Stress Monitoring Using Mobile Phone and Wearable Technology: Stress Catcher

Aslina Baharum[1], Minshen Chai[1], Siti Hasnah Tanalol[1], Nurul Hidayah Mat Zain[2], Mohd Nabil Zulhemay[2], Emelia Abdul Rahim[3], Muhammad Omar[3]
[1]*Faculty of Computing and Informatics, Universiti Malaysia Sabah, Kota Kinabalu, Sabah, Malaysia.*
[2]*Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, Jasin Campus, Melaka, Malaysia.*
[3]*Faculty of Business Management, Universiti Teknologi MARA, Sarawak Campus, Malaysia.*
aslinabaharum@gmail.com

***Abstract*—Individuals nowadays suffered from stress due to high workload from works or studies. However, most of them could not identify their stress level or some of them did not even know that they were exposed to consideration amount of stress. A study was carried out in order to study the mobile application and wearable technology towards the development of stress monitoring application, namely as 'Stress Catcher'. Through the study, stress-monitoring application was developed based on users' heart beat rate and users' perception was evaluated to see how people reacted towards the application. In order to develop the stress monitoring application, Mobile-D methodology was applied. After the study, the stress monitoring application was expected to measure users' heart beat rate and compared to the heart rate from the signal of pulse that sent to the wearable device, which was Mio Alpha. Mobile application will display the stress level through the display screen. It was hope that Stress Catcher will give early alarm to the users in the early phase to prevent severe stress.**

***Index Terms*—Stress Monitoring; Heart Rate Variability; Mobile Phone; Wearable Technology.**

I. INTRODUCTION

Individuals nowadays suffered from stress due to high workload from works or studies. Assessment pressures resulted absenteeism of students [1]. A study was carried out in order to study the stress monitoring application using mobile phone and wearable technology.

Stress would cause a lot of damages in work-related environments. Some studies claimed that one third of the non-attendance from works was related to sickness due to stress. Besides, students from university may suffer from stress too due to high workload in their studies [2]. Students were unable to find solutions since their works were too difficult. Accordingly, overload displayed itself in low confidence and working motivation [3]. Individual should be aware of this threat. Most of the time, individuals did not understand that their bodies were exposed to consideration amount of stress due to work or daily life.

Little research had done on stress monitoring application due to limited resources in Malaysia. Furthermore, there was growing proof that showed high level of stress was prevalent among university students due to high amount of workloads. Besides, high level of stress might cause high risk of developing ill health and mental health problem [4].

This paper is organized as follows. In Section 2, a general description of wearable technology and related studies on stress monitoring system will be presented. Section 3 demonstrates the methods applied in developing stress monitoring system based on heart rate variability (HRV). The data collection obtained is illustrated in Section 4 and followed by a conclusion.

II. WEARABLE TECHNOLOGY AND RELATED STUDIES ON STRESS MONITORING SYSTEM

Wearable technology is defined as electronic technologies or computers that assimilated with clothing or accessories, which can comfortably be worn on the body by the users [5]. Wearable technology is widely applied today since it provides scanning and sensory features, which can outperform some of the hand-held devices such as laptop devices. The study focuses on wearable computing, which segregated wearable devices, as it was programmable and reconfigurable as the family desktop. The significance and uses of wearable technology are proved to be applied in various fields such as medical, health, fitness, education, transportation, enterprise, finance, gaming and music. The application included augmented memory, finger sensor, face recognition, visual filter, navigation through Global Positioning System (GPS), repair guideline, communication management through speech recognition, remote assistance for detection and maintenance, medical and health [5]. FitBit, Jawbone, smart watches and smart running shoes were the most common wearable technologies, which could monitor physical activity. Wearables were networked devices, which they could store data and transmit to another devices apart from gathering data from body of users or from environment. Wearable technologies were believed to be the next step in advancement of ubiquitous computing through describing how the technology played an important role in our daily lives [6]. The application of the wearable technology is computed in the Table 1.

