes and cameras are compared with the wearables that are used to monitor the heart rhythm.

TABLE II
PRINCIPAL DEVICES FOR CAPTURING HEART RHYTHM

Characteristics	Devices	
	Sensors, electrodes or cameras	Wearable
Portability	Uncomfortable (requires careful use when performing activity to prevent device damage)	Easy (it can be used as an accessory)
Easy to use	Complicated (requires necessary knowledge to understand the reading)	Easy (personal use and no requires technical knowledge)
Validation	[2], [3], [7], [8] [16], [17],	[2], [3], [4], [9], [10], [12], [16], [17]
Data extraction	Extraction has a high level of difficulty; also requires complex algorithms for reading and use	Data is extracted in a simple and continuous manner; also, it can be easily connected with smartphones

To develop the proposed solution, wearables were chosen based on the information presented in the table above. Because the reviewed literature does not mention advantages of any particular wearable or brand, a Fitbit Smartwatch Versa 3 was selected due to its opened code, its community of developers and its own platform to simulate tests. However, despite of the fact that this solution is thought to be integrated in the previously mentioned device, there is a possibility to perform a manual recording of the heart rhythm for not conditioning the proposal to obtaining the device.

C. Evaluation of Cloud Platforms

Cloud platforms have been revolutionizing business dynamics due to its practicality when contributing to deployment and securing continuity of technological solutions. For the present study, IaaS will be used for the deployment of the solution. To select a cloud service provider, benchmarking was conducted among the main providers, like Microsoft Azure, Amazon Web Services and Google Cloud. This analysis focused on the following criteria: price, resources, security, support and ease of implementation. When analyzing and quantifying the criteria, Amazon Web Services was selected as the service provider of storage and deployment of solutions.

D. Technological Solutions for monitoring anxiety

A limited number of solutions that seek to monitor and reduce anxiety through the use of technological solutions have been found. One of this solution proposes the use of a mobile application for controlling and reducing problems related with anxiety. The proposal compiled people's activities to identify commitment with the use of the application, and it monitored anxiety by answering a questionnaire. Besides, the application ascertained the causes of anxiety through the option "Things that make me anxious". Users utilized this option and recorded the event and level of anxiety associated with it; additionally, the application provided support to reduce anxiety via the option "Social Cloud" where the users could share pieces of advice and help their peers. [18]

On the other hand, there is a proposal that provides a system that identifies social anxiety via a trained algorithm that identifies anxiety throughout visible symptoms. The conducted experiment in the project includes monitoring with a camera and electrocardiogram placed on people's chest while they are giving a speech. Regarding the decrease of anxiety, 3 methods were used: The first one is focused on group therapy intervention and relaxation techniques for relaxing; the second one is based on group therapy intervention and relaxation techniques based on cognitive behavior therapy; and the third one is based on self-help support focused on solving procrastination, learning challenges, and relaxation problems. The literature concludes that these 3 methods are effective to reduce anxiety. [13].

Furthermore, when doing literary research, a solution was found that analyzes the nerve system to determine the level of anxiety before oral report presentations and thesis defense. This proposal monitors physiological variables as heart rate and skin response via bracelets and anklets. Once all data is collected, it is used to elaborate a dataset that will serve as a model of high and low anxiety. This system employs a trained algorithm to ascertain the state of anxiety via visible symptoms; besides, it demonstrated that anxiety is linked to the heart rate, for that reason, this proposal can identify anxiety problems in real time. [3].

However, none of those solutions considered in the revised literature proposed an integrated system that permit both the specialists to monitor using a web or the patients to self-manage anxiety decrease using a mobile app and a wearable. Additionally, despite of the fact this proposal is designed for college students, it can be applied in any daily life situation, such as social, work or academic environment.