A study towards measuring stress with smartphones and wearable devices during workday and sleep had been conducted. In the study, the stress recognition was compared using smartphones in the daytime and heart rate HRV during night. The smartphone features were based on audio, physical activity and social interaction features while HRV features were based on time domain features, non-linear features and frequency domain features. The research demonstrated that HRV features were more significant than smartphones features and model using HRV data performed better than smartphones data with higher accuracy since the categorization of models had to be based on user-specific data [7].

Table 1
Application of Wearable Technology

Application	Product categories (Wearable Technology)
Healthcare and medical	Blood pressure monitors; Continuous glucose monitors; Defibrillators; Drug delivery products; ECG monitors; Hearing aids; Insulin pumps; Smart glasses; Patches; PERS; Pulse oximetry
Fitness and wellness	Activity monitors; Emotional measurement; Fitness and heart monitors; Food pods and pedometers; Head-up displays; Sleep sensors; Smart glasses; Smart clothing; Smart watches; Audio ear buds
Infotainment	Bluetooth headsets; Head-up displays; Imaging products; Smart glasses; Smart watches
Military	Hand-worn terminals; Head-up displays; Smart clothing
Industrial	Hand-worn terminals; Head-up displays; Smart clothing; Smart glasses

Furthermore, deStress, which was mobile and remote stress monitoring and management platform. In the system design, terminal versatility was achieved since the software could run on most of the common mobile operating systems. The data transmission was followed by two types, which were channel between stress monitor and terminal and channel between central server and terminal while cloud-based storage was applied to ensure the storage capacity to store sensor data of users was sufficient since deStress is used in large scale. The application was mainly on stress monitoring and stress relief [8].

III. METHODOLOGY

Mobile-D had increased progress visibility, enabled carrying out repair of technical issues through earlier discovery and contained fewer flaws in final product with constant progress during development [9]. Hence, in the study of application in monitoring stress through mobile phone and wearable technology based on HRV, Mobile-D would be applied as a method (Figure 1). The first phase of the process is Explore. In this phase, project establishment are defined through exploring of stress level among university students in UMS. Objectives of the study are defined and the scope definition is conducted. The data set is collected from university students in UMS. Besides, the variable of the measurement is also limited to one, which is HRV rather than using SpO_2 and blood pressure as variables. Through this, a more accurate result would be obtained.

During the second phase, which is Initialize, preliminary study was applied to study the current issues related to stress level among the university students in UMS. Around 30 university students are taken as study samples. Five mobile applications related to stress monitoring based on HRV are reviewed and compared in terms of features. Questionnaires are designed and distributed among the study samples. The HRV of the study samples are taken through the mobile application chosen, which is Stress Locator and wearable technology, which is Mio Alpha smart watch. Stress level among the study samples is analyzed based on the measurements and readings taken and the results are obtained.

In the third phase, which is Productionize, quick design has been carried out. The database, user interface and system are designed before the prototype is implemented. These designs would be based on the information gathered during the previous phases. Data Flow Diagram (DFD) and Entity Relationship Diagram (ERD) are drawn. Hence, the implementation of the prototype would be guided along the way. The prototyping process would be carried out. The prototype should include the features that have been mentioned. System testing would be applied during the implementation of functionalities according to the pre-established plan. Working version of the system is produced and validated through testing.

The final two phases, which are Stabilize and System Test & Fix are aided in product finalization and user testing. The users will review prototype and presentation about the prototype would be given to users to improve their understandability. Some modifications might be done based on the users' review and documentation is done.

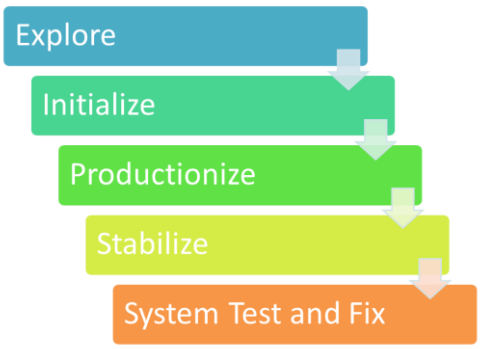


Figure 1: Mobile-D for Stress Catcher Development.