The proposed solution seeks to identify levels of anxiety caused by college life among students from Lima, Peru through a wearable. Moreover, the solution has an application that provides pieces of advice about health care, shows the prescribed treatment by a specialist and breathing techniques to control and reduce the level of anxiety experienced by the patients. In order to validate the results, the previous state was compared with the posteriori state after the patients follow the pieces of advice given by the application while they are experiencing anxiety events (oral report presentation, taking quizzes or exams, waiting for grade revealing, among other stressors).

III. ASSISTIVE AND RAPID SYSTEM: A TECHNOLOGICAL SOLUTION PROPOSAL

A. Description of the Solution

Based on the revised solution in the literature [5], a solution is proposed that is able to monitor, identify and reduce anxiety in people throughout the utilization of a wearable device. The proposal of this investigation focuses on acute stress; however, it was used as a model for our investigation due to the similarities with mental health problems and extraction of the physiological variables. This proposal contemplates two types of users: the specialist who is responsible for monitoring the patient and providing a treatment to reduce the anxiety recorded by the patient; and the patient who utilizing the wearable and the mobile application records his heart rhythm in order to determine the level of anxiety experienced; moreover, the patient follows the pieces of advice and relaxation techniques to control and reduce his anxiety. The Front-end was developed with VueJs, Kotlin mobile app and Back-end with NodeJs. The solution was deployed in the EC2 of AWS service. The relationship of the solution components can be visualized in figure 1.

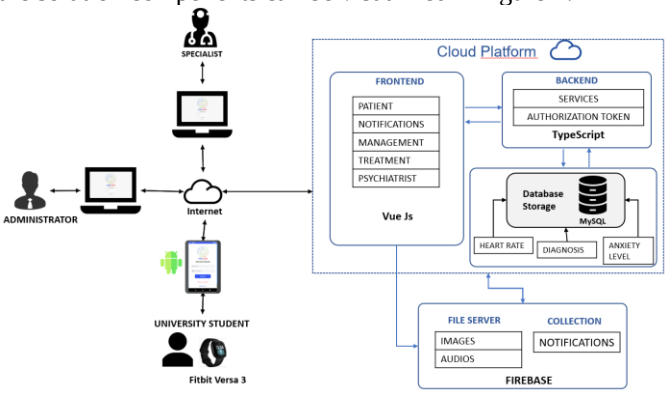

Figure 1. Integration of architecture

B. *Phases of the solution*

The proposed solution is based on 5 phases, which are detailed below:

1) Collecting physiological variables through the wearable

This phase includes data collection obtained by the wearable. In order to gather physiological signals, the patient must not do any physical activity because it could affect data accumulation. The patient enters the mobile application and activates the synchronization with the smartwatch, once the synchronization has been established from the wearable, activate the heart rate option so that the capture of the physiological signal begins. It is necessary to clarify that the synchronization between the devices is not mandatory, this is only necessary when the automatic sending of the data is going to be carried out, which will be explained in the next point.

2) Integrating the wearable and the mobile application

Once data is gathered by the wearable, all data can be sent in two ways. The first one integrates both the wearable and the application; however, this type of connection can be made by Fitbit Versa 3 smartwatch, to perform this integration, the patient enters into the interface of the wearable, which continually captures the heart rhythm and transmits the data to a cloud central database; then the mobile application captures the data and shows them in the interface "Measure" while it consumes a service to record in the database. The second way is a manual recording of the data captured by the wearable. The reason why it was decided that two means were used to send data is to prevent connection only with the wearable, through which the integration was performed, and to give other options to the patients. Additionally, the Fitbit Versa 3 was selected because of the development option and deployment platform of the application, which will be installed in the wearable.

3) Storage of captured data

When data is integrated either using the wearable or manual manner, a service is consumed via an http request. The consumed service records all data, after that, it will be used to observe the patient history and evolution by both the assigned specialist and the patient himself. Besides, when the recording is done, a diagnosis is generated once the heart rhythm is compared with previously established range levels. It is necessary to state that if the identified level of anxiety is high, notification collections in the Firebase server records a file; this server also stores documents such as profile picture, prescription and audios that will be used by both the web and mobile application.