A. *Preliminary Study*

In this section, analysis of stress level among UMS students based on the results obtained from the mobile application chosen, which is Stress Locator and wearable device, Mio Alpha will be presented. From Figure 2, plethysmogram is a technique used to determine and identify lungs function through the measure of lungs that displayed the multitude of functional and structural aspects. Plethysmogram is applied in the Stress Locator application since it is proved that heart rate, which is the number of times individuals' heart beat per minute could be measured through photoplethysmography (PPG) in which the readings of the heart rate could be measured through sensors and analyzed through the existing software [10]. Fingers were mostly targeted as measurement of the heart rate.

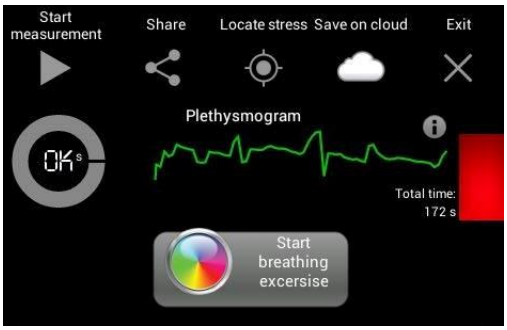


Figure 2: Plethysmogram of Stress Locator

From Figure 3, physical index, concentration index and relaxation index are the variables used in Stress Locator to define stress level of users. Physical index is defined as the capability of an individual in performing daily tasks without excessive fatigue and disability of body function [11]. On the other hand, concentration index and relaxation index are defined as the ability of individuals to concentrate and relax.

They are usually referred to the standard measurement tools applied in health field to define equity and inequality in health and health care [12]. Based on the result shown, the physical index is 99%, which indicates that functional ability of the user is excellent and could be able to perform everyday work at optimal rate. In addition, the concentration index of the user is 47% while relaxation index of the user is 24%, which represent that the ability to concentrate of the user is moderate and the ability to relax of the user is low. Hence, the user requires more sleep since sleep could be able to improve mental health [13].

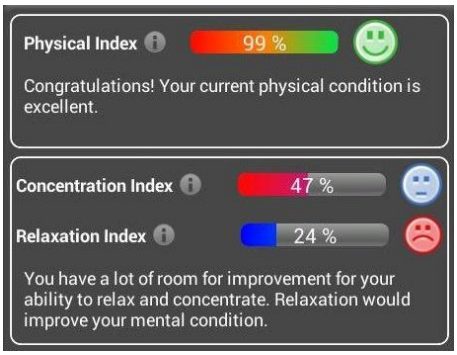


Figure 3: Output data of Stress Locator

Figure 4 shows the HRV statistics of the previous study sample. Based on the result shown in the statistics, the maximum heart rate is 94.2 bpm while the minimum heart rate is 58.3 bpm. Standard Deviation of Beat-to-beat Interval (SDNN) of the user is 209 while the mean heart rate is 77.

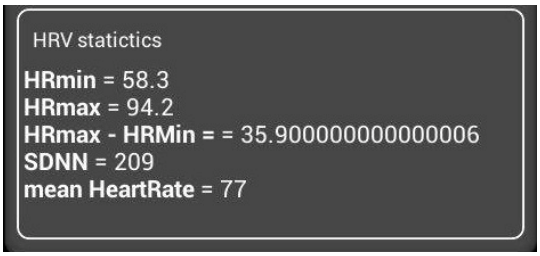


Figure 4: HRV statistics of Stress Locator

Figure 5 shows the HRV statistics of Mio Alpha. The heart rate of the previous study sample obtained through Mio Alpha is linked to Iphone 6 through Bluetooth and the result is illustrated through mobile application, Health. The maximum heart rate is 90 bpm while the minimum heart rate is 64 bpm. The HRV obtained from both different technologies applied, which are Stress Locator and Mio Alpha are almost identical. Therefore, the HRV obtained from Mio Alpha would be used as the variable to compare with the HRV obtained from Stress Catcher to improve the study accuracy and dependability in measuring stress level.

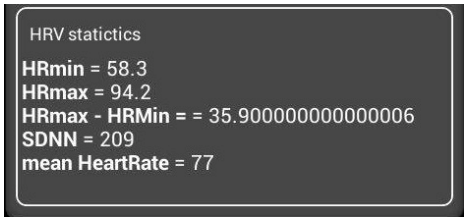


Figure 5: HRV Statistics of Mio Alpha

Based on the results obtained from 30 samples, the physical index of almost all the study samples is excellent. This proves that the university students in UMS could be able to perform daily tasks without excessive fatigue. Besides, the concentration level of most of the study samples is moderate while the relaxation level of them is low. The low level of relaxation might be due to the feeling of nervous and anxious in studies and examination as well as feeling tired based on the questionnaires distributed to them. Hence, they might require more rest and carry out some activities that reduce stress.

Table 2
Statistics of Gender

Gender	Concentration level		Relaxation level	
	Moderate	Low	Moderate	Low
Male	8	6	1	13
Female	14	2	0	16

Table 3
Statistics of Ethnic

Ethnic	Concentration level		Relaxation level	
	Moderate	Low	Moderate	Low
Malay	7	3	0	10
Chinese	10	0	1	9
Kadazan-Dusun	5	5	0	10

Table 4
Statistics of Age

Age	Concentration level		Relaxation level	
	Moderate	Low	Moderate	Low
18-19	0	0	0	0
20-21	3	2	0	5
22-23	15	5	1	19
24 and above	4	1	0	5

Table 5
Statistics of Years

Years	Concentration level		Relaxation level	
	Moderate	Low	Moderate	Low
First	0	0	0	0
Second	3	2	0	5
Third	5	2	0	7
Final	14	4	1	17

Table 6
Statistics of Faculties

Faculties	Concentration level		Relaxation level	
	Moderate	Low	Moderate	Low
FK	4	1	0	5
FKI	9	4	0	13
FSSA	6	1	0	7
FSMP	3	2	1	4

Besides, the HRV statistics of Stress Locator are also be used to compare to the HRV statistics obtained by using Mio Alpha. Based on the results obtained, the accuracy of the readings is proved since the differences between the maximum and minimum HRV obtained from both Stress Locator and Mio Alpha in the 30 results are small, which are within 5 bpm to 10 bpm. Hence, the readings of the HRV obtained from Mio Alpha could be used to compare and contrast with the HRV results obtained from Stress Catcher later in the study and thus indicate stress level of the users. Table 2 to Table 6 illustrate the statistics of 30 study samples towards concentration and relaxation level based on heart beat rate through Stress Locator.

Furthermore, questionnaires survey has been distributed towards the 30 samples to further study their stress symptoms, and stress management techniques. The results are then demonstrated in Figure 6 and Figure 7. Based on the results shown, the most prevalent stress symptoms are fatigue and feeling tired, which are 22 with a percentage of 73.33%. Besides, feeling irritable or angry is also one of the stress symptoms, which is popular among university students with a frequency of 20, which occupies a percentage of 66.67%. While the least chosen stress symptom is change in appetite, which is 5 only. For stress management techniques, most of the samples prefer surfing Internet and going online as their ways to distress, which are 26 and a percentage of 86.67%.