4) Integrating the solution with the web application

When the patient records the data via the mobile application, if the patient experienced a high level of anxiety, there is an alert notification, which can be visualized in the notification interface. Additionally, through the web, the specialist can monitor the patient, visualize his evolution, prescribe treatments, schedule medical appointments, visualized set appointments and take advantage of other functions.

5) Monitoring, treatment and identification of anxiety

To determine the level of anxiety: The cloud stores data about the heart rhythm that includes each level of anxiety. 4 levels of were established: no anxiety, mild anxiety, moderate anxiety, and severe anxiety. Through the reviewed literature, it is known that there is a relationship between anxiety and heart rate; However, it does not specify the levels of anxiety, for this reason the association between the level of anxiety and the heart rate was established by taking the Zung anxiety scale to people who went through potentially stressful situations while in parallel they were average heart rate. The scale divides anxiety into the aforementioned levels, the results of which helped classify and calculate the limits of the range of each anxiety level. The data of the heart rhythm recorded by the patient is analyzed in order to assess the level that the patients are experiencing in that moment. Such information is returned

to the phone while it is being stored in the database. A notification can be generated by the specialist if the level is severe. In addition, the application has an "anxiety test" option that contains questions from the Beck Inventory Anxiety (BIA).

A. Control of anxiety:

The solution has provided recommendations in the mobile application to decrease the level of anxiety. The application gives two types of recommendations that the patient can use to reduce anxiety, they are: breathing techniques and relaxation sounds. Besides, it furnishes "relaxation tips" that help people to maintain normal emotional health and treatments documented by the specialist depending on the patient's situation:

i) Breathing technique:

This breathing exercise is guided where the patient inhales and exhales repetitively over a period of time. The patient follows the blue sphere and performs the action that is showed in the center of the sphere as presented in figure 2.

Figure 2. Breathing exercise in the mobile application

ii) Relaxation sounds:

The patient listens to a set of audios for relaxing. These audios have nature sounds and when listened, they provide a sense of peace and quietness. Also, when those sounds are combined with meditation, the person reaches a state of relaxation as a sensory response. Some compiled sounds are presented in figure 3.

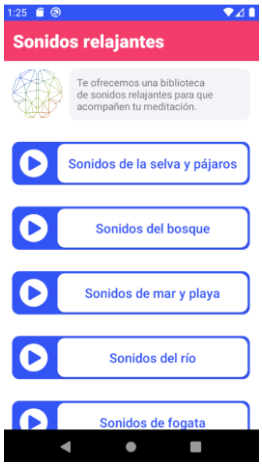

Figure 3. Relaxation sounds

iii) Treatment:

The specialists can provide treatment for their patients from the web, they have instructions, a list of medicine dosage, frequency and image of doctor's prescription if necessary. On the patient's end, they can ask questions about their treatment using the "Treatment" option; the active treatment is on the top side and the treatment history is listed on the bottom side as it can be observed in figure 4.

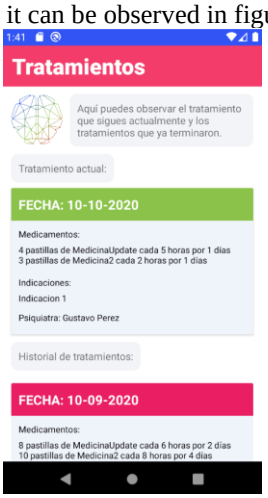

Figure 4. Treatment

iv) Relaxation tips:

The option "tip" is presented in figure 5, where there is a resourceful counseling group that helps people to stay in a healthy emotional state, by providing information about the meaning of anxiety, steps that reduce the probability to develop high levels of anxiety, such as resting adequately, doing physical activities, healthy eating, among others.