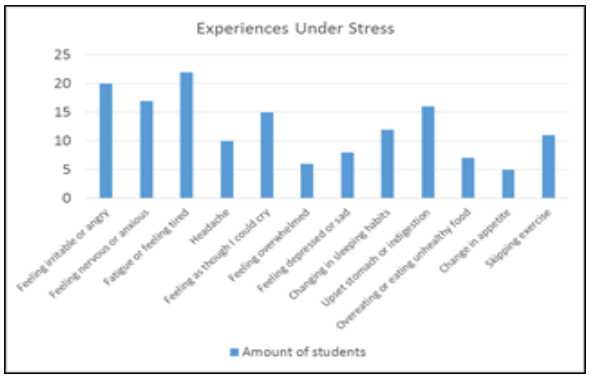


Figure 6: Results from Stress symptoms

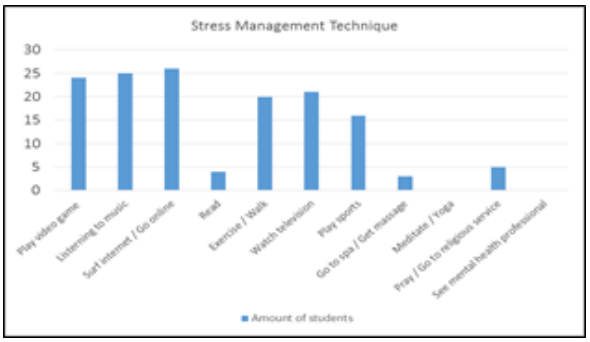


Figure 7: Results from Stress management technique

Moreover, they also select listening to music and playing video game as alternatives to reduce their stress level, which are 25 and 24. They occupy 83.33% and 80% in the bar chart. However, none of them choose meditate or yoga and see mental health professional as their stress management techniques. For demography part, 53% of the samples are male with a value of 16 while 47% is female with a value of 14. In age group, 67% of the samples are aged around 22-23 with a value of 20. Samples with age of 24 and above as well as 20-21 are having the same amount of students, which are 5. Most of the samples belong to final year students, which are 18 in amount while 7 of the samples are third year students. In addition, 5 of the samples are second year students.

However, none of them belong to first year students. For faculty, most of the samples come from Faculty of Computing and Informatics (FKI). Second largest group belongs to samples from Faculty of Science and Natural Resources (FSSA). Samples from Faculty of Engineering (FKJ) and Faculty of Food Science and Nutrition (FSMP) are having the same amount of samples, which consist of 5. From the results shown, it is proved that most of the university students feeling fatigue and tired when they are under stress and they prefer surf internet, go online, listen to music and play video game as their stress management techniques in order to mitigate stress.

B. Stress Catcher Development

Generally, Stress Catcher consisted of four main functions which including edit profile details such as age and gender, measure heart beat rate, indicate stress level and results sharing. Besides, the data collected was stored in Stress Catcher Data Store. After users input their gender and age, User_Detail would select User_Heart to start HRV measurement to indicate stress level through User_Stress. The measurement takes about 1 minute to complete. After 1 minute, the result page will be displayed in which users can identify their personal details and determine their maximum value, minimum value and mean value of HRV. The results from User_Heart and User_Stress would be shared through User_Share. Furthermore, they will be notified about their stress level. It displayed the profile details that users inputted at My Profile page previously as well as the maximum, minimum and mean HRV after the scanning of heart beat rate through camera. Besides, it also showed the stress level of users. Figure 8 shows the user interface design for Stress Catcher.

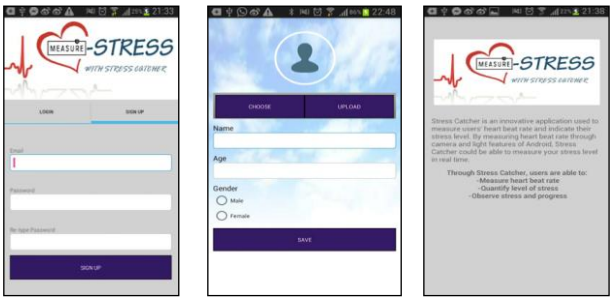


Figure 8: Part of User Interface Design of Stress Catcher

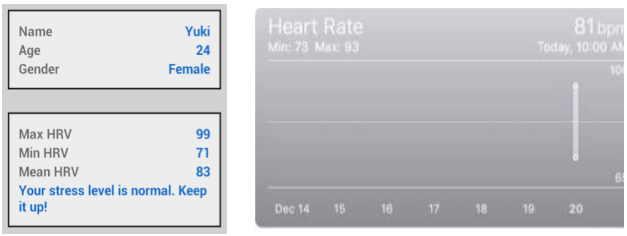
C. Participants and Procedures

In the study, the questionnaires designed are adapted from the report from American Psychological Association, which released on February 11, 2014. American Psychological Association [14] had conducted the stress in America survey, which measured the approach and consciousness of stress among the general public besides determined leading sources of stress, common behaviors in handling stress and consequences of stress on lives. Hence, it would be taken as references in designing the questionnaires to be distributed among 30 study samples in UMS. Throughout the study, the sample size taken is 30 participants randomly (university's students) in UMS. For the procedures, the study sample would be given a presentation and guideline on how to use Stress Catcher apps in correct manner. After that, he/she would carry out the measurement of HRV through Stress Catcher to obtain their minimum HRV, minimum HRV, mean HRV and stress level. At the same time, the HRV data from Mio Alpha would be collected to prove the study accuracy and dependency of Stress Catcher. Then, he/she would be given the questionnaires to evaluate the product, which was Stress Catcher.

IV. Results and Discussion

Figure 9 (a) shows the screenshot of Stress Catcher in illustrating the personal information and HRV results with stress level. It was shown that the first box displayed the demography results of users, which included Name, Age and Gender of the users. As for the second box below, it displayed the HRV results and stress level of the users. For example, it showed that the maximum HRV of the user was 107 bpm while the minimum HRV of the user was 71 bpm. Besides, the mean HRV of the user was 84 bpm. Based on the study carried out by Beckerman [15] regarding to the heart rate myths, it was proved that a normal heart rate was between 60 to 100 beats per minutes. Hence in the study, for the result of the mean HRV, which was between 60 to 100 bpm, the stress level should show normal. For the mean HRV that was between 100 to 140 bpm, the stress level would consider high while for the mean HRV that was 140 bpm and above, the stress level would consider extremely high. The result obtained from Stress Catcher was compared to the result obtained from the wearable device, Mio Alpha, which was shown in Figure 9 (b).

From the Figure 9 (b), the heart rate of the previous study sample obtained through Mio Alpha was linked to Iphone 6 through Bluetooth and the result was illustrated through mobile application, Health. The maximum heart rate was 93 bpm while the minimum heart rate was 73 bpm. The HRV obtained from both different technologies applied, which were Stress Catcher and Mio Alpha were almost identical. Therefore, the HRV obtained from Mio Alpha would be used as the variable to compare with the HRV obtained from Stress Catcher to improve the study accuracy and dependability in measuring stress level. Based on the results obtained, the accuracy of the readings was proved since the differences between the maximum and minimum HRV obtained from both Stress Catcher and Mio Alpha in the 30 results were not big, which were within 10 bpm to 15 bpm.



(a) (b)

Figure 9: (a) HRV Results from Stress Catcher, (b)HRV Statistics from Mio Alpha

Based on the results obtained from 30 samples, there were 24 samples having normal stress level while the other 6 samples faced high stress level. Among the 24 samples that had normal stress level, there were 8 male samples and 16 female samples. However, among the 6 samples that had high stress level, there were 5 male samples and 1 female sample. This showed that female students in UMS faced less stress compared to male students. Furthermore, among 24 years old samples, there existed 2 samples out of 10 with high stress level while among 23 years old samples, there existed 2 samples out of 11 with high stress level. For 22 years old samples, there was only 1 sample out of 7 having high stress level. Hence, the percentage of the study samples having high stress level was samples of the age of 24, which was 20% compare to the samples of the age of 23, which was 18%.

Table 2
Statistics of Gender

Gender	Stress Level	
	Normal	High
Male	8	5
Female	16	1

Table 3
Statistics of Age

Age	Concentration level	
	Moderate	Low
20-21	1	1
22-23	15	3
24 and above	8	2

V. Conclusions

Through the research on HRV, it was proved that HRV could be taken as variables in order to measure stress level of individuals. This is because when individuals were facing stress, their bodies would be under consideration amount of tensions and hence, increasing heart beat rate. Through the development of Stress Catcher, users could be able to measure their HRV anytime when they wished to and monitor their stress level from time to time. Therefore, they could be able to understand their bodies' current stress condition and manage to take actions to reduce stress. For future development, Stress Catcher could be improved by applying various method besides users testing and system testing. Another method to be applied was usability testing which was not included in the study. Furthermore, the method for data collection could be improved by applying other methods like systemic sampling, stratified sampling, convenience sampling, judgement sampling or quota sampling instead of cluster sampling and random sampling. Moreover, the functionalities of Stress Catcher could be improved by allowing users to choose methods such as questionnaire based in indicating stress level besides HRV.

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