Figure 5. Tips de relajación

B. Monitoring anxiety

When recording the measure of the heart rhythm, the application calculates the patient's state description, this detail indicates the level of anxiety experienced when the data is being captured. This data can be visualized in the web and mobile application through a graphic that shows the hearth rhythm recorded over a period of time. Additionally, there is measure history, where details of the heart rhythm annotation done by the patients are shown. As it was previously mentioned when assessing a severe level of anxiety through the capture of the heart rhythm, a notification is sent to the specialist so she can take actions to help her patient.

IV. Case Study

A. *Background*

The set scene for conducting the validation process of the solution is virtual classes due to the current context is laughable to intend to have traditional classrooms as the scene; for that reason, college students were asked to participate. 10 people were asked to help who were enrolled and were between 17 and 25 years old. The employed criterion to select those people considered availability and accessibility so they could be part of this experiment; however, people who did exhausting physical routines, who had a heart condition or suffer from an illness that could damage the capture of the used physiological variable. To carry out the experiment, the participants were asked to provide the time and day of their exposures or exams to send an evaluator to monitor it through the event, the evaluator placed the participant's smartwatch and linked it to a mobile device with the purpose of being able to observe the variations of the heart rate during the event The evaluator limited himself to observing the participant and guiding him if necessary in the use of the mobile solution to control the level of anxiety. Once the event was over, the devices were desynchronized and the results were saved.

The solution was validated in events like oral work report, taking quizzes or exams, and waiting for grade revealing.

B. *Implementation*

1) Validation Process

The validation process was conducted in order to demonstrate the relationship between the experienced anxiety by people and heart rhythm; moreover, it pursues to verify the efficiency of the solution in reducing the level of anxiety, and the acceptance of the solution by both the specialists and the patients. Process validation has 3 parts:

The first part validates the relation between anxiety and heart rhythm in people. For this purpose, participants agreed to have their hearth rhythm measured before and after one of 3 anxiety-triggering events; and at the same time, participants answered an anxiety BIA questionnaire to establish heart rhythm ranges of the anxiety levels based on the obtained results.

The second part was performed among a 5-person sample group drawn from the participants in the first part; this smaller group agreed to continue helping in the investigation. The procedure was similar to the first validation, the difference is that data is captured during the anxiety-triggering event and after following the recommendations given by the application. A specialist was asked to validate the recorded diagnosis while each sample group member's data was being captured. The process ended satisfactorily when the specialist stated that there was a true reduction of the anxiety experienced by the participants who had followed the recommendations.

The third part was conducted a survey in the target group, for that purpose, the chosen people were those who fit the user profile, a college student or specialist (psychiatrist o physiologist). The survey run among the college students was on the mobile application and its functionalities. On the other hand, another survey conducted among the specialists was on the approval of the web site and the process through an interview where they pointed out the characteristics of the solution.

2) Metrics

The employed metrics to validate the success of the case study are detailed in table III:

TABLE III
METRICS ASSOCIATED WITH THE PROPOSED SOLUTION

N°	Metric	Formula
1	Degree of effectiveness of the solution	$GES = \frac{CR}{CT}$
2	Degree of acceptance by the user patients	$GAP = \frac{SPR}{PMC}$
3	Degree of acceptance by the specialists	$GAE = \frac{SPRE}{PMCE}$

Where:

- GES: Degree of effectiveness of the solution
- CT: Number of total cases
- CR: Number of cases where anxiety was reduced
- GAP: Degree of acceptance by the patients
- SPR: Sum of the scoring given by the patients
- PMC: Highest score obtained in the patient questionnaire
- GAE: Degree of acceptance by the specialists
- SPRE: Sum of the scoring given by the specialists
- PMCE: Highest score obtained in the specialist questionnaire

C. *Results*

When analyzing data of the first phase of the validation process, it was observed a decrease of the heart rhythm after the event finished. For this reason, it was demonstrated that there is a true relation between the heart rhythm and anxiety. In figure 6, it is presented the decrease of the heart rhythm in the considered simple once the event ended.

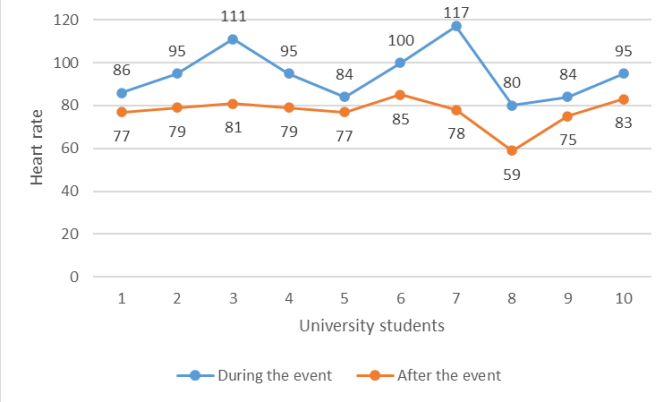

Figure 6. Heart rhythm before and after the event

The data analysis of the second phase of the process demonstrated that the degree of effectiveness of the solution is 80%, because this is the percentage of the participants that the experiment indicated reduce level of anxiety resulting from compliance with the recommendation given by the application. In figure 7, it is showed the variation of the hearth rhythm recorded by the participants.

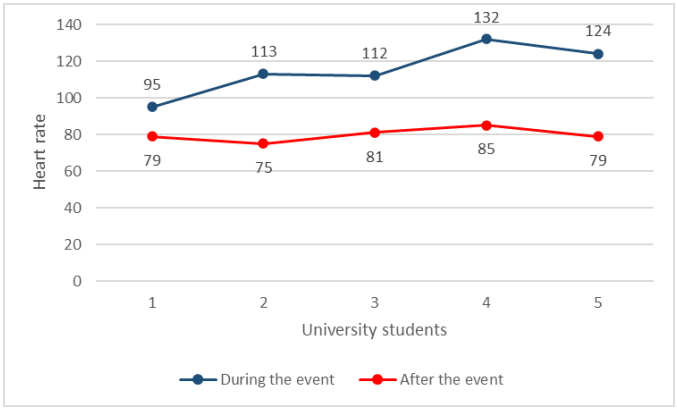

Figure 7. Heart rhythm before and after advice

The data analysis of the third phase of the validation process demonstrated that degree of acceptance by the patients was 88% and the degree of acceptance by the specialists was 95%.

V. Conclusions

The present assignment proposes a solution to monitor and reduce the level of anxiety by utilizing a system that integrates a web application, a mobile application and a wearable device. According to the previously analyzed literature and to this research performed for this project purposes, it was proved that there is relation between physiological variables and anxiety experienced by people. Moreover, the research proved that college students could experience anxiety when they are under a lot of pressure by an academic situation. This proposal uses as initial data the person's heart rhythm in order to establish the level of anxiety experienced during a probable stressful event. Anxiety can be reduced by using breathing techniques, listening to relaxation or calming sounds, or changing life habits to other healthier ones. The present technological solution pursues the identification, monitoring and treatment of anxiety among people. Furthermore, this project can improve by implementing a communication booth with the specialist and with the community where the patients have the opportunity to talk and support each other; this is based on the success of those features in the consulted literature.

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References

[1] Kebede, M.A., Anbessie, B., Ayano, G.: Prevalence and predictors of depression and anxiety among medical students in Addis Ababa, Ethiopia. International Journal of Mental Health Systems, 13(1). (2019)
[2] Wang, M., Zhang, S., Lv, Y., Lu, H.: Anxiety Level Detection Using BCI of Miner's Smart Helmet. Mobile Networks and Applications, 23(2), 336-343. (2018)
[3] Wen, W., Liu, G., Mao, Z.-H., Huang, W., Zhang, X., Hu, H., Yang, J., Jia, W.: Toward Constructing a Real-time Social Anxiety Evaluation System: Exploring Effective Heart Rate Features. IEEE Transactions on Affective Computing, 11(1), 100-110. (2020)
[4] Elgendi, M., Menon, C.: Assessing anxiety disorders using wearable devices: Challenges and future directions. Brain Sciences, 9(3). (2019)
[5] Raymondi, L.G.A., Guzman, F.E.A., Armas-Aguirre, J., Agonzalez, P.: Technological solution for the identification and reduction of stress level using wearables.
[6] Almalik, M., Alnowaiser, A., El Meligy, O., Sallam, J., & Balkheyour, Y.: Clinical Anxiety among Saudi Postgraduate Pediatric Dentistry Students in Jeddah City. International Journal of Dentistry, 2018. (2018)
[7] Giannakakis, G., Pediaditis, M., Manousos, D., Kazantzaki, E., Chiarugi, F., Simos, P.G., Marias, K., Tsiknakis, M.: Stress and anxiety detection using facial cues from videos. Biomedical Signal Processing and Control, 31, 89-101. (2017)
[8] Trotman, G.P., Veldhuijzen van Zanten, J.J.C.S., Davies, J., Möller, C., Ginty, A.T., Williams, S.E.: Associations between heart rate, perceived heart rate, and anxiety during acute psychological stress. Anxiety, Stress and Coping, 32(6), 711-727. (2019)
[9] Goessl, V.C., Curtiss, J.E., Hofmann, S.G.: The effect of heart rate variability biofeedback training on stress and anxiety: A meta-analysis. Psychological Medicine, 47(15), 2578-2586. (2017)
[10] Fiol-Veny, A., De la Torre-Luque, A., Balle, M., Bornas, X.: Diminished heart rate complexity in adolescent girls: a sign of vulnerability to anxiety disorders? Anxiety, Stress and Coping, 31(4), 375-386. (2018)
[11] Judah, M.R., Shurkova, E.Y., Hager, N.M., White, E.J., Taylor, D.L., Grant, D.M.: The relationship between social anxiety and heartbeat evoked potential amplitude. Biological Psychology, 139, 1-7. (2018)
[12] Elgendi, M., Menon, C.: Machine Learning Ranks ECG as an Optimal Wearable Biosignal for Assessing Driving Stress. IEEE Access, 8, 34362-34374. (2020)
[13] Reiss, N., Warnecke, I., Tibubos, A.N., Tolgou, T., Luka-Krausgrill, U., Rohrmann, S.: Effects of cognitive-behavioral therapy with relaxation vs. imagery rescripting on psychophysiological stress responses of students with test anxiety in a randomized controlled trial. Psychotherapy Research, 29(8), 974-985. (2019)
[14] Zou, P., Sun, L., Yang, W., Zeng, Y., Chen, Q., Yang, H., Zhou, N., Zhang, G., Liu, J., Li, Y., Ao, L., Cao, J.: Associations between negative life events and anxiety, depressive, and stress symptoms: A cross-sectional study among Chinese male senior college students. Psychiatry Research, 270, 26-33. (2018)
[15] Cipra, C., Müller-Hilke, B.: Testing anxiety in undergraduate medical students and its correlation with different learning approaches. PLoS ONE, 14(3). (2019)
[16] Val-Calvo, M., Álvarez-Sánchez, J.R., Ferrández-Vicente, J.M., Fernández, E.: Optimization of Real-Time EEG Artifact Removal and Emotion Estimation for Human-Robot Interaction Applications. Frontiers in Computational Neuroscience, 13. (2019)
[17] Gong, J., Huang, Y., Chow, P.I., Fua, K., Gerber, M.S., Teachman, B.A., Barnes, L.E.: Understanding behavioral dynamics of social anxiety among college students through smartphone sensors. Information Fusion, 49, 57-68. (2019)
[18] Matthews, P., Topham, P., Caleb-Solly, P.: Interaction and engagement with an anxiety management app: Analysis using large-Scale behavioral data. Journal of Medical Internet Research, 20(10). (2018